ECONOMIC GROWTH REVISITED: IDENTIFYING A CLASS OF GROWTH MODELS FOR THE NEW ZEALAND ECONOMY

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Abstract

Using data on twenty industries that comprise the market sector of the New Zealand economy, this thesis sets out to indirectly test three classes of economic growth models for the New Zealand economy. This is achieved by investigating the empirical relationships between TFP growth, output and input price growth, and factor intensities; and then comparing these empirical relationships against the predictions of five growth models. On the basis of this comparison some evidence is found to support the hypothesis that the rival human capital class of endogenous growth models is the most appropriate for the New Zealand economy.

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Finally, to my best friend Bronwyn Rose McLellan. At times you probably wished that the terms "total factor productivity growth" and "regression model" were banned from the English language. Thank you for being tolerant and understanding. When I commenced this thesis you were a 'Heath'; now you are McLellan. I dedicate this thesis to you.

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List of Abbreviations

DFI	Direct Foreign Investment
FDI	Foreign Direct Investment
OECD	Organisation for Economic Cooperation and Development
ONZPRDB	Official New Zealand Productivity Research Database
TFP	Total Factor Productivity

Chapter One
Introduction

Begin with the end in mind. (Covey, 1989, p. 99)

Economic growth now has centre stage in macroeconomics. After a period of three decades – a period that bore little new research on economic growth, following the classic work of Solow (1956) and Swan (1957) – there has been a resurgence in the literature on economic growth. In many ways, the commencement of this resurgence was heralded by the completion of Paul Romer's (1983) PhD thesis: *Dynamic Competitive Equilibria with Externalities, Increasing Returns and Unbounded Growth.* Shortly after the completion of this PhD thesis, economic growth moved to the forefront of macroeconomists' research agendas, and during this time a large number of models were developed that sought to introduce endogenously determined technical change as the driving force of growth. These models – the so-called 'new or endogenous growth models' – generally exhibit increasing returns to scale by introducing the 'public good' character of knowledge into the analysis.[1] In doing so, long-run growth is sustained. However, in noting the development of endogenous growth models, more lately there has been a revival in support for the neoclassical model (*a la* Solow, 1956; Swan, 1957) and its variants (see, e.g., Klenow and Rodriguez-Clare, 1997b).[2]

To date, a large amount of the empirical literature on economic growth has been concerned with distinguishing between the two broad class of growth models: endogenous versus exogenous. Often convergence – the idea that there is a narrowing of the inter-economy differential in growth rates and per capita income levels over time, and a property of the neoclassical model – has been used as the deciding factor.[3] Despite the high degree of heterogeneity amongst models of endogenous growth, with models differing in both

[1] As will be discussed in Chapter Two, Section 2.2, there are some exceptions.

[2] These models are often termed *exogenous* growth models.

[3] This is a crude characterisation of convergence. A more refined discussion is provided in Chapter Two, Section 2.1.

positive and normative implications, few studies have been undertaken to empirically distinguish between different classes of endogenous growth models. As Klenow and Rodriguez-Clare (1997a, p. 599) highlight: "... there has been disappointingly little empirical work testing and discriminating between theories of endogenous growth." This is particularly the case for the New Zealand economy. While a substantial amount of research has investigated New Zealand's aggregate and sectoral growth, with considerable attention being devoted to 'proximate' and 'ultimate' sources of growth, little attention has been given to testing the applicability of different formal growth models.[4]

This thesis seeks to identify a class of endogenous growth model for the New Zealand economy by replicating, and then extending, the work in Klenow's (1998) paper: *Ideas versus rival human capital: Industry evidence on growth models.* In doing so, this thesis aims to add to the literature in two distinct ways. First, by identifying a class of growth model for a *small open economy.* Second, by extending the literature that has sought to test alternative growth models for the New Zealand economy. This research has been greatly aided by the advent of the Official New Zealand Productivity Research Database (ONZPRDB) (Department of Labour, New Zealand Treasury, and Reserve Bank of New Zealand, 1999).

This thesis is organised as follows. Chapter Two reviews the international theoretical and empirical growth literature. In particular, the chapter seeks to elucidate the critical role played by knowledge in New Growth Theory. Chapter Three reviews the New Zealand growth literature, providing a context for the research in the chapters that follow. Chapter Four outlines the methodology and the data employed. Results are reported in Chapter Five. Chapter Six provides a discussion of these results in the light of the predictions of

[4] The literature on economic growth often makes the distinction between 'proximate' and 'ultimate' sources of output growth. Proximate sources of output growth are input accumulation (for example, labour and capital) and growth in total factor productivity (TFP) (which is also known as the Solow residual). Ultimate sources of output growth are those factors that *influence* input accumulation and growth in TFP (for example, government policy).

several growth models. Finally, Chapter Seven ends with conclusions and future research suggestions.

Chapter Two

Models of Economic Growth

Is there some action a government of India could take that would lead the Indian economy to grow like Indonesia's or Egypt's? If so, what, exactly? If not, what is it about the 'nature of India' that makes it so? ***The consequences for human welfare involved in questions like these are simply staggering: Once one starts to think about them, it is hard to think about anything else.*** (Lucas, 1988, p. 5; emphasis added)

2.0 Introduction

This chapter reviews the theoretical and empirical growth literature. Section 2.1 provides a brief review of the neoclassical growth model, before surveying the research on the phenomenon of convergence. The following section details a number of endogenous growth models and their empirical testing. Given the vast literature on endogenous growth models, coverage is only given to a selection of the key models. Section 2.3 builds on Section 2.2 by looking at those endogenous growth models that have introduced international trade. Section 2.4 considers the role played by human capital in models of economic growth, before the final section provides a summary of this chapter.

2.1 The Neoclassical Model and Convergence

The neoclassical model of Solow (1956) and Swan (1956) presents output growth as a function of input growth (labour and capital) and technical progress, where, in the original specification, technical progress is a function of time and hence, exogenous to the model. The production function exhibits constant returns to scale, implying that the accumulable factor, capital, will eventually face diminishing returns. Given that in the limit the return to capital (the factor that is the driving force of growth in the neoclassical model) approaches zero, *ceteris paribus*, growth will eventually cease. This means long-run growth can only be sustained by calling on the exogenous factor – technical progress.

The concept of diminishing returns to capital is a distinguishing feature of the neoclassical model. From this one derives the convergence property of the model, that is, the idea that economies experience 'catch up' or convergence in growth rates and per capita income over time. Baumol's (1986) work exploits this property of the neoclassical model, testing for convergence using data on a sample of sixteen developed economies. Although he finds evidence of convergence, the result is challenged on two fronts. First, Abramovitz (1986) contends that convergence only takes place after World War Two. Second, De Long (1988) argues that convergence is a *fait accompli* because Baumol's sample includes only those economies that have already industrialised.[1]

Despite these criticisms there is still widespread support for the neoclassical model. Sala-i-Martin (1996) argues that even though De Long (1988) finds little support for convergence, once Baumol's study is widened to include developing countries, this does not constitute a basis for rejecting the neoclassical model. Sala-i-Martin's (1996, p. 1027) argument surrounds the distinction between absolute and conditional β convergence:

> Only if all economies converge to the same steady state does the prediction that poor economies should grow faster than the rich ones holds true. This is because with common steady states, initially poorer economies will be unambiguously away from their steady state. In other words, the conditional convergence and the absolute convergence hypotheses coincide, only if all the economies have the same steady state. *Since the neoclassical model predicts conditional convergence, the evidence on absolute convergence... says little about the validity of the model in the real world.* (emphasis added)

Conditional β convergence is the idea that growth rates and per capita income levels converge once cross-country differences in economic conditions are taken into account.[2] In

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[1] In other words, the economies that were selected to be included in the sample generally were those with ready available data, which tended to be richer economies in 1970 (that is, economies that had already industrialised). This means there is selection bias in Baumol's sample because economies that had not industrialised in 1870, were generally only included if they experienced rapid growth in the intermediate one hundred years.

[2] These different economic conditions can be measured by what Barro (1997, p. 8) describes as "choice and environmental variables." Choice variables are those that relate to the Solow model. Environmental variables are other relevant variables that affect the steady-state.

other words, there is the 'conditioning' of economies' steady states. For example, in Solow's initial specification of the neoclassical model the growth rate of savings is assumed to be homogenous across countries. In reality the homogeneity assumption is incorrect, therefore an allowance for this must be incorporated into any cross-country analysis because the neoclassical model predicts differences is savings will lead to different steady states. Absolute convergence is the idea that growth rates and per capita income levels converge regardless of inter-economy differences in economic conditions. In other words, all economies have the same steady state.[3]

Barro (1991 and 1997), Sala-i-Martin (1996), and Barro and Sala-i-Martin (1995) find empirical support for conditional convergence using two quantitative techniques. The first technique involves testing for conditional convergence by using a set of choice and environmental variables, chosen using economic theory as a guide, to control for economies' steady states. The second involves restricting the sample to those economies with similar steady states, and then testing for *absolute convergence* (for example, Sala-i-Martin (1996) uses OECD economies). This latter technique relates to the phenomenon of 'club convergence,' that is, the idea that economies with similar institutional and structural features experience absolute convergence, and hence become a 'club' of economies.

A lot of effort has been devoted to testing for convergence, often as a means of validating the neoclassical model, and, as a consequence, discrediting endogenous growth models.[4] The use of 'convergence' as a means of discriminating between the neoclassical and endogenous growth models is becoming less important because endogenous growth models are being modified to exhibit the convergence property (see, for example, Barro & Sala-i-Martin, 1997). Moreover, the finding that a particular sample of economies exhibits conditional convergence in per capita income levels does little in terms of elucidating what

[3] In the literature attention is also given to σ convergence, that is, the idea the variation in per capita income across economies decreases over time. See for example Quah (1996).

[4] These models are discussed in Section 2.2.

is causing it. Is it the result of capital accumulation or technological catch-up (Klenow and Rodriguez-Clare, 1997a, pp. 608-609; Temple, 1999, pp. 136-137)?[5].

Klenow and Rodriguez-Clare (1997a, p. 611; 1997b, pp. 73-74) characterise the dialogue between those who favour capital accumulation versus those who favour technological catch-up, as the A versus K debate, where A represents productivity and K capital accumulation (in the broadest sense). Romer (1993) frames the debate using an alternative semantic structure. He views the two alternate views on convergence as the 'object' versus the 'ideas' gap. An economy that lacks physical capital is indicative of one suffering from an object gap. An economy that lacks technical know-how is confronted with an idea gap. In framing the debate in terms of these two extremes, the two sets of authors are not arguing that economies are characterised by a dichotomous process of either capital accumulation of technological catch-up, but rather that "... economists must make an accurate assessment of the relative importance of idea gaps and object gaps before they can provide comprehensive guidance on development policy" (Romer, 1993, p. 544).

Klenow and Rodriguez-Clare (1997a, p. 609) argue that primacy must be given to the role of 'technology catch-up.' They base their contention on their estimate that approximately 90% of the variation in growth rates of per capita income can be explained by differences in the growth rate of total factor productivity (TFP).[6] Bernard and Jones (1996, p. 1038) argue that the explanation of convergence through the accumulation of capital ignores what economic historians and technologists have known for many years: "Technology transfer

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[5] In the seminal article on convergence Baumol (1986, pp. 1077-1078) discusses the possibility of convergence being caused by a combination of technology catch-up and capital accumulation.

[6] TFP is usually specified as an index of technical progress, however, as Easton (1991, pp. 70-71) reminds us, it encompasses more than just technological progress:

> ... advances in knowledge, changes in the lag of the application of advanced knowledge, improved allocation of resources, economies of scale, acquisition of education and skills by the labour force, changes in labour force composition, changes in capital goods composition, externalities, any interaction effects, changes (if any) in weather, changes in the physical environment not captured by capital stock estimates, and changes in that mystical incantation known as better economic management.

is... logically a potential force behind convergence." Thus the authors (ibid., 1996, p. 1040) argue that "... the ability to reap from the efforts of others [that is, other economies] determine the relative positions of countries in the long-run, even if they have similar population growth rates and investment rates."[7]

The other influential research that has lent empirical support to the neoclassical model is the work by Mankiw et al. (1992) and Young (1992 and 1995). Klenow and Rodriguez-Clare (1997a and 1997b) argue that this work constitutes a neoclassical revival; a swing back in support of the neoclassical model, after the initial appeal of endogenous growth models.

Mankiw et al. (1992) augment the basic neoclassical growth model by adding human capital as an input into the production function, in addition to labour and capital. Using the proportion of the working age population that is in secondary school as a measure for human capital accumulation the authors find that approximately 80% of the variation in per capita income between economies can be explained by the Solow model. Mankiw et al. (1992, p. 408) thus note:

> Given the inevitable imperfections in this sort of cross-country data, we consider the fit of this simple model to be remarkable. It appears that the augmented Solow model provides an almost complete explanation of why some countries are rich and other countries are poor.

The authors' conclusion bears further consideration. While the adjusted R^2's are high for the sample of non-oil and intermediate economies (samples where measurement error problems are also the greatest), the adjusted R^2 for the sample of OECD economies is substantially lower at 0.28. This would tend to indicate that Mankiw et al.'s 'augmented' neoclassical growth model lacks explanatory power in accounting for the variation in per capita income between developed economies. However, Mankiw et al. (ibid., p. 428) explain this result by positing that OECD economies are further away from their steady states, relative to the other economies in the entire sample. In support of this explanation is

[7] Section 2.3 considers those models that have attempted to formalise technology transfer, as well as the empirical evidence on the extent of technology transfer between economies.

the higher adjusted R^2 (approximately 0.65) obtained once allowance is made for transitional dynamics from the steady state. In addition, when Nonneman and Vanhoudt (1996) further augment the neoclassical growth model by adding a proxy variable for domestic technological know-how, as well as making allowance for transitional dynamics, the augmented augmented (!) neoclassical model explains approximately 80% of the variation in per capita income between OECD economies.[8]

Phelps (in Mankiw, 1995, p.312) critiques Mankiw et al.'s work, noting that the use of human capital as another input into the production function is "very static and deterministic." As an alternative, Phelps argues that human capital should be modeled as a means of facilitating the absorption of technology[9]. More fundamentally, Romer (in Mankiw, 1995, pp. 313-320) takes issue with Mankiw et al.'s assumption that technology is a pure public good. Mankiw's (1995, p. 322) response to both these criticisms is that the neoclassical model still does a remarkable job at explaining the variation in standards of living across space and time. Klenow and Rodriguez-Clare (1997b) challenge this assertion. After widening Mankiw et al.'s (1992), measure of human capital to include primary and post-secondary schooling, in addition to secondary schooling, Klenow and Rodriguez-Clare find that input accumulation accounts for only a small proportion of variation in per capita income. Klenow and Rodriquez-Clare (1997a, p. 613), thus, argue "... that differences in productivity are the primary cause of the large international dispersion in income per capita."

The work of Young (1992, 1995) seeks to challenge what the author sees as the erroneous belief "... that productivity growth in these [the East Asian Newly Industrialised Economies], particularly in their manufacturing sectors, has been extraordinarily high" (Young, 1995, p. 671). He (ibid., p. 672) estimates growth rates for TFP of 2.3%, 0.2%,

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[8] The ratio of gross domestic expenditure on R&D to GDP acts as the proxy variable for domestic technological know-how.

[9] This will be given greater coverage in Section 2.4.

1.7%, and 2.1%, for Hong Kong, Singapore, South Korea, and Taiwan, respectively.[10] He (ibid., p. 671) notes that these growth rates are similar to other developing and developed economies, concluding rapid output growth in these economies is primarily due to factor accumulation; particularly labour in the manufacturing sector.

Klenow and Rodriguez-Clare (1997a, pp. 608-609) argue that Young's estimates of the growth of TFP are biased downward. The authors' (Klenow and Rodriguez-Clare, 1997b) argument centres on 'feedback' effects from productivity to physical capital, where an increase in productivity raises the marginal product of capital, thereby increasing the rate of capital accumulation. The growth rate of TFP in the East Asian Newly Industrialised Economies is substantially higher when this feedback effect is taken into account.

In concluding this section, it is apparent that there is a body of empirical literature that confirms the hypothesis of conditional convergence. However, to reiterate, this does not constitute a basis for endorsing the neoclassical growth framework in its totality because endogenous growth models have also been developed that exhibit conditional convergence. Thus, the economist is (once again!) confronted with the problem of *observational equivalence* – an empirical generalisation being consistent with more than one economic model. Moreover, while many economists accept the sample evidence in support of conditional convergence, the debate still rages as to the force/s that is/are driving this phenomenon. In terms of an assessment it seems that the augmented neoclassical model performs very well at explaining inter-economy variation in per capita income, however, as various authors note (for example, Klenow and Rodriguez-Clare, 1997a, p. 607), tautologically the only way to explain world growth is by calling on endogenous growth models. The following section considers a number of these models.

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[10] Growth rates are for the entire economy for the period 1966-1990 (the exception is Hong Kong; its growth rate is calculated for the period 1966-1991). Agriculture is excluded for Korea and Taiwan.

2.2 Models of Endogenous Growth

Models of endogenous growth seek to bring technical progress to the forefront of the analysis. Romer (1994, pp. 13-14) notes that in doing so, the economist faces the challenge of introducing 'knowledge' into the analysis. This is problematic from a modeling standpoint because knowledge, in part, has the public good characteristics of being non-rival and non-excludable. Yet, as Stiglitz (1999, p. 8) argues, it is only disembodied knowledge that is purely non-rival, and that the non-rivalrousness of knowledge needs to be kept conceptually distinct from the low costs associated with dissemination. In relation to the excludability of knowledge, if knowledge were not partially excludable there would be no incentive for firms to produce knowledge.

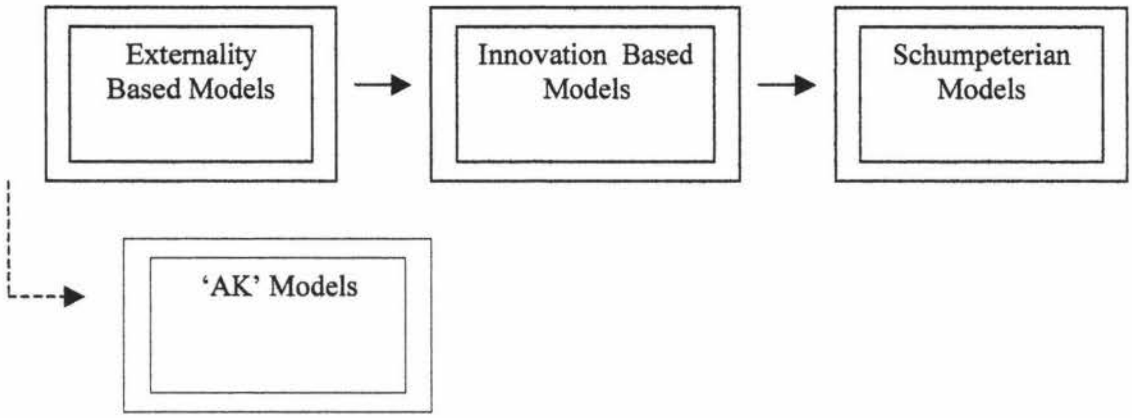
Successive models of endogenous growth have sought to incorporate these characteristics of knowledge (the exception being more recent 'AK' models, which tend to focus more on the accumulation of capital (broadly defined)).[11] Figure 2.1 presents a simplified diagram of their development[12].

Models of externality based growth (Romer, 1986; Lucas, 1988) convey the notion that because knowledge is a public good, an externality is generated that overcomes diminishing returns that are characteristic of the neoclassical model. Models of innovation based growth (Romer, 1990; Grossman and Helpman, 1991) are based on the contention that "... growth is driven fundamentally by the accumulation of a partially excludable, nonrival input", that is, knowledge (Romer, 1990, p. S74). In other words, recognition is given to the idea that technical change is the result of deliberate action by economic agents who pursue market incentives. The models of Schumpeterian growth (Aghion and Howitt, 1992) build on the previous insights, in addition to introducing Schumpeter's notion of 'creative destruction'. AK models of endogenous growth differ from the previous models

[11] 'AK' models of endogenous growth gain their name because the production function takes the general form Y=AK. In these models the only factor of production is capital (K), however, capital is broadly defined to include private physical capital, land, infrastructure, knowledge, etc. Other factors are assumed to grow automatically (in proportion) with capital e.g. labour, technological knowledge, etc.

by focussing more on the accumulation of capital (broadly defined), rather than the accumulation of knowledge.

Figure 2.1 – Development of Endogenous Growth Models[13]



Romer (1986) constructs a model of endogenous growth where the sum of all inputs in the production of the final good exhibit increasing returns to scale. Romer achieves this by allowing the production of knowledge to display increasing marginal productivity, thus overcoming diminishing returns that are characteristic of the neoclassical model. In essence, this is the result of an externality generated by the production of knowledge, whereby the production of knowledge raises the productivity of all firms in the economy (Romer, 1986, p. 1003). Romer's specification implies that the production function is convex in the stock of knowledge. However, a maximum is obtained because the research sector faces diminishing returns in the production of knowledge (ibid., p. 1006).

Like Romer (1986), Lucas (1988) formulates a general framework for the analysis of growth, using a 'Marshallian' external effect, where human capital generates this externality. Lucas presents two models of human capital accumulation: one where

[12] These classifications are in part based on Grossman (1996).

[13] Romer (1994) suggests two reasons for the emergence of endogenous growth models. First, the difficulties associated with reconciling empirical evidence with the neoclassical model. Second, the availability of a viable alternative to perfect competition with developments in the field of industrial organisation.

accumulation is the result of schooling, the other, learning by doing. In both of these models, growth is sustained through the accumulation of human capital.

It is Lucas' (ibid., p. 19) contention that human capital accumulation is primarily a social activity. It is through the interaction of individuals with each other that this externality is generated.[14] This externality is 'external' in the sense that its impact on the economy as a whole is not influenced by the action of any one individual. Due to this externality the equilibrium paths for both models are suboptimal. In highlighting this result, Lucas (1988, p. 31) discusses appropriate policy to rectify the divergence between social and private outcomes. In the model of human capital accumulation by schooling, a subsidy to schooling is the appropriate policy. In the 'learning by doing' model, a subsidy to firms producing 'high-technology' goods equates the private and social equilibria.

In order to incorporate the additional insight that knowledge is a partially excludable good, a number of endogenous growth models use the framework developed by Dixit and Stiglitz (1977) to introduce imperfect competition into the analysis. One such model is Romer (1990). In this model a final good is produced using human capital, labour and a variety of capital inputs. Each of the capital inputs is produced by a monopolist who purchases a production license from a research firm.

In Romer's (1990) specification technical progress is synonymous with an increase in the number of capital varieties. Knowledge is still a public good because research firms draw on the available stock of knowledge in producing further blue prints of capital inputs. However, knowledge is also partially excludable because research firms have patents on the design of capital inputs. Romer (ibid., p. S74) achieves this view of knowledge as a "nonrival partially excludable input" by separating the rival component of knowledge

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[14] In discussing this externality, Lucas (1988, pp. 35-39) provides an illuminating argument that this is one of the reasons for the existence of the modern city. Using standard economic analysis he points out that cities should 'fly apart' as land on the periphery falls in price. He posits that the reason they do not is because of the externalities that are generated in city life; otherwise "[w]hat can people be paying Manhattan or downtown Chicago rents *for*, if not for being near other people?" (Lucas 1988, p. 39).

(human capital) from the nonrival component (the pool of knowledge available to the research sector).

Grossman and Helpman (1991) pursue a slightly different approach to the one that Romer (1990) adopts. In their framework technical progress is measured by an increase in the *quality* of consumer goods, where this is gauged by movement up a "quality ladder". This framework differs from Romer's (1990) in two respects. First, differentiation occurs in the final good rather than the intermediate input. Second, differentiation is vertical (increasing quality) rather than horizontal (increasing quantity). These differences between the two alternate frameworks, however, are less important than would first appear. Indeed, Grossman and Helpman (1991, pp. 53-55) augment their basic model where *horizontally* differentiated products can be viewed as either intermediate capital inputs or final consumer goods, although the authors note the models differ in normative implications (Grossman and Helpman, 1991, p. 54).

In this model an increase in quality is achieved through Research and Development (R&D). The benefit from undertaking this R&D effort is the discounted stream of profits that a firm will receive until such time that the consumer good on the quality frontier is displaced by an entrant who produces a new innovation. Assuming potential entrants can acquire the knowledge to produce a good by purchasing it on the market allows for retainment of the public good character of knowledge (Grossman and Helpman, 1991, p. 47). The existence of enforceable patents provides the incentive for firms to invest in R&D.

The model itself contributes to the literature in two distinction ways. First, the model is set up in such a way that the outcome of R&D is inherently uncertain. This contrasts with other models where the output of R&D follows a deterministic process. Second, a "business stealing" effect is introduced where new innovations capture the profits of the industry leader. The authors (Grossman and Helpman, 1991) achieve this by introducing advances from the field of industrial organisation into a general equilibrium model of economic growth.

In an effort to highlight the complementarity between learning-by doing and innovation based growth, Young (1993) constructs a model that incorporates both features. This model is based on the premise that, in the broad sweep of history, "just as a recognition of potential bounds on serendipitous learning makes the rate of learning dependent on the rate of invention, so a recognition of the need to actualize the productive potential of newly invented technologies makes the incentives to engage in costly invention, and hence the rate of invention, dependent on the rate of learning" (Young, 1993, p. 447). Young thus constructs a hybrid model to incorporate the insights of both models that highlight intentional innovation by firms, and a subclass of externality based models, where spillovers are generated as a by-product of learning to produce goods.

Models of 'Schumpeterian' growth seek to incorporate Schumpeter's insight of innovation, by profit maximising firms, as the engine of capitalism. Models of 'creative destruction' – the idea that new innovations can render previous inputs and production methods obsolete – add another dimension to the models based on innovation. Thus, in the Schumpeterian paradigm, a basic trade-off exists between the benefits of innovation from future research, and the costs associated with rendering some inputs and production methods obsolete (Aghion 1993, in Caballero and Jaffee, 1993, p. 74).

Aghion and Howitt (1992) formulate a model based on Schumpeterian innovation. In presenting their model they make use of the notion that continual improvements in the quality of an intermediate input increases the efficiency of producing the final good (ibid., pp. 322-328). In other words, intermediate products are differentiated vertically (*a la* Grossman and Helpman, 1991). Innovation is the result of firms pursuing market incentives under conditions of uncertainty. Qualitatively, this model differs from Grossman and Helpman (1991) by *explicitly* incoporating 'creative destruction'.

Aghion (1993, in Caballero and Jaffe, 1993, p. 76) suggests that one extension of basic Schumpeterian models is to consider the difference between fundamental and secondary innovation. Models built along the lines of Brezis, Krugman, and Tsiddon (1993, p. 1212), where the distinction is made between incremental technological change – the gradual improvement of technology that is the normal course of affairs – and fundamental technological change – major technological breakthroughs – may prove to be a fruitful research area.

Jones (1995a) contends that models of growth based on innovation are inconsistent with the time series evidence for a number of developed countries. The author justifies this viewpoint by noting the exponential increase in the number of scientists and engineers devoted to R&D, but the constant or negative growth in TFP for the corresponding time period (ibid., p. 517). He (ibid, p.519) points out that this is at odds with the models of innovation such as Romer (1990), Grossman and Helpman (1991) and Aghion and Howitt (1992). In order to rectify this deficiency Jones (1995b, p. 779) constructs a model of "semi-endogenous" growth, where the growth of output "crucially depends" on population growth, which is assumed to be exogenous. Aghion and Howitt (1998, Chapter 12, pp. 417-420) perform a similar exercise. They address Jones' (1995a) critique by highlighting two stylised facts. First, due to the increasing complexity of technology more resources need to be devoted to R&D to hold the rate of innovation constant. Second, the externality generated by the marginal innovation has a smaller impact on the stock on knowledge. On the basis of these, Aghion and Howitt (ibid.) present a model where economic growth does not hinge on population growth.

Caballero and Jaffe (1993) use an innovative (pun intended!) approach to assess the quantitative significance of the Schumpeterian growth paradigm. Using a variant of the model constructed by Aghion and Howitt (1992), the authors formulate a calibrated general equilibrium model, seeking to incorporate the insights of Schumpeter. More specifically, the authors construct an empirical model that seeks to incorporate 'creative destruction' and knowledge spillovers into a model of economic growth.[15] The model has three equations at its core. The first equation, entitled the 'citation equation,' models the relationship between

[15] As Caballero and Jaffe (1993, p.18) point out, the creation of new ideas affects the current stock of knowledge in two ways. First, new ideas render old ideas obsolete. This relates to 'creative destruction'. Second, new ideas impact on the relevance of old ideas to the creation of new ones. This relates to knowledge diffusion.

past research and the current productivity of labour in research (ibid., p.30). It has its foundation in the public good character of knowledge "... inventors rely and build on the insights embodied in previous ideas" (ibid, p. 16). The authors estimated this equation using patent data for 567 United States firms. The second equation is the innovation equation, which is a function of 'research inputs' and patents, as well as the estimate of labour's productivity in research, which is obtained from the first equation (ibid., p. 46). The third equation estimates the degree of 'creative destruction' caused by new innovations.

On the basis of the estimates obtained for the 'citation equation', Caballero and Jaffe (1993) note that knowledge diffusion would appear to be very rapid, being in the vicinity of one to two years. Moreover, the magnitude of these spillovers has decreased over time (ibid., p. 19).[16] The average rate of creative destruction, as gauged by the erosion of a firm's market value, is approximately 3.5% per year, but there is large degree of variation both across sectors and over time (ibid., 56). Overall, these results would tend to confirm a role for Schumpeterian innovation in a modern developed capitalist economy.

Jones and Manuelli (1990) and Rebelo (1991) formulate endogenous growth models that have been subsumed under the title 'AK' models, entitled so because capital (K), which is broadly defined, is the only accumulable input.[17] In these models economic growth is sustained because capital does not enter the space where it faces diminishing returns.[18] In other words, long-run growth is sustained without calling on increasing returns to scale, thus, the assumption of perfect competition is maintained. This implies the decentralised equilibria of these models are socially optimal.

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[16] After controlling for the rate of 'creative destruction' Caballero and Jaffe (1993, pp. 19 & 43-44) estimate that the externality generated by an average idea presently, compared with the average idea at the turn of the century, is about five times less.

[17] After developing the author's basic model, Rebelo (1990) augments the model to explicitly include physical and human capital as separate inputs.

[18] This is achieved by constraining the models so that the subjective discount rate ρ is less than the marginal revenue product of capital.

Based on the AK models' prediction that a permanent increase in the investment rate generates a permanent increase in growth, Jones (1995a) performs two very simple time-series tests on a sample of fifteen OECD countries to test the validity of these models. The author uses both total investment and producer durables investment data in performing these tests. The latter would seem to be particularly important given that De Long and Summers (1991) find machinery and equipment investment is strongly correlated with growth.[19] On the basis of the test statistics Jones (1995a, p. 509) concludes, "... AK models do not provide a good description of the driving forces behind growth in developed countries." Other authors reach different conclusions. For example, Kocherlakota and Yi (1996) find that changes in non-military equipment capital and non-military structural capital have permanent effects on the growth rate of the United States' economy. They argue that "this is evidence in favor of endogenous growth models" (ibid., p. 132).

The models outlined in this section provide a richness that is lacking in the neoclassical model. They have enormous potential in accounting for the variety of 'growth stories' for different economies. For example, Lucas' (1988) model of human capital accumulation and Aghion and Howitt's (1992) model of innovation by 'creative destruction' suggest that an economy may get caught in a underdevelopment trap. The following section extends these models by looking at growth in the context of open economies.

2.3 Trade and Models of Endogenous Growth

Grossman and Helpman (1994, p. 38) contend that it is imperative for models of growth to give credence to the interdependence between economies:

> Countries trade with one another, communicate with one another and learn from one another more than ever before. The increased exchange of goods and ideas has fostered a growing interdependence among countries' technological fortunes and long-term performances. When the new models of endogenous innovation are extended to include international movements of goods, capital, and ideas, they yield a theoretical framework that is rich in predictions and consistent with a host of observed phenomena.

[19] De Long and Summers (1991, p. 454) find that a 3% increase in machinery and equipment's share of GDP leads to an increase in the growth of GDP per worker by approximately 1%.

This section reviews some of these developments. In part these models complement the models of new trade theory, that give emphasis to *intra-industry trade.*

The notion that technological change can influence the pattern of specialisation and trade has been given recognition in a number of endogenous growth models. Traditionally, comparative advantage has been the underlying force in driving the static gains from trade. Grossman and Helpman (1990) incorporate comparative advantage into a dynamic general equilibrium setting with the aim of analysing the effect of trade on economies' growth processes. They construct a two-economy, three-sector model of endogenous growth, based on Romer (1990), where an increase in technical progress is driven by an increase in the number of intermediate inputs used in the production of the final good. The two economies exhibit comparative advantage in either R&D or in the manufacture of intermediate inputs.

The model encompasses a number of interesting theoretical possibilities. For example, an increase in the demand for the final good produced by the economy with the comparative advantage in R&D, leads to a reallocation of resources from the R&D sector to the intermediate input sector. This leads to a fall in world growth as the rate of intermediate input accumulation declines. Perhaps of more interest are the possibilities that arise when the two economies institute trade protection and/or industrial support. In some states of the world, tariffs or export subsidies can actually raise world growth.[20]

The other novel innovation, which the authors (Grossman and Helpman, 1990) introduce, relates to the diffusion of knowledge. In their basic model they acknowledge the nonrivalrous nature of knowledge by allowing knowledge spillovers between the two economies. However, they assume that diffusion is instantaneous and costless. In a bid to rectify what they see as an unrealistic assumption, they extend the model to allow for lags

[20] It is important to note that an increase in the growth of output does not necessarily mean an increase in economic welfare. Grossman and Helpman (1994, p. 41) emphasise this point.

in the diffusion of knowledge. Grossman and Helpman (1990, pp. 813-814; emphasis added) find that:

> Once we allow for lags in the diffusion of scientific knowledge and differential speeds of diffusion within versus between countries, we find a richer set of possibilities for the long-run effects of trade policy. Comparative advantage continues to play a critical role in determining whether policy in one country will speed up or decelerate growth. *But comparative advantage must now be interpreted with care, because it reflects not only natural ability but also the (endogenous) benefits from cumulative experience.*

Grossman and Helpman (1991), in extending their previous work, present a number of models where international trade is integral to technological progress. In a number of these models (but not all) openness to international trade allows economies to absorb technology from economies that are on the technology frontier. The potential gains from openness to international trade can be particularly large for smaller economies in their models.

Romer (1990) provides a suggestive discussion as to the effects of economic integration on economic growth. He points out (ibid., S98) that when integration occurs between two similar economies the resulting increase in the stock of human capital raises the growth of world output. Rivera-Batiz and Romer (1991) further develop the idea that economic integration between similar economies causes 'scale effects.' They conceive their model of endogenous growth and trade in the context of integration between similar economies, controlling for comparative advantage as the other justification for trade. Rivera-Batiz and Romer (1991) consider two scenarios, amongst others. The first is trade in the intermediate capital input but not knowledge. The second is trade in both knowledge and the intermediate capital good. In the case of the first scenario integration results in an increase in world output (which is probably welfare improving), but not the growth rate. In the second scenario both output and its growth rate increase, as a result of an increase in the stock of knowledge that both economies can draw upon when designing blueprints. [21]

[21] In this paper Rivera-Batiz and Romer (1991) set down two specifications for the R&D technology. The first is based on Romer (1990), and is the focus of the discussion above. The second technology, which the authors term "lab equipment specification", does not give knowledge a central role.

In developing the idea that technology transfer is fundamental to economic growth, Brezis et al. (1993) construct a model of 'leapfrogging' in technology leadership. In this model incremental technical progress induces greater specialisation in the production of a particular good, but fundamental innovation commences a process whereby specialisation may eventually be reversed as the economy that was the technological leader is surpassed by the other economy.

The rich nexuses that emerge when global linkages are incorporated into endogenous growth models, call for a decisive role to be played by quantitative analysis in identifying those theoretical possibilities that coincide with 'real world' growth processes. In this area there is now a burgeoning empirical literature that investigates the impact of 'openness' to international trade on economic growth. Those models that have sought to incorporate interdependency in the global economy, where "... more open countries have a greater ability to capture new ideas being developed in the rest of the world" (Edwards, 1998, p. 384), have motivated this research.

In a cross-country context, when ascertaining the impact of openness on growth, the researcher is confronted with the dual problem of formulating a methodological basis for measuring openness and collecting data, whereby a comparative measure can be constructed. Edwards (1993) reviews some of the difficulties. In realising some of these deficiencies will never be totally overcome, Edwards (1998) investigates the relationship between openness and growth, using nine indices of openness. He (ibid., p. 386) argues that in using a variety of openness measures, the robustness of the relationship is tested.[22] Edwards (1998, p. 391) reports the econometric results exhibit "tremendous consistency" in revealing a positive relationship between openness and TFP growth.

Levine and Renelt (1992) find little sample evidence in support of the hypothesis that openness is *directly* related to output growth, however, the authors do find a robust positive

[22] Edwards (1998, pp. 392-393) also estimates a "'grand' composite index" of openness using principle component analysis.

relationship between the trade share of GDP and the investment share of GDP.[23] With these results in hand, Levine and Renelt (1992, p. 954) posit that trade influences growth via investment in the form of "enhanced resource allocation."

Sachs and Warner (1995) provide evidence in support of a link between openness and growth. They find evidence of conditional convergence between open developing economies and developed economies and non-convergence between closed developing economies and developed economies. As discussed previously, knowledge/technology transfer could be driving this convergence. In fact, Romer (1993, p. 546) argues in this direction:

> Cross-country regression evidence on the role of machinery imports and direct foreign investment, historical accounts of the transmission of technology, and case studies of individual country performance and individual industries all point to the important role played by international flows of ideas.

Some economists, however, are still dismissive of the notion that openness to international trade is a key to the promotion of growth. For example Edwards (1993, p. 1360) cites Taylor (1991, p. 119 and 114) in "arguing that 'the trade liberalization strategy is intellectually moribund,' and that there are 'no great benefits (plus some loss) in following open trade and capital market strategies.'" In addition, Edwards discusses some country specific studies that provide support for trade protection *as part of* an economy's development. For example, the Korean economy, which has been lauded as a 'success story,' provided their tradeables sector with a high degree of protection during the 1950s and early 1960s, however, this protection was eventually reduced to a minimal level.

Coe and Helpman (1995) develop a more explicit framework with a view to investigating the extent of knowledge transfer between economies. More specifically, the authors investigate the impact of R&D spillovers, between 22 developed countries, on TFP growth.[24] The authors specify a model where an index of TFP is dependent on the domestic R&D capital stock and the foreign R&D capital stock. For a particular economy,

[23] The authors use two measures of openness, which are also used in Edwards' (1998) analysis.

[24] 21 OECD countries and Israel.

the latter is calculated by first weighting a country's trade partners domestic stock by the fraction of imports that come from each country, and then multiplying by the country's total import share.

The results obtained by Coe and Helpman (1995) indicate that the domestic and foreign R&D capital stock have a positive effect on productivity. The authors also find the domestic R&D capital stock generally has a greater impact on productivity than the foreign R&D capital stock for large economies. The opposite is true for most small open economies (the notable exceptions being Australia, Finland, New Zealand, and Spain). The results confirm the notion of knowledge spillovers between developed economies, with these spillovers having a greater impact on productivity for small open economies. Coe et al. (1997) also explore R&D spillovers from developed to developing economies. Following a methodology similar to that employed by Coe and Helpman (1995) the authors (Coe et al., 1997, p. 135) find:

> ... that a developing country's total factor productivity is larger the larger is its foreign R&D capital stock, the more open it is to machinery and equipment imports from the industrial countries and the more educated is its labour force.

In other work, Engelbrecht (1997a) disaggregates the results of Coe and Helpman (1995) and evaluates the ability of individual economies to innovate and absorption international knowledge spillovers. He finds a diverse pattern. That is, for some economies spillovers have a positive affect on TFP growth, for others, their impact is negative.

In a world where there is widespread exchange in goods and ideas, and where there are strong interdependencies between economies, models of endogenous growth that incorporate elements of international trade provide a closer approximation of reality, than do closed economy models. While the nexus between openness and economic growth is still under investigation, cross-country regression analysis provides some support in favour of a positive relationship between openness and growth.

2.4 Human Capital and Economic Growth

There are two dominant views in the literature of the part played by human capital in the growth process. Both strands of the literature see human capital as fundamental to economic growth. However, the way in which it affects growth is different. Aghion and Howitt (1998, Chapter 10) summarise the two alternative views. The first, described as the 'Lucas approach', sees the accumulation of human capital as a determinant economic growth.[25] This view is termed after the work of Lucas (1988), where the level of human capital affects productivity growth. It is related to the approach adopted by Mankiw, et al, (1992) and Nonneman and Vanhoudht (1996) in their augmented Solow models (although it is not exactly the same), where human capital is treated as an input into the aggregate production function. This view of human capital is, therefore, common to some endogenous growth models, as well as the neoclassical model and its variants. The second view is named the 'Nelson-Phelps approach,' after the seminal work undertaken by Nelson and Phelps (1966), where human capital is involved in the creation and absorption of new technology. In this paradigm, human capital is usually modeled by interaction with a productivity catch-up variable.

How do these competing approaches coincide with the empirical evidence? A number of authors' fail to establish a positive relationship between human capital accumulation and economic growth in cross-country studies. For example, Benhabib and Spiegel (1994) estimate an aggregate Cobb-Douglas production function, using data on seventy-eight economies, and find that the coefficient on their proxy variable for human capital accumulation is not statistically significant from zero, with the point estimate often being negative in sign. However, Temple (1998) shows that Benhabib and Spiegel's results are sensitive to influential outliers. When these outliers are dropped from the sample, the point estimate become positive and, in some cases, are significantly different from zero at standard significant levels. On the other hand, Pritchett (1997) gains similar qualitative results to those of Benhabib and Spiegel (1994) (using a different data set), even after

[25] This work on human capital has its antecedent in the human capital theory of Becker (1964).

performing a number of robustness checks. On balance these results cast some doubt on the appropriateness of treating human capital as if it were another factor input.

Benhabib and Spiegel (1994), after challenging the validity of the neoclassical approach to modeling human capital, go on to assess a model where TFP growth is a function of both the level of human capital and an interactive human capital/productivity catch-up variable, in the spirit of Nelson and Phelps (1966). The empirical results obtained by Benhabib and Spiegel's framework tends to confirm the appropriateness of the 'Nelson and Phelps approach' to modeling human capital. On this basis the authors conclude: "The results suggest that the role of human capital is indeed one of facilitating the adoption of technology from abroad and creation of appropriate domestic technologies rather than entering on its own as a factor of production (Benhabib and Spiegel, 1994, p.160)."

It is also interesting to note that Barro (1991) finds that the initial level of real per capita GDP and the initial level of human capital are inversely related to growth, with the author (ibid, p. 437) pointing out that "... poor countries tend to catch up with rich countries if the poor countries have high human capital per person (in relation to their level of per capita GDP), but not otherwise." This result would also appear to be consistent with the 'Nelson-Phelps approach' to human capital.

As was discussed in the previous section Coe and Helpman (1995) consider the extent of R&D spillovers in the context of the international economy. Engelbrecht (1997b) extends this work by incorporating the role played by general human capital. He shows that general human capital, as measured by average years of schooling for the population over 25 years of age, as well as R&D capital both have distinct roles in influencing TFP growth. In relation to the former, Engelbecht (ibid., pp. 1486-1487) concludes that "[h]uman capital enters not only as a factor of production, but also as predicted by new growth theories, but only if it is interacted with a productivity catch-up variable." This finding, in part, concurs with the 'Nelson-Phelps' view of human capital. Engelbrecht (ibid., p. 1487) goes on to suggest that this means there are "... distinct roles for human capital and R&D capital in both domestic innovation and in the absorption of international knowledge spillovers."

In the frameworked developed by Coe and Helpman (1995), and extended by Engelbrecht (1997a, 1997b), international trade provides the means for the transmission of knowledge spillovers. However, as Engelbrecht (1997a, pp. 318-319) states "[o]ther knowledge transfer mechanisms include multinational companies, foreign direct investment, business trips, education and training received abroad, migration of skilled people, purchase of patents and trademarks, reverse engineering, electronic information transfers, importation of journals and books, etc." Borensztein et al. look specifically at the role played by foreign direct investment (FDI) in knowledge transfer from developed to developing economies, and the impact that this has on economic growth.[26] Based on a model of endogenous growth, where technical progress is synonymous with an increase in the number of capital varieties (*a la* Romer, 1990), Borensztein et al. model the relationship between FDI and economic growth, giving prominence to the role of human capital in the absorption of foreign technology. On the basis of the empirical evidence the authors (Borensztein et al., 1997, p. 117) suggest:

> ... that FDI is in fact an important vehicle for the transfer of technology, contributing to growth in larger measure than domestic investment. Moreover, we find that there is a strong complementary effect between FDI and human capital, that is, the contribution of FDI to economic growth is enhanced by its interaction with the level of human capital in the host country. However, our empirical results imply that FDI is more productive than domestic investment only when the host country has a minimum threshold stock of human capital.

Once again, this is consistent with the 'Nelson-Phelps' view of human capital in the absorption of knowledge spillovers.

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[26] Coe et al. (1997, p. 136) also acknowledge the potential role played by foreign direct investment in knowledge diffusion in their research , but choose to focus on the role played by international trade:

> DFI [direct foreign investment] that involves technology transfer can be a very potent source of learning... While we plan to examine the role of direct foreign investment in future work, the empirical work presented here focuses on foreign trade as the carrier of knowledge.

2.5 Summary

With the resurgence of research on economic growth, following the development of a number of new endogenous growth models, a group of researchers attempted to reestablish the ability of the neoclassical model to explain cross-country differences in growth rates. As was discussed in section 2.1, this was largely achieved by augmenting the standard model of Solow (1956) and Swan (1957). In reviewing the empirical literature associated with neoclassical growth theory, it was shown that these models could explain a large amount of the variation in cross-country growth rates. Yet in doing so, the neoclassical growth model, and its variants, remains deficient because eventually it needs to call on technological progress – an exogenous factor in the model – in order to explain *long-run* growth. Thus, neoclassical theory is an incomplete theory of economic growth. On the other hand, tautologically, endogenous growth theory is the only way to account for world growth. A selection of these models was presented in Sections 2.2 and 2.3. The latter section, which reviews a number of endogenous growth models that incorporate international trade, is particularly important given the interdependencies between countries in the global economy. The final section in this chapter considered the role played by human capital in the growth process.

Chapter Three

New Zealand's Postwar Economic Growth

> *... the contribution of technical progress to productivity growth in New Zealand is less than in several other countries* (Blyth, 1965, p. 20).
>
> *In all countries, the single largest contributor to growth was total factor productivity. This item is also predominantly responsible for determining the differences in growth rates between countries. It is in this area that New Zealand's performance has been markedly worse than other countries. The basic message from these growth accounts is that, while some of New Zealand's poor growth performance is due to high population growth relative to the growth rate of capital, most of the deficiency is due to slow growth of total factor productivity* (Grimes and Smith, 1990, p. 143).

3.0 Introduction

This chapter reviews the literature on New Zealand's postwar output and productivity growth, providing a context for identifying the most appropriate sub-class of growth models for the New Zealand economy in the chapters to follow. After commencing with a brief discussion of the early contributions by Blyth (1960 and 1965) and Philpott (1966 and 1977), Section 3.2 provides a brief synthesis of the literature on New Zealand's aggregate and sectoral growth performance. Section 3.3 considers the various factors that have been advanced as 'determinants' of economic growth. Section 3.4 evaluates the economic reforms since 1984; reforms that have dramatically changed the structure of the New Zealand economy. Section 3.5 reviews the literature that tests the appropriateness of different types of growth models for the New Zealand economy. Finally, Section 3.6 provides a summary of this chapter.

3.1 Early Studies

Early quantitative work on New Zealand's economic growth was carried out by Blyth (1960 and 1965) and Philpott (1966 and 1971). Using the growth accounting methodology pioneered by Solow (1957) and Denison (1967), both authors decompose New Zealand's output growth into two parts – that attributable to input (i.e. labour and capital) accumulation and that attributable to increases in TFP. While a substantial amount of research on New Zealand's economic growth has been subsequently undertaken, the findings of both authors have remained broadly valid over the entire postwar period: that approximately two-thirds of New Zealand's output growth is due to input growth, with the remaining third being attributable to TFP growth.[1]

3.2 New Zealand's Growth Record

Gould (1982, pp. 20-24) lends support to the argument that in the early 1950s New Zealand boasted one of the highest standards of living in the world. Citing Heston, Kravis, and Summers' (1980) study, which compares the real per capita incomes of countries using purchasing power parities (PPP), Gould notes of the 119 countries in their study, Heston et al. (1980) find that in 1950 New Zealand had the third highest level of real per capita income. By 1977, however, New Zealand had fallen to eighteenth position in Heston et al.'s rankings. Bollard (1992, pp. 4-6) reports New Zealand's rank in the OECD per capita income stakes fell from eighth in 1955 to twenty-fourth in 1990. Or, in other words, New Zealand's per capita income was 26% above the OECD average in 1955, but by 1990 had fallen to 27% below the average (ibid., p. 4). This decline in New Zealand's relative position reflects the economy's poor growth in real per capita income.

There is a general consensus that New Zealand's postwar growth record has been lackluster at the economy-wide level. Dowrick and Nguyen (1989), who look at the growth performance of OECD economies, classify New Zealand as a 'serious under-performer'. Grimes and Smith (1990, p. 144) paint a similarly bleak picture. Over the postwar period 1950-1984 they note that New Zealand's per capita income growth was 1.47% below the OECD average (excluding Japan); and that New Zealand was the only OECD economy whose per capita income fell as a proportion to that of the United States – the world's per capita income leader. Grimes and Smith (1990) blame a large proportion of this poor real

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[1] The majority of New Zealand studies have followed in the tradition of Blyth and Philpott in employing the neoclassical growth accounting methodology.

per capita output growth on the slow growth in TFP. This is consistent with several cross-country studies that find a large amount of the variation in output growth is explained by differences in the growth rate of TFP (see, for example, Klenow and Rodriguez-Clare, 1997b).

Other authors reach similar conclusions about New Zealand's postwar growth. Easton (1991, p. 71) acknowledges New Zealand's poor per capita output growth, relative to OECD economies, but places less emphasis on the contribution of TFP growth.[2] Hall (1996, pp. 64 and 45-47) reports "New Zealand recorded one of the worst real GDP and per capita growth rate performances of any OECD country during the post War years to 1984, and on average since then," highlighting TFP growth as "... the dominant and modestly positive source of variability in GDP growth rates."[3] Diewert and Lawrence (1999), whose comprehensive study utilises data for the period 1978–1998, reach similar conclusions.

There are a few studies that consider growth at the sectoral level (Chapple, 1994; Philpott, 1995; Diewert and Lawrence, 1999). What is evident when comparing these studies is that for the postwar period output growth has been strongest in the primary sector; the sector that has also displayed the strongest TFP growth.[4] At the same time there has been a change in the sectoral composition of GDP away from the primary sector towards the manufacturing and service sectors. This change in the sectoral composition offers a partial explanation for New Zealand's relative decline in growth performance, in addition to highlighting the point that New Zealand is an exception to the rule that a fall in primary based production is usually associated with an increase in real income (Gould, 1982, p. 42).

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[2] Easton considers the postwar period 1950-1990.

[3] Hall considers the postwar period 1948-1993.

[4] For example, of the 20 industries considered in Chapple's (1994) study for the period 1972-1991, the four primary sector industries rank in the top nine for output growth and the top seven for TFP growth.

3.3 Sources of Growth

The international literature makes the distinction between 'proximate' sources of growth – output growth that is attributable to growth in TFP and factor inputs – and 'ultimate' sources of growth – the more fundamental sources of growth. In relation to New Zealand's 'proximate' sources of growth, Smith and Grimes (1990), for the period 1950-1984, find approximately two-thirds of New Zealand's output growth is due to input growth, the remaining third being attributable to growth in TFP. These results are roughly identical to those of Philpott's (1971) for the period 1950-1971. This would tend to indicate that these results are fairly robust over time.

A number of studies in the international literature have sought to identify 'ultimate' sources of growth. The majority of these studies consider correlates of growth using cross-country data. For example Kormendi and Meguire (1985), Fischer (1993), Barro (1991 and 1997), Barro and Lee (1994), and Sachs and Warner (1997) assess the validity of a number of potential sources of economic growth, which include, human capital, government consumption, the terms of trade, the inflation rate, political stability, and geographical location. While these studies reach conclusions that confirm a number of these variables (or more accurately, what these variables 'deputise' for) as sources of economic growth, the conclusions reached in these studies should be treated with some caution for two main reasons. First, Levine and Renelt (1992) show that a number of the results are not robust, as ascertained by an Extreme Bounds Analysis, where the number of explanatory variables is varied in the regression specification. Or, in other words, a number of variables are fragile to the inclusion or exclusion of other variables. Second, because of problems associated with reverse causation. For example, Londregan and Poole (1990) argue that causation runs from economic growth to political instability, not the other way around.[5]

On account of New Zealand's status as a small open economy the terms of trade has been given consideration as a source of output growth. Grimes (1989) finds that for the period

[5] Given 'feedback' effects, some authors have employed instrumental variable techniques or simultaneous equation models.

1961-1987 a 9% cumulative decline in the terms of trade led to a 1% cumulative decline in output. In a similar vein, Easton (1991, p. 84.) proffers that "... if the New Zealand terms of trade had not fallen during the postwar era, then New Zealand GDP per capita would have kept a similar relativity to average OECD per capita." For the later reform period, Hall (1996, pp. 56 – 57) reports that New Zealand's terms of trade had a positive impact on output growth. Hall reaches this conclusion on the basis of the results obtained from 'shocking' the National Bank of New Zealand's DEMONZ model. Diewert and Lawrence (1999, p.33) question this finding. Employing a methodology developed by Diewert and Morrison (1986) and Fox and Kohli (1998), Diewert and Lawrence (1999, p. 33) argue:

> The terms of trade actually has the smallest impact on real GDP over the 20 years of the four factors examined [productivity, capital, labour, and the terms of trade]. Although a deterioration in the terms of trade between 1978 and 1986 would have reduced real GDP by around 10 per cent, all else unchanged, this was quickly recovered between 1986 and 1990 and plateaued at a level around three per cent below 1978 real GDP from 1992 onwards.

De Long and Summers (1991) present evidence that machinery and equipment investment is an important determinant of growth. Based on this null hypothesis, Chapple (1994) considers the relationship between equipment investment and GDP for twenty industries comprising the market sector of the New Zealand economy. Using simple correlation coefficients, Chapple (1994, pp. 46-47) finds little sample evidence that equipment investment is important to growth, given that "[t]he correlations between investment and growth are persistently higher for land and buildings investment rather than plant and equipment."[6]

Following the revival in research on economic growth, a considerable amount of attention has been devoted to the phenomenon of convergence.[7] As discussed previously, this can be due to input accumulation and/or technological catch-up. In the case of New Zealand, Conway and Hunt (1998) find some evidence of convergence between the New Zealand

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[6] Although, Chapple (1994, p. 47) notes that this is based on the assumption that the externality is internal to the industry.

[7] For a discussion of this phenomenon see Chapter Two, Section 2.1.

economy and the United States (the technology leader). Cashin (1995) finds evidence of conditional convergence between the colonies of Australasia over the period 1861-1991.[8]

Smith and Grimes (1990) utilise the work of Dowrick and Nguyen (1989), who find evidence of convergence in TFP between OECD economies over the period 1950-1985, to allow for technological 'catch-up' when calculating the growth of TFP. Easton (1991, pp. 74-75) questions the relevance of Dowrick and Nguyen's (1989) work for the New Zealand economy. Noting that New Zealand was initially above the OECD average (in the 1950s), Easton points out that 'convergence' is one possible explanation for the slowing in output growth, however, for the rest of the postwar period, when the New Zealand economy was below the OECD average, the economy continued to diverge. As an alternative hypothesis, the author (Easton, 1991, p. 75) advances the explanation that New Zealand was not as adversely affected by World War Two, as where other economies, and presumably did not experience the increase in aggregate demand that accompanied rebuilding.

Even after adjusting for technological catch-up Grimes and Smith (1990, p. 143) still highlight New Zealand's poor postwar productivity performance. They (ibid., pp.146-147) advance three reasons for this. First, the lack of competition within New Zealand. Second, product and factor market rigidities perpetuated by government regulation and intervention. Third, the presence of domestic trade barriers, which insulated the New Zealand economy from the rest of the world. They do note, however, that these three reasons have been addressed by the significant market liberalisation undertaken in New Zealand's recent economic history.

Easton (1991) provides a challenge to the reasons advanced by Grimes and Smith (1990). After arguing that New Zealand's postwar growth has been driven primarily by factor accumulation, the author (ibid., pp. 75-76) considers the "misallocation of resources and inflexibility of the New Zealand economy" (presumably due to government intervention and

[8] At one stage the states of Australia and New Zealand were colonies of Britian, hence the justification for the title of Cashin's paper: *Economic Growth and Convergence Across the Seven Colonies of Australasia.* In addition, between 1840 and 1841, New Zealand was a dependency of New South Wales.

trade barriers) as an unimportant factor in explaining New Zealand's poor performance. Easton (1991) cites evidence from Easton (1980) and Philpott and Stroombergen (1986) that domestic trade barriers result in *allocational losses* of less than one percent of total output. He also points to the study by Campbell (1984, p. 36) that finds "... quantitative forms of protection have been one of the characteristics contributing to *higher* rates of residual growth in New Zealand manufacturing industries."[9] This is a very static view of the consequences of trade barriers. A more comprehensive view needs to incorporate dynamic considerations. It does not, for example, take into account the impact that border protection may have in blocking 'technology spillovers' into the New Zealand economy. This is important in the light of the research by Coe and Helpman (1995) and Engelbrecht (1997a and b), where R&D spillovers, which are facilitated by an openness to international trade, may have a positive impact on domestic productivity.[10]

Philpott (1993) discusses the relationship between government expenditure and TFP growth in the context of Aschauer's (1989a, b) work. Philpott (1993, pp. 41-42) emphasises Aschauer's concern about the possibility of the fall in United States's productivity, during the 1970s, being associated with the corresponding decline in the accumulation of government public capital. Philpott (1993, p. 42) goes on to discuss Aschauer's (1989a) finding of "... a highly significant positive effect of growth in government non market capital stock on growth in total factor productivity, such that over the period a 1 percentage point rise or fall in Government K [capital] raised (or lowered) private sector TFP by 0.4

[9] More specifically, Campbell (1984, p.45) hypothesises a non-linear relationship between productivity growth and border protection with "... residual growth being high at first when quantitative restrictions are low but are being built up rapidly; weakening when high levels of protection are reached, and growth in protection and output slackens." Campbell's (ibid.) explanation: "The early positive response of gR [residual growth] to increased protection might be ascribed to the effects of a secure market on the confidence of entrepreneurs and on their willingness to adopt innovations; but prolonged protection from international competition may reduce incentives to innovate."

[10] Engelbrecht (1997a) finds that for the period 1971-1990 R&D spillovers had, on average, a negative impact on New Zealand's TFP growth. He (ibid., p. 318) offers as an explanation for this result the hypothesis that a greater level of domestic R&D may be necessary to increase the capacity of the New Zealand economy to absorb foreign R&D.

percentage points." Philpott (1993, pp. 42-43) argues that these results are consistent with the data from his (Philpott, 1991; 1992a, b, and c) "provisional growth data base" for the New Zealand economy.

Economic theory suggests that inflation may have a negative impact on economic growth.[11] In the New Zealand context Orr (1989) considers the relationship between inflation and labour productivity. When viewing this relationship the problem arises as to the direction of causation: does causation run from inflation to labour productivity or the other way around? A strong case can be made that productivity can be either a 'demand' or a 'supply' side phenomenon. Orr (1989, p. 39) provides a summary of both arguments. On the demand side, where causation runs from productivity to inflation, firms, when faced with a decline in labour productivity, are more likely to increase output prices rather than reduce nominal wages or profit. On the supply side, where causation runs in the opposite direction, a higher rate of inflation leads to uncertainty and an increase in the 'noise' associated with price signals, thus reducing productivity. Orr (1996) investigates the inflation-productivity nexus, using Granger causality tests.[12] He concludes "... that the arguments postured above supporting the hypothesis that inflation, or at least variations in price movements, *precede* variations in productivity, outweigh those arguments to the contrary for the case of the New Zealand manufacturing sector" (ibid., p. 43).

At the industry level a number of explanations have been offered for inter-industry productivity growth differences. Campbell's (1984) seminal work, which analyses the productivity performance of 132 industries over the period 1952-1973, considers a number of factors that may explain the inter-industry productivity differences. These include uncertainty and effective rates of protection. Perhaps of more consequence are those factors that Campbell (1984) considers which do not appear to directly affect TFP growth. These

[11] Briault (1995) provides a summary of this literature.

[12] Granger causality tests should be treated with some caution because "... causality does *not* imply a cause-effect relationship, but rather is based on 'predictability'"(Griffiths, Hill, and Judge, 1993, p. 696). In addition, Granger causality tests are very sensitive to the number of lags specified in the model (Gujarati, 1995, p. 622).

include: the proportion of employees in R&D and in managerial/technical jobs; growth in average weekly hours; and industry concentration (Campbell, 1984, p. 37). In addition to analysing the performance of the manufacturing sector at a highly disaggregated level, Campbell's (1984) study employs an index number methodology, calculating the growth rate of TFP, using nine inputs into the gross output production function.

3.4 Economic Reform

Over the last fifteen years the New Zealand economy has undergone a period of substantial reform. Evans, Grimes, Wilkinson, and Teece (1996) present a systematic account of these reforms as well as a brief discussion of their outcomes. They note that the initial impetus for reform was the 'currency crisis' faced by the incoming Labour government, which was precipitated by the refusal of the incumbent National government to devalue an already overvalued exchange rate. The decision of the incoming Labour government to immediately devalue the New Zealand dollar by 20% heralded the commencement of the economic reforms.

Broadly speaking, liberalisation proceeded in the following order: financial and goods market deregulation; public sector reform, including taxation and budgetary reform; and finally, labour market deregulation (Evans et al., 1996, p.1863). While the Reserve Bank Act (1989), with its focus on price stability, only became law after five years of reform, in 1984 there was a view that monetary policy should be directed toward containing inflation (Evans et al., 1996, p. 1864). In this sense, monetary policy reform took place between 1984 and 1990.[13] In terms of key principles underlying the economic reforms Evans et al. (1996, p. 1893) highlight "... their comprehensive and coherent nature, their emphasis on time consistency, their comparative-institutional analysis of policy options, and their extensive use of contracts." Bollard (1992, p.9) points out that efficiency gains were to be primarily achieved through microeconomic reform, with macroeconomic reform providing a necessary framework.

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[13]The Reserve Bank Act was passed into legislation in 1989, however, it did not take effect until February 1990 (Evans et al., 1996, p. 1864)

At the macroeconomic level Evans et al. (1996, p.1862) identify the intellectual influence of Edmund Phelps and Milton Friedman on the development of policy. At the microeconomic level they point to the interest of public sector officials, especially from Treasury, in "... developments in microeconomic theories concerning public choice, market competition and governance: contracting issues including property rights, asymmetric information and transaction costs; and institutional economics more generally" (ibid.). Philpott (1999, p. 2) writes in a similar vein, arguing that the reforms since 1984 are based on what has come to be known as the 'Washington Consensus', that is, the economic policy advice proffered by the World Bank, International Monetary Fund, and the United States Treasury. The author (Philpott, 1999, p. 2) identifies "fiscal discipline and public expenditure priority on education and health; tax reform; market determined interest rates; liberalised trade policies; openness to foreign direct investment; privatisation of government owned businesses; deregulation; and minimalist role for government" as the economic principles underpinning this 'consensus'.

New Zealand commentators still debate the success of the reforms, with opinion ranging from endorsement to derision. The study undertaken by Evans et al. (1996, p. 1894) surmises:

> ... the reforms have markedly improved New Zealand's economic prospects and represents a radical break from New Zealand's past policies of heavy regulation and import protection, and the accompanying, by OECD standards, relatively large fiscal deficits and high rates of inflation.

They qualify this, however, by pointing out that it is difficult to assess how much of the growth of output between 1991 and 1995 is attributable to structural rather than cyclical factors, and that the 'sustainability' of the reforms has yet to be tested under the Mixed Member Proportion (MMP) electoral system.

Dalziel (1999) offers a different view point; that being the reforms are a failure. Based on the observation that for the period 1976-1984 New Zealand's growth rate of real GDP was similar to Australia's, he (ibid., p. 5) argues that the cumulative loss in output, relative to if

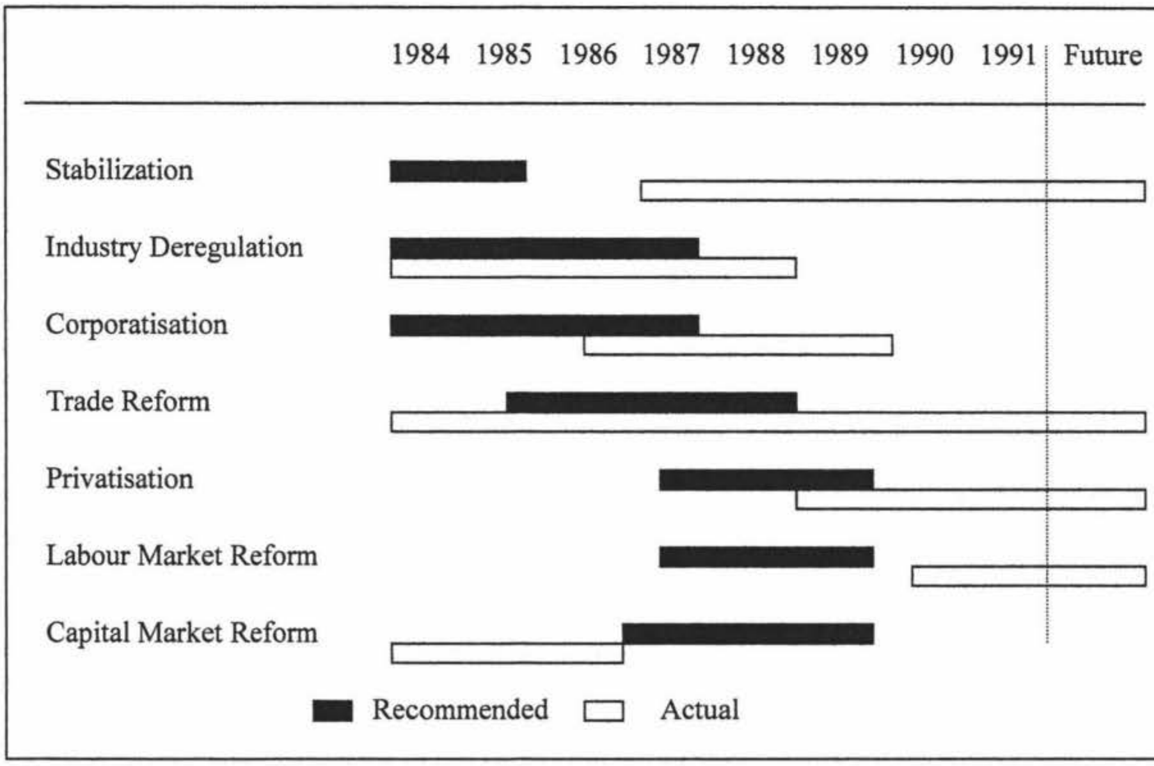
New Zealand had grown at the same rate as Australia for the period 1985-1998, is $210 billion (1995/6 prices). This is two and a half times greater than New Zealand's total GDP in 1998. Dalziel (1999, p. 6), thus, judges "... the lesson from New Zealand is that the 'big bang' economic reform programme involved an enormous sacrifice of output during the late 1980s that showed no sign of being compensated for by higher growth rates in the 1990s." Bollard (1992, pp. 24-25) discusses the "big bang versus gradual approach" to economic reform. He (ibid., p. 24) notes that while the gradual approach attempts to neutralise some of the negative impacts of economic reform, "... adjustment costs may end up being so large that they negate the reform, or that they dissuade reformers from completing their programme." Bollard (1992, p. 25) also notes the readiness of officials to pursue a 'big bang' approach.

A related issue to the success of the reforms is their sequencing. Even those commentators who commend the reforms as praiseworthy question their sequencing. In particular, Bollard (1992, pp. 25 and 47) observes the lack of general equilibrium considerations and reformers "paying too little attention to transition paths and adjustment costs." This is put more forcibly by Philpott (1999, pp. 14-15):

> Many [of the reforms]... were admirable in raising efficiency of resource use when looked at individually but they were rarely examined or administered in an overall coherent growth context. In the jargon of Economics the reforms and the increased efficiencies to which they were to lead were formulated in a *partial equilibrium* context. No attempt was made to provide an overall *general equilibrium* or *macroeconomic* framework, let alone to formulate such a general equilibrium growth policy to enquire as to the extent to which labour and capital disengaged from inefficient areas would be absorbed into existing or new efficient areas.

Bollard (1992, p. 26) questions the wisdom of commencing structural reform before curbing government expenditure, deregulating output markets before input markets, and 'opening-up' the economy to international competition before deregulating domestic markets. Figure 3.1 provides a comparison of Bollard's 'recommended' sequencing of reform with what actually took place.

Figure 3.1 – Actual and Recommended Sequencing of Reforms



Source: Bollard (1992, p.27). Bollard's diagram is based on Genberg's (1991) recommended reform sequencing.

Undoubtedly the disinflationary process cost the New Zealand economy dearly. For the period 1986-1993 Hall (1996, p. 53) reports that New Zealand's trend rate of inflation fell from 15.4% to 1.1%. The sacrifice ratio – that is the cumulative loss in aggregate output to the fall in trend inflation – corresponding to the same period was 7.7%. In other words, on average every 1% decline in trend inflation resulted in a 7.7% cumulative loss in real aggregate output. Although Debelle (1995, p. 18) points out that sacrifice ratios should be treated with caution, because other factors that influence output are not controlled for, this figure gives support to the view that the disinflationary process cost the New Zealand economy in terms of lost output.[14]

[14] Ball (1993) finds that disinflationary periods are costly for a number of economies. The average sacrifice ratios for Australia, Canada, France, Germany, Italy, Japan, Switzerland, the United Kingdom, and the United States, for the period 1960-1991, was 1.4%. This reveals the enormous cost of New Zealand's disinflationary process, relative to the experience of a number of other developed economies.

Hutchison and Walsh (1998) investigate the short-run tradeoff between output and inflation in more detail. They find empirical evidence that after the introduction of the Reserve Bank Act (1989) there has been an increase in the tradeoff between output and inflation. The authors (Hutchison and Walsh, 1998, pp. 712-717) arrive at this conclusion on the basis of formal tests for structural instability and forecasting error. They (ibid., p. 720) identify two counteracting forces affecting this tradeoff. First, economies with historically lower rates of inflation tend to have higher tradeoffs during disinflationary phases[15]. Second, policy credibility – the degree to which central banks' policy announcements are believed by agents – tends to reduce the tradeoff during disinflationary periods. Hutchison and Walsh's (ibid, pp. 720-721) results confirm the view that "[t]he net effect of a lower inflationary environment and greater credibility following the 1989 central bank reform [in New Zealand] appears to have increased the short-run output-inflation tradeoff."

Razzack (1997) also finds the reverse is true when the economy faces an expansion in aggregate demand (presumably when the economy is operating near full capacity). For the purpose of simulation, he constructs a model for a small open economy, where expectations are formed rationally, where the central bank keeps inflation within a tight band, and where the public has perfect information on the monetary rule employed by the central bank. After running a simulation on the model where a demand shock hits the economy and the central bank a) reacts immediately and b) reacts after a two period lag, Razzack (1997, p. 12) concludes:

> Delays in monetary policy responses to positive demand shocks leads to an increase in the inflation rate, and large losses in bringing inflation down. This is attributable to the asymmetry of the Phillips curve, and the persistence of inflation, and occurs despite the fact that expectations are rational.

Other authors, most notably Galbraith (1997), also contend that the Phillips Curve is asymmetric for the United States. When output increases there is a negligible increase in inflation, whereas, when output decreases there is a noticeable fall in inflation.

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[15] Hutchison and Walsh (1998, p. 719) suggest that this could be due to an increase in nominal rigidities.

The main channel through which the disinflationary process resulted in lost output was the real exchange rate. With the Reserve Bank pursuing a tight monetary policy, and the Government struggling to restrain its expenditure in the economy, the real exchange rate continued to appreciate. Bollard (1992, p. 33) describes the result:

> ... the strongly growing exchange rate... implied that the traded sector was not internationally competitive; as a result, many New Zealand manufacturers gave up domestic assembly, became importers or distributors, or went out of business entirely. The manufacturing sector decreased by a third during the reform period; some of these firms only existed because of protection, and would probably never have become internationally competitive.

In the light of this, Philpott (1999, p. 14) argues that the real exchange rate should have been set at a level that allowed the tradeable sector to adjust to operating in an international context.

Hall (1996, pp 61-63) provides a quantitative assessment of the benefits that *may* have accrued to the New Zealand economy *if* the government had been able to control its fiscal balance (as measured by the ratio of gross public debt to GDP). Based on the results obtained from a simulation on the National Bank's DEMONZ macroeconometric model, where the author reduces the government expenditure to GDP ratio, Hall (1996, p. 62) finds little evidence that net gains in GDP (relative to baseline) would have been achieved before 1997.

Evans et al. (1996, p. 1870) conjecture that "New Zealand's ability to achieve early credibility for its disinflationary policies and its inability to free up labour markets much earlier undoubtedly cost it heavily." Hall (1996, pp. 57-61) again simulates the National Bank's model to gain some quantitative assessment of the benefits that *may* have resulted *if* the labour market had been deregulated earlier in the reform period. After shocking wages and labour productivity at the beginning of 1986,[16] Hall (1996, p. 59) reports "[i]n a broad

[16] Hall reduces wages by 2.5% (below baseline) in the first two quarters of 1986, where they remain for the following two years, before rising by 0.2% per quarter until baseline is reached in the third quarter of 1994. Labour productivity is increased by 5% over baseline, at 0.5% per quarter, commencing at the beginning of 1986.

sense... [this] combined shock would have resulted in significantly improved real GDP, employment and unemployment outcomes over the following decade, as well as modest initial reductions in macroeconomic fiscal and external imbalances." Hall (1996, p. 61), thus, concludes: "[r]esults from this illustrative 'combined wages-productivity shock', especially those for the real GDP and unemployment outcomes, are not inconsistent with the arguments of those who have suggested there could have been significant real sector benefits from having introduced the ECA [Employment Contracts Act (1991)] around five years earlier."

The simulation undertaken by Hall (1996) is based on the assumption that labour market deregulation leads to a fall in labour costs and an increase in labour productivity. Therefore, it is important to consider the impact the Employment Contracts Act (ECA) had on these variables. Maloney (1998) finds evidence of a slowing in labour productivity and no change in real ordinary or total-time hourly earnings following the introduction of the ECA. He justifies these conclusions using the results obtained from an extensive regression analysis. Maloney (1998, pp. 118-119) notes that part of this can be attributable to the fall in the capital/labour ratio, but also notes "the indirect effects of the ECA on both union density and output can account for a slowdown in the annual productivity growth rate of between one-quarter and one-half of a percentage point." Diewert and Lawrence (1999), however, warn that Maloney's (1998) conclusions should be treated with caution. After re-estimating, using an alternative function form to the one used by Maloney (1998) (that is, a normalised quadratic production function instead of a Cobb-Douglas production function), the authors (Diewert and Lawrence, 1999, p. 121) point out:

> ... Maloney's strong conclusions about the effects of the ECA rest on the use of a Cobb-Douglas production function methodology and... this functional form is simply not flexible enough to adequately describe the trends in the New Zealand economy. The use of a more flexible functional form may well lead to a different conclusion than the one that Maloney obtained.

Undoubtedly, one of the forces that led to the commencement of the reform period was a desire to rectify New Zealand's poor economic growth. Yet to date there is little empirical evidence to support the hypothesis that New Zealand's output and productivity growth have increased as a result of the reforms. For example, Hall (1996, p. 64) writes:

> There is, as yet, insufficient evidence to conclude that New Zealand's growth performance in the ten years since 1984 has been both significantly and sustainably higher than the previous decade or that any difference can be conclusively associated with the (still ongoing) reform process.

In fact Diewert and Lawrence (1999, pp. 29-32) find sample evidence of a drop-off in TFP for the period immediately after 1984.[17] This, however, is not surprising, given trade liberalisation initially rendered substantial amounts of physical capital obsolete, causing a reduction in output.

Even at the sectoral level, where the range in TFP growth rates is high, there is not a lot of evidence to suggest that post-reform TFP growth rates are significantly higher. For example, Chapple (1994, p.53) finds "there is no overwhelming evidence from this study that the sectors of the New Zealand economy have generally shifted onto a new higher growth path since 1984."

3.5 Testing Exogenous versus Endogenous Growth Models for New Zealand

All the New Zealand studies that were discussed in the previous section adopt the neoclassical growth framework in analysing economic growth. What is apparent when reviewing the New Zealand literature is that minimal quantitative work has been undertaken in order to empirically distinguish between different classes of growth models for the New Zealand economy.[18] There are, however, a couple of notable exceptions.

In his study Chapple (1994, pp.47-52) undertakes two indirect tests of the general category of endogenous growth models. The first tests the scale economies of 20 industries comprising the market sector of the New Zealand economy. Chapple's (1994, p. 47)

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[17] Diewert and Lawrence (1999) test for this using the linear spline technique. They also find evidence of a structural break in 1982.

[18] This is partly due to the fact that the identification of growth models for particular countries is now only moving to the forefront of the research agenda on economic growth. For a survey of some of the empirical literature on endogenous growth see Chapter Two, Section 2.2.

rationale for performing this test is that "... increasing returns to scale are frequently used as the force driving endogenous (new growth) theory."[19] If there are a number of industries exhibiting increasing returns to scale, there may be some degree of support in favour of growth being determined endogenously for the New Zealand economy. Chapple (1994, p. 48) finds evidence of increasing returns to scale in seven out of twenty industries, noting that there is "... some support to the increasing returns element of new growth theory for some sectors." However, he warns that caution should be exercised given the dubious nature of some of the results.[20] The second test Chapple performs involves the estimation of an externality to human capital accumulation, based on Romer (1986). This test also produces results that appear to conform with the general category of endogenous growth models, however, the results are not statistically significant.

In attempting to distinguish between exogenous and endogenous growth models for the New Zealand economy, Oxley and Zhu (1999) provide a more direct test. In doing so the authors use Human Capital and R&D growth models presented by Romer (1996). After employing the time series methodology, Oxley and Zhu (1999) find "weak support" for exogenous growth in the New Zealand context.[21] Hossain and Chung (1999) also employ a time-series methodology to test the consistency of the neoclassical model with data from the New Zealand economy. They (ibid., pp. 1080-1081) find little sample evidence in support of the neoclassical model.

3.6 Summary

This chapter has sought to provide a review of the literature on New Zealand's postwar economic growth, both a the aggregate and sectoral level. In doing so a number of broad themes have been examined. This chapter has also set the context for the research that is to

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[19] See Chapter Two, Section 2.2.

[20] Chapple finds that for five of the seven industries exhibiting increasing returns to scale, the sum of the exponents (on labour and capital) is negative! This highlights some of the data quality issues associated with Chapple's study.

[21] This is after performing 'second stage' tests. Initially, Oxley and Zhu find *observational equivalence* for the different growth models.

follow. The literature on the empirical testing of growth models for the New Zealand economy is scarce. In addition, the research that has been undertaken has focussed on the testing of the two broad categories of growth models (that is, exogenous versus endogenous growth models). Building on this work, the identification of sub-classes of models within these two broad categories would add to the body of knowledge on the New Zealand economy.

Chapter Four

Methodology and Data Sources

By far the largest portion of the literature on total factor productivity is devoted to problems of measurement rather than to problems of explanation. In recognition of this fact changes in total factor productivity have been given such labels as The Residual or The Measure of Our Ignorance. (Jorgenson and Griliches, 1967, p. 249)

4.0 Introduction

In Klenow's (1998) article, *Ideas versus rival human capital: Industry evidence on growth models*, the author attempts to indirectly test a series of growth models using data on 449 United States manufacturing industries. In summary, the methodology employed by Klenow (1998) is described as follows: a series of ordinary least squares (OLS) regressions are performed, the results of which are compared with the predictions of three classes of growth models. This chapter begins by outlining the specifics of the methodology used to replicate Klenow's study on data for twenty industries comprising the market sector of the New Zealand economy. As is discussed in Section 4.1, because this thesis uses a sample with relatively fewer industries than that used by Klenow, an alternative estimator is required and outlined. The data that is used in conjunction with this estimator, in order to obtain the results necessary for comparison with the different growth models, is discussed in Section 4.2.

4.1 Methodology

In Klenow (1998) the author runs a series of simply regressions, in order to investigate the relationship between two or more economic variables, and then uses these regression results to evaluate the predictions of five growth models. Each of these models can be assigned to one of three different classes of growth models: exogenous growth models, revival human capital models, and idea accumulation models. The latter two classes of growth models belong to the broader class of endogenous growth models. The reason for discriminating between rival human capital models and idea accumulation models is that both classes of models have different positive and normative implications. Chapter Six, Section 6.8, provides a detailed discussion of these implications, in the context of the New Zealand economy.

4.1.1 Specification and Estimation of TFP Growth Relations

The following are the ten TFP growth relations (based on Klenow, 1998) from which estimates are used to evaluate the predictions of three classes of growth models with data for the New Zealand economy. The first set corresponds to the TFP growth relations to be estimated with real gross output data; the second set, real value added data.

Gross Output:[1]

$$DEF_{it} = \beta_1 + \beta_2 TFP_{it} + \varepsilon_{it} \quad \textbf{(i)}$$

$$TFP_{it} = \beta_1 + \beta_2 LS_{it} + \varepsilon_{it} \quad \textbf{(ii)}$$

$$TFP_{it} = \beta_1 + \beta_2 NPLS_{it} + \varepsilon_{it} \quad \textbf{(iii)}$$

$$TFP_{it} = \beta_1 + \beta_2 CS_{it} + \beta_3 MS_{it} + \varepsilon_{it} \quad \textbf{(iv)}$$

$$TFP_{it} = \beta_1 + \beta_2 CS_{it} + \beta_3 MS_{it} + \beta_4 CSBC_{it} + \beta_5 CSPMTE_{it} + \beta_6 MSDEF_{it} + \varepsilon_{it} \quad \textbf{(v)}$$

Real Value Added:

$$DEF_{it} = \beta_1 + \beta_2 TFP_{it} + \varepsilon_{it} \quad \textbf{(vi)}$$

$$TFP_{it} = \beta_1 + \beta_2 LS_{it} + \varepsilon_{it} \quad \textbf{(vii)}$$

$$TFP_{it} = \beta_1 + \beta_2 NPLS_{it} + \varepsilon_{it} \quad \textbf{(viii)}$$

$$TFP_{it} = \beta_1 + \beta_2 CS_{it} + \varepsilon_{it} \quad \textbf{(ix)}$$

$$TFP_{it} = \beta_1 + \beta_2 CS_{it} + \beta_3 CSBC_{it} + \beta_4 CSPMTE_{it} + \varepsilon_{it} \quad \textbf{(x)}$$

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[1] TFP growth relations (v) and (x) differ from Klenow (1998) because the ONZPRDB contains capital deflators for both the building and construction capital stock and the plant, machinery, and equipment capital stock. An attempt was made to combine the two deflators but difficulties were encountered.

i = 1, ..., 20; t = 1, ..., 3 (each time series observation is a six-year average).[2]

where *DEF* = Average annual compound growth of the output deflator

TFP = Average annual compound growth of TFP

LS = Average labour share

NPLS = Average non-production labour share

CS = Average capital share

MS = Average material share

CSBC = Product of the average capital share and the average annual compound growth of the building and construction capital deflator

CSPMTE = Product of the average capital share and the average annual compound growth of the plant, machinery, and equipment capital deflator.

MSDEF = Product of the average material share and the average annual compound growth of the input deflator

ε = Random error term

The ONZPRDB contains data on twenty New Zealand industries, a considerably smaller number than that used by Klenow(1998) in his analysis. If the regression analysis was performed using this sample of twenty industries, and growth rates calculated over an eighteen year period, the precision of the estimates is likely to be poor, due to a lack of spread for each independent variable.[3] In order to overcome this problem of micronumerosity, it is common practice to 'pool' the data. As Vinod and Ullah (1981, p. 248) note:

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[2] The index i is for the twenty industries comprising the market sector of the New Zealand economy. As will be discussed in Chapter 5, the TFP growth relations are also estimated for manufacturing and primary industries, as well as manufacturing industries only. In these cases the index i runs from 1 to 13 and 1 to 9, respectively.

[3] The ONZPRDB has eighteen time-series observations for each industry. When an OLS regression was run on twenty industries for growth rates calculated over an eighteen year period, this was indeed the case. The only exception was the coefficient on output deflator growth for TFP growth relation (i).

> When dealing with cross-section and time series data, where each individual cross-section sample is small so that sharp inferences about the coefficients are not possible, it is common practice in applied work to pool all data together, and estimate a common regression. The basic motivation for pooling time series and cross-section data is that if the model is properly specified, pooling provides more efficient estimation, inference, and possibly prediction.

This thesis employs this approach, pooling data on twenty New Zealand industries.

As the regression analysis is performed using cross-section and time-series data, *a priori* one would expect the presence of heteroskedasticity and autocorrelation. In order to check for the presence of heteroskedasticity, a series of Breusch-Pagan-Godfrey test statistics were computed. These tests provide strong sample information in support of a heteroskedastic error variance. (See Appendix One for a discussion of the testing procedure, as well as the actual values for the Breusch-Pagan-Godfrey test statistics.) Testing for autocorrelation is more problematic. Given that the sample is comprised of only three time-series observations, it would prove futile to test for the presence of autocorrelation.[4] Yet, *a priori,* if the sample were widened one would expect the Durbin-Watson test statistics to provide strong sample evidence in favour of the hypothesis of autocorrelated errors. Based on this rationale, the data is assumed to exhibit autocorrelation. As an aside, this problem of testing for autocorrelation serves to highlight some of the inadequacies of the data set under study, as well as the need to proceed with caution.

Given the above information, the error term for each TFP growth relation is assumed to exhibit the following statistical properties (Kmenta, 1986):

$E(\varepsilon_{it}) = \sigma_i^2$		Heteroskedasticity
$E(\varepsilon_{it}\varepsilon_{jt}) = 0$	(i≠j)	Cross-section independence
$\varepsilon_{it} = \rho\varepsilon_{i,t-1} + u_{it}$		Autocorrelation of the 1^{st} order

[4] Section 4.1.3 provides a discussion as to why growth rates are calculated over a six-year period (that is, why there are only three times series observations, even though there are eighteen annual time series observations for each industry in the ONZPRDB).

$$u_{1t} \sim N\left(0, \sigma_{u_1}^2\right)$$

$$\varepsilon_{i1} \sim N\left(0, \frac{\sigma_{u_1}^2}{1-\rho_i^2}\right)$$

$$E\left(\varepsilon_{i,t-1} u_{jt}\right) \qquad \text{for all i,j.}$$

In the presence of heteroskedasticity and autocorrelation the OLS estimator is no longer a best linear unbiased estimator (BLUE). In this situation the BLUE is a generalised least squares estimator (GLS), such as the one available when using the POOL command in the econometric software package SHAZAM. In computing the parameter estimates of the TFP growth relations, SHAZAM (SHAZAM User's Reference Manual Version 8.0, 1997, pp. 269-270) works through the following GLS procedure:

1. Estimate the parameters β by OLS and then obtain estimates for the residuals ε_{it}.
2. Use the estimates of the residuals to obtain an estimate of the autoregressive parameter ρ.
3. Use the estimate for ρ to transform the observations, and then re-estimate the transformed model using OLS.
4. Obtain the GLS estimator.

The model is also specified so that the parameter ρ is restricted to have the same value for all cross sections. More formally this is denoted as follows:

$$\rho_i = \rho_j = \rho \qquad \text{for all i, j} = 1, \ldots, 20$$

This restriction is placed upon the estimation process out of necessity. Ideally, ρ_i should be allowed to vary over cross sections. However, given that the estimator for ρ_i is $\hat{\rho}_i = \frac{\sum_{t=2}^{T} e_{it} e_{i,t-1}}{\sum_{t=2}^{T} e_{i,t-1}^2}$, and that T = 3, there are too few time series observations to find an estimate for ρ_i. ρ_i is, therefore, restricted to be the same over all cross sections. Likewise, it would be advantageous to drop the assumption that $E(\varepsilon_{it}\varepsilon_{jt}) = 0$, allowing for cross-sectional correlation.[5] However, because T < N, the error variance-covariance matrix would be singular, making estimation impossible.

4.1.2 Total Factor Productivity

The growth of TFP is used as the dependent variable in TFP growth relations (ii)-(v) and (vii)-(x), and as the independent variable in TFP growth relations (i) and (vi). Put simply, TFP is the ratio of output to all inputs in the production process. In pursuing Solow's (1957, p. 312) methodology[6] a generic aggregate production function (gross output) with Hicks neutral technology (output augmenting) is denoted as follows:[7]

$$Y = A(t)f(L, K, M) \tag{4.1}$$

where Y = Real Gross Output

$A(t)$ = Index of TFP

L = Labour Hours Worked

K = Capital

M = Materials

Differentiating (4.1) with respect to time, and then dividing by Y yields:[8]

$$\frac{\dot{Y}}{Y} = \frac{\dot{A}}{A} + A\frac{\partial f}{\partial L}\frac{\dot{L}}{Y} + A\frac{\partial f}{\partial K}\frac{\dot{K}}{Y} + A\frac{\partial f}{\partial M}\frac{\dot{M}}{Y} \tag{4.2}$$

---

[5] That is $E(\varepsilon_{it}\varepsilon_{jt}) = \sigma_{ij}$

[6] In Solow's (1956) original specification the author used a value added production function.

[7] This is the gross output production function corresponding with TFP growth relations (i)-(v). The value added production function, which corresponds to TFP growth relations (vi)-(x), is net of the material input. However, the approach used to obtain the growth of TFP is the same.

[8] Dot notation is used to denote the derivative with respect to time.

Which after rearrangement and substitution gives:

$$\frac{\dot{A}}{A}=\frac{\dot{Y}}{Y}-w_L\frac{\dot{L}}{L}-w_K\frac{\dot{K}}{K}-w_M\frac{\dot{M}}{M} \tag{4.3}$$

Where $w_L=\frac{\partial Y}{\partial L}\frac{L}{Y}$, $w_K=\frac{\partial Y}{\partial K}\frac{K}{Y}$, and $w_L=\frac{\partial Y}{\partial M}\frac{M}{Y}$ are production elasticities with respect to each input.

In other words, the growth of TFP is found by subtracting the weighted average of factor input growth from output growth, where production elasticities act as weights.

4.1.2.1 Cobb-Douglas Production Function

If we allow (4.1), the generic aggregate production function, to assume the Cobb-Douglas functional form with homogeneity of degree one,[9] then (4.1) becomes:

$$Y=A(t)L^{\alpha}K^{\beta}M^{1-\alpha-\beta} \tag{4.4}$$

This implies that (4.3) assumes the following form:

$$\frac{\dot{A}}{A}=\frac{\dot{Y}}{Y}-\alpha\frac{\dot{L}}{L}-\beta\frac{\dot{K}}{K}-(1-\alpha-\beta)\frac{\dot{M}}{M} \tag{4.5}$$

The same procedure can be followed to obtain the growth of TFP with real value added data, where materials are not an input into the Cobb-Douglas production function.

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[9] This implies that the production function exhibits constant returns to scale.

4.1.3 Growth Rates

A large component of this research is concerned with growth rates. In this thesis, instantaneous growth rates are estimated using a log-linear regression model, from which a compound growth rate is found.[10] This is not the usual practice. As Temple (1999, p.119) has written:

> The usual method [for calculating growth rates] uses only initial and final output. Since either of these may be some distance from trend path of output, it may well be preferable to use the least squares growth rate... This should be more robust to short-run instability, such as business cycle effects.

This study heeds Temple's advice, estimating annual average compound growth rates using ordinary least squares (OLS), in a bid to remove cyclical fluctuations.[11] Calculating growth rates by OLS does raise another question: what time horizon should be used to estimate growth rates? As Temple (1999, p. 132) notes this issue is still "largely unsettled." The small number of time series observations used in the empirical analysis suggests that a shorter time horizon would be more appropriate, given the conflicting goals of maximising the amount of time-series information that can be obtained from the panel, as well as removing cyclical variation from the data. This thesis estimates growth rates over a six-year period. The justification for this six-year split, as well as the time periods themselves, is given below.[12]

Figure 4.1 illustrates the path of real GDP over the period 1978-1995. As can be seen from Figure 4.1, over the entire period GDP has tracked upwards. However, there is a degree of deviation from the linear trend. This can be seen when viewing the annual percentage change in real GDP for each year for the period 1978-1995 (Figure 4.2). Casual inference identifies three distinct phases in the growth of GDP over the entire period: 1978-1983,

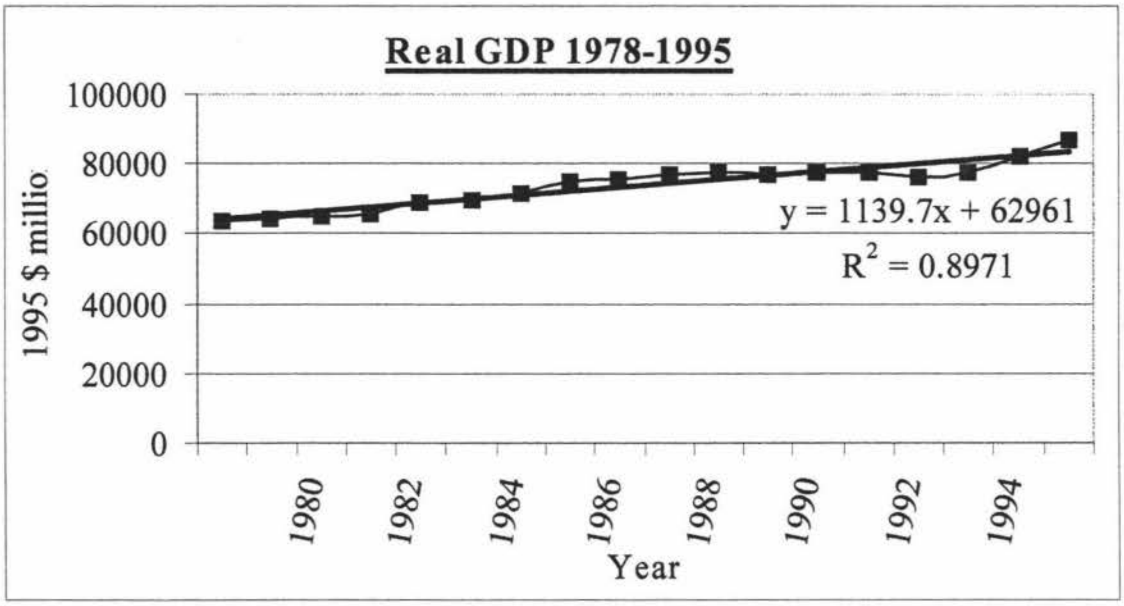
[10] An instantaneous growth rate measures growth at a point *in* time, whereas a compound growth rate measures growth *over* time. Therefore, for the purposes of this thesis, the compound growth rate is more appropriate (Gujarati 1995, p.171).

[11] This is because the OLS procedure estimates a trend growth rate, thus smoothing out fluctuations.

[12] Having noted this, as part of the sensitivity analysis, different time horizons are utilised to verify the robustness of the regression results.

1984-1989, and 1990-1995.[13] 1978-1983 corresponds to the pre-reform Muldoon years. This period was characterised by high unemployment and inflation, and "a pattern of cycles of economic 'boom and bust'" (Dalziel and Lattimore, 1999, p. 19). The second phase, 1984-1989, was the reform period of the fourth Labour Government. During this period output stagnated, as the government initiated a comprehensive programme of economic reform, resulting in a recession.[14] The final period, 1990-1995, was characterised by strong economic growth, as the economy entered the expansionary phase of the business cycle.

Figure 4.1 Real GDP 1978-1995



Source: Dalziel and Lattimore (1999), Data Appendix, p. 120.

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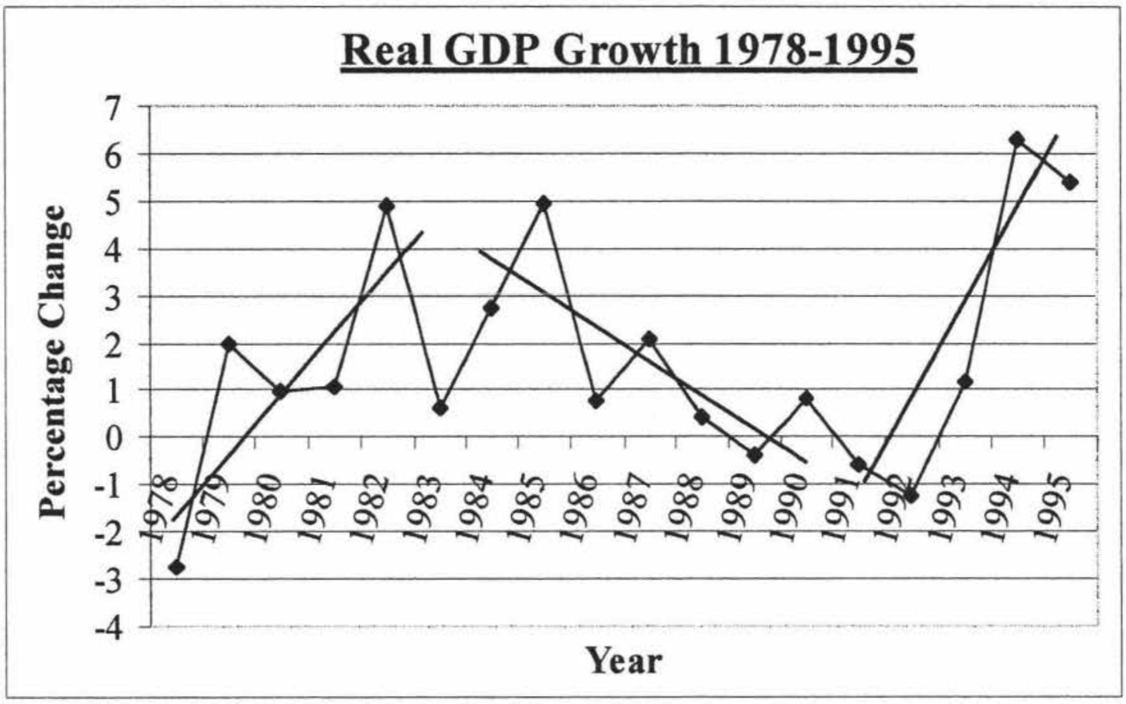
[13] A formal technique – the linear spline test (Diewert and Lawrence, 1999, pp. 30-31) – was also employed to test for structural breaks in 1984 and 1990. The test provides sample evidence of a structural break in 1984 but not 1990. Details can be found in Appendix Two.

[14] One could argue from viewing Figure 4.2 that the second phase did not end until 1992, yet from a 'convenience' standpoint it is more amenable to calculate growth rates over six years. In addition, the linear spline test provides no sample evidence of a structural break in 1992.

Figure 4.2 Real GDP Growth 1978-1995



Source: Dalziel and Lattimore (1999), Data Appendix, p. 120.

While recognising that output 'trends' for some industries may differ from the trend in aggregate output, these periods provide a convenient six-year split for estimation purposes.

4.2 Data

The ONZPRDB contains data on the following industries that comprise the market sector of the New Zealand economy (see Diewert and Lawrence, p. 37):

1. Agriculture
2. Fishing and Hunting
3. Forestry and Logging
4. Mining and Quarrying
5. Food and Tobacco
6. Wood and Wood Products
7. Pulp and Paper Products, Printing, and Publishing
8. Basic Metal Products
9. Textiles, Clothing, and Footwear
10. Petroleum, Chemical, Plastics, and Rubber Products
11. Non Metallic Mineral Products
12. Machinery and Equipment
13. Other Manufacturing
14. Electricity, Gas, and Water
15. Construction
16. Trade, Restaurants, and Hotels
17. Transport and Storage
18. Communications
19. Finance, Insurance, Real Estate, and Business Services
20. Community, Social, and Personal Services

Industries 1-4 constitute the primary sector and industries 5-13 constitute the manufacturing sector; industries 14 and 15 are often classified as support industries;[15] and industries 16-20 constitute the service (tertiary) sector.

4.2.1 Output

At the 2-digit level there are twenty-seven industry classifications, however, only data on the twenty market sector industries is employed in this thesis. The two industries 'Primary Food' and 'Other Food, Beverages, and Tobacco' have been aggregated to form a single industry – Food and Tobacco. 'Wholesale' has been included in Trade, Restaurants, and Hotels due to an incomplete data series for both industries over the period 1978-1995. Ownership of dwellings has been excluded due to severe measurement problems.

Data on real and nominal gross output for the twenty industries, for the period 1978-1995, was drawn from the Annual Production Accounts from the ONZPRDB. Chapple (1999) provided this data on Excel files. Real Production GDP (value added $1992 million) for

[15] These two industries are usually added to the manufacturing sector to make up the secondary sector.

the twenty industries, for the period 1978-1995, was obtained from the ONZPRDB (Diewert and Lawrence, 1999, Table C1, pp. 291-292). Likewise, information on Nominal Production GDP, for the period 1978-1995, was taken from the ONZPRDB (Diewert and Lawrence, 1999, Table C2, pp. 293-294). The output price deflator series for gross output and value added were calculated by simply dividing nominal observations by real observations.

4.2.2 Labour

The ONZPRDB contains an 'hours worked' labour series (Diewert and Lawrence, 1999, Table C5, pp. 297-298) that can be utilised as a labour input in TFP calculations. This series was formed using three other data sources: the Household Labour Force Survey (HLFS), the Quarterly Employment Survey (QES), and the Economic Survey of Manufacturing (ESM).

Chapple and Keegan (1998, p. 21) advise that this labour series should be used with "extreme caution," given different sources across industry and through time. They note that the manufacturing sector has the most reliable 'hours worked' series; Agriculture and Fishing the least reliable. The remaining industries lie somewhere in between.

4.2.3 Capital

The real gross and net capital stock series ($1992 million), for the period 1978-1995, are drawn from the ONZPDB (Diewert and Lawrence, 1999, Tables C12-C15, pp. 312-319). The procedure used for calculating real gross and net capital stocks is outlined in Diewert and Lawrence (1999, Appendix D, pp. 332-339). Both series use Philpott's (1992) assumed asset lives. Capital deflators are taken from the ONZPRDB (Chapple, 1999).

Other New Zealand studies have tended to use an average of the gross and net capital stocks series when calculating TFP. For example, Philpott (1994, 1995) uses this approach noting that "[I]n this respect, we follow the procedure recommended by Denison given the almost counteracting imperfections in each of these concepts" (Philpott, 1995, p. 2). In this thesis, TFP is calculated using the gross capital stock series. However, as part of the sensitivity analysis (Chapter Five, Section 5.2.3), TFP is also calculated using the net capital stock series. In doing so, a lower and upper bound estimate of TFP is found, with a view to verifying the robustness of the parameter estimates for the TFP growth relations. In addition, Statistics New Zealand (1999, Attachment) provides an alternative capital stock series for manufacturing industries at the 2-digit level. This series is also employed during the sensitivity analysis.

4.2.4 Materials

The difference between nominal gross output and nominal value added is used as the nominal material input in this thesis. This corresponds to nominal intermediate consumption in the Annual Production Accounts. Calculating the material input in this way is a valid procedure, given a gross output production function that is homogenous of degree one, which, according to Euler's theorem, implies that factor inputs are paid their marginal revenue product. Thus, value added is simply the value of gross output less the material input. The real material input is calculated by dividing nominal materials by the input deflator from the ONZPRDB (Chapple, 1999).

4.2.5 Imports

Import data for manufacturing industries is drawn from the OECD STAN Database for Industrial Analysis (OECD, 1997). This data was used to calculate import shares for each manufacturing industry.

4.2.6 Factor Shares

Factor shares are calculated using data from the Annual Production Accounts (Chapple, 1999). For TFP calculations based on gross output data, labour's share is calculated by dividing compensation of employees by nominal gross output; capital's share by dividing operating surplus by nominal gross output; and materials share as a residual, by subtracting labour's and capital's share from one. For TFP calculations based on value added data, labour's share is calculated by dividing compensation of employees by nominal GDP and capital's share is calculated as a residual from one. This approach is based on the assumption that the production function exhibits constant returns to scale (that is, factor shares sum to one), where under perfectly competitive conditions, factor inputs are paid their marginal revenue product.

When adopting the above approach, it is likely that labour's share will be understated, particularly in sectors such as Agriculture and Fishing. This is because compensation of employees in the Annual Production Accounts excludes payments made to self-employed persons. Problems associated with this bias are discussed in Chapter Five, Section 5.2.5.

1976, 1986 and 1996 Census Data (Statistics New Zealand, 1977, 1987, and 1997a), in addition to information from the ONZPRDB, were used to calculate nonproduction labour's share in the following way. First, the number of nonproduction workers for each industry was obtained.[16] Once this had been done, the corresponding average estimated ordinary-time earnings for nonproduction workers was multiplied by the number of nonproduction workers. This figure was then divided by the corresponding average nominal gross output or average nominal value added figure.

As will be discussed in Chapter Five, Section 5.1.1, nonproduction labour's share provides a measure of industry human capital intensity, *albeit* an imperfect one. In an effort to refine the measurement of industry human capital intensity, high skilled labour's share is also calculated. This is found in a similar manner to nonproduction labour's share. However, high skilled workers are considered to be professional, technical, and managerial workers only.

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[16] Where nonproduction workers are classified as professionals, technical, managerial, clerical, service, and sales workers.

4.2.7 Data Problems

In their report *Measuring New Zealand's Productivity*, which utilises data from the ONZPRDB, Diewert and Lawrence (1999, p. 69) note: "[i]t is important to express the need for caution in interpreting sectoral and industry productivity results. Sectoral information is likely to be less reliable than aggregate economy wide information." The authors go on to state some of the specific problems associated with industry data from the ONZPRDB. These include (ibid., pp. 69-70):

1. Classification problems, that is, firms changing industry classification as their output changes over time. Diewert and Lawrence (1999, p. 69) point out that this can lead to substantial distortions in the data, especially during times of extensive restructuring such as the New Zealand economy has undergone in the last fifteen years.
2. Data collection problems. When databases are constructed information is usually drawn from a number of sources. This can result in incoherent sectoral and industry data, due to variations in the data that has been collected by statistical agencies. Given that some of the data in the ONZPRDB is formed from a variety of sources, this problem may be particularly acute.
3. Measurement problems. In some industries, particularly those in the service sector, there are problems associated with the measurement of output and inputs. For example, given the intangibility of output in a number of service sector industries, the number of transactions is often used to measure real output.

These shortcomings of the data should be borne in mind when interpreting the results of the TFP growth relations.

4.3 Summary

This chapter has outlined the methodology and data used in this thesis. Due to the unavailability of disaggregate data for the New Zealand economy, relative to Klenow (1998), data is pooled in order to achieve greater precision when estimating the parameters of the TFP growth relations. In addition, this chapter has sought to highlight some of the inadequacies with the ONZPRDB. These shortcomings should be kept in mind when considering the results that are presented in the chapter that follows.

Chapter Five

Results

> *Beware of testing too many hypotheses; the more you torture the data, the more likely they are to confess, but confession under duress may not be admissible in the court of scientific opinion'* (Stigler, 1987, in Gujarati, 1995, p. 115)

5.0 Introduction

This chapter has two main foci. The first is to report the results from the estimation of the TFP growth relations, which were outlined in Chapter Four. In doing so, parameter estimates are presented for three samples: the entire economy, primary and manufacturing industries, and manufacturing industries only. The other focus of this chapter is to check the robustness of these basic results. This is achieved by performing a number of sensitivity analyses. The final section of this chapter provides a summary of the results. This aids discussion of results, in relation to several theoretical growth models, in Chapter Six.

5.1 Basic Results

Figures 5.1 and 5.2 depict the annual average compound growth of TFP for the three periods 1978-1983, 1984-1989, and 1990-1995.[1] From Figure 5.1, where the growth of TFP is calculated using a gross output Cobb-Douglas production function, it is evident that for manufacturing and the service sector industries the growth of TFP has remained relatively constant over the three time periods, with TFP growth fluctuating within a narrow band. There are, however, two industries that are notable exceptions: Basic Metal Products and Petroleum, Chemical, Plastics, and Rubber Products. In these industries the range of TFP growth is quite high. On the other hand, primary sector industries experienced a dramatic fall off in TFP growth over the entire period. In only three industries –

[1] Appendix Three presents tables of TFP for twenty industries in the New Zealand economy obtained with gross output and value added data for the periods 1978-1983, 1984-1989, and 1990-1995.

Figure 5.1 Average Annual TFP Growth Real Gross Output: 1978-1983, 1984-1989, and 1990-1995

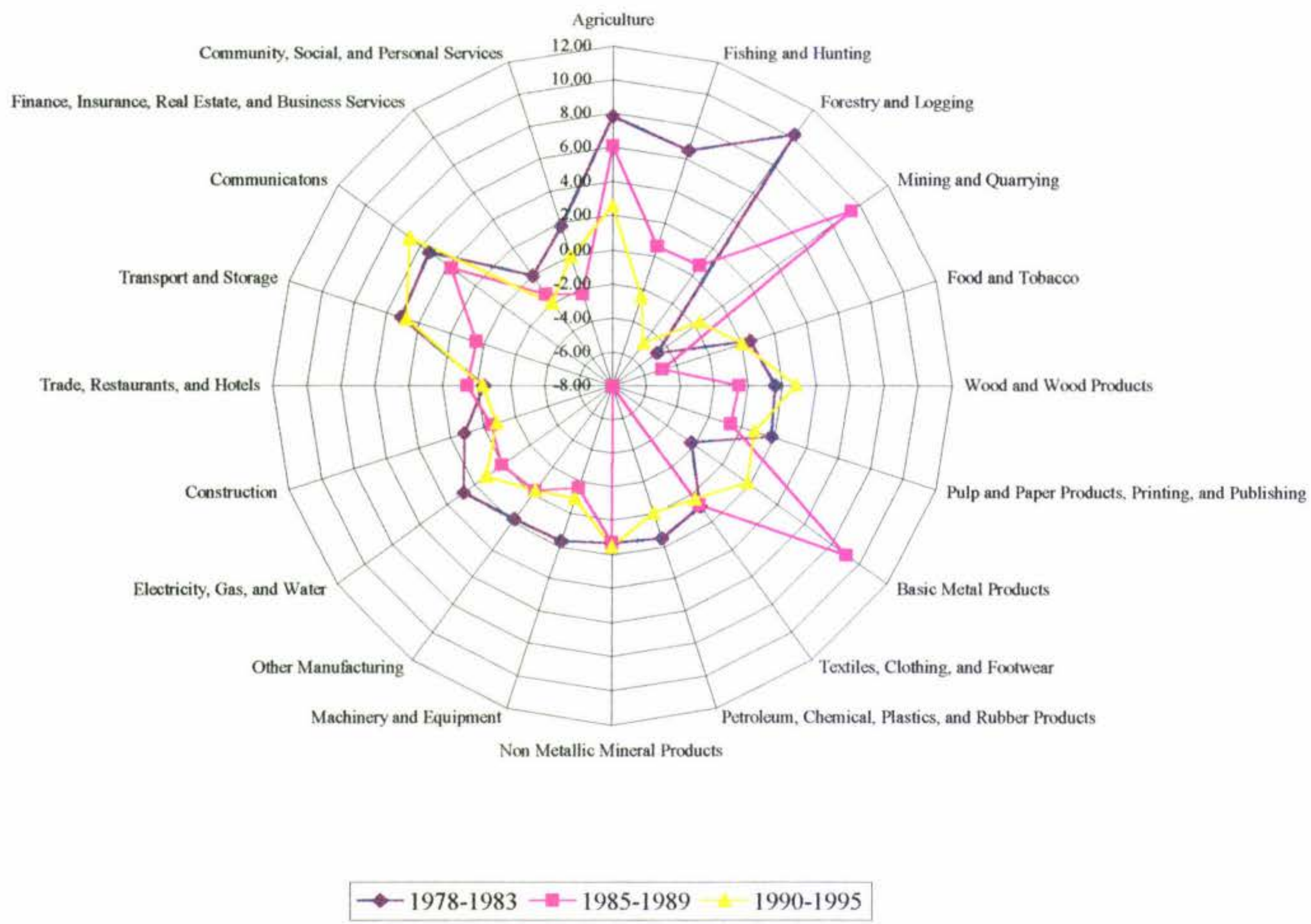
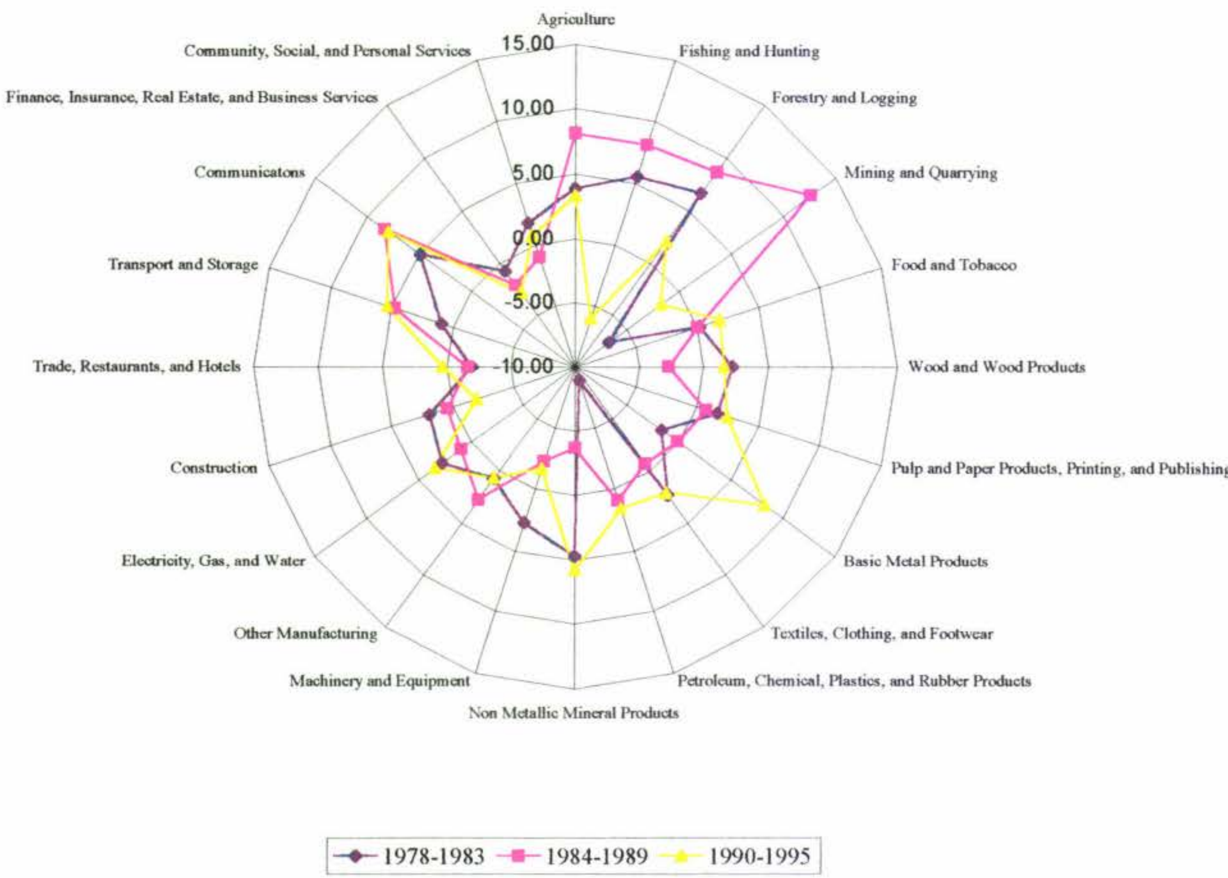


Figure 5.2 Average Annual TFP Growth Real Value Added: 1978-1983, 1984-1989, and 1990-1995



Communications, Non Metallic Mineral Products, and Wood and Wood Products – is TFP growth higher over the period 1990-1995 than 1978-1983, with the increases being of small magnitude.

Results gained with value added data are qualitatively similar. TFP growth for manufacturing and service sector industries appears to have been relatively constant over time (the exceptions, once again, being Basic Metal Products and Petroleum, Chemical, Plastics, and Rubber Products), while primary sector industries initially experienced a surge in TFP growth in 1984-1989, then a substantial drop-off in 1990-1995. Only seven out of the twenty industries exhibited higher TFP growth over the period 1990-1995 than 1978-1983.

5.1.1 Results for the Entire Economy

Tables 5.1-5.4 present some descriptive statistics and the correlation coefficients, for real gross output and real value added data, for industries comprising the market sector of the New Zealand economy.

Table 5.1 Entire Economy Descriptive Statistics – Gross Output

Variable	Mean	Std. Deviation	Minimum	Maximum
TFP	1.088	3.436	-7.958	10.193
DEF	8.081	6.241	-5.918	19.106
LS	0.199	0.085	0.063	0.592
CS	0.162	0.090	0.032	0.408
NPLS	0.084	0.076	0.010	0.324
MS	0.639	0.109	0.230	0.807
CSBC	1.635	1.374	0.134	5.816
CSPMTE	0.997	1.047	0.059	4.436
MSDEF	5.648	4.291	0.086	17.404

Source: ONZPRDB

Table 5.2 Entire Economy Descriptive Statistics – Value Added

Variable	Mean	Std. Deviation	Minimum	Maximum
TFP	1.528	3.896	-8.896	12.607
DEF	8.081	6.241	-5.918	19.106
LS	0.484	0.168	0.130	0.714
CS	0.535	0.161	0.288	0.870
NPLS	0.195	0.139	0.020	0.593
CSBC	5.495	3.703	0.898	14.554
CSPMTE	3.371	3.000	0.396	11.102

Source: ONZPRDB

Table 5.3 Entire Economy Correlation Coefficients – Gross Output

	TFP	DEF	LS	CS	NPLS	MS	CSBC	CSPMTE	MSDEF
TFP	1.00	-0.29	0.21	0.03	-0.04	-0.18	0.26	0.29	0.22
DEF		1.00	0.19	-0.02	0.18	-0.13	0.43	0.41	0.68
LS			1.00	-0.23	0.69	-0.59	0.02	0.01	0.05
CS				1.00	0.10	-0.65	0.55	0.43	-0.17
NPLS					1.00	-0.36	-0.08	-0.07	-0.20
MS						1.00	-0.47	-0.40	0.10
CSBC							1.00	0.95	0.50
CSPMTE								1.00	0.57
MSDEF									1.00

Source: ONZPRDB

Table 5.4 Entire Economy Correlation Coefficients – Value Added

	TFP	DEF	LS	CS	NPLS	CSBC	CSPMTE
TFP	1.00	-0.15	-0.17	0.16	-0.29	0.09	0.01
DEF		1.00	0.19	0.11	0.14	0.54	0.52
LS			1.00	-0.95	0.36	-0.21	-0.10
CS				1.00	-0.37	0.35	0.26
NPLS					1.00	-0.33	-0.26
CSBC						1.00	0.95
CSPMTE							1.00

Source: ONZPRDB

When considering the correlation coefficients in Table 5.3 a number of results stand out. First, it is apparent that the growth of TFP is weakly correlated with the other variables. Second, material's share has a strong negative correlation with labour's and capital's share. Labour's share is also negatively correlated with capital's share, however, the correlation is substantially weaker. Third, there is a strong positive correlation between labour's and nonproduction labour's share.

The above generalisations are also broadly consistent with correlation coefficients in Table 5.4. TFP growth is weakly correlated with the other variables, although the relationship with nonproduction labour's share is stronger than the others. The correlation between labour's and capital's share remains negative (and is very high), and the correlation between labour's and nonproduction labour's share remains positive.

Tables 5.3 and 5.4 show that there is a very high positive correlation between the share-weighted plant, machinery, and equipment capital deflator and the share-weighted building and construction capital deflator. This strong positive correlation is also evident for primary and manufacturing and manufacturing results (see Tables 5.10, 5.11, 5.16, and 5.17). This suggests there may be a multicollinearity problem for the fifth TFP growth relation.[2] The classic 'tell-tale' sign of multicollinearity is high R^2s and few coefficients that are statistically significant from zero at the set significance level. Yet, for all three sets of results, all coefficients were found to be significantly different from zero at the 10% significance level, even though the R^2s are reasonably high (see below). This seems to suggest that multicollinearity may not be a large problem when estimating the fifth TFP growth relation – yet this is not certain. We will return to this in Section 5.2.6.

Tables 5.5 and 5.6 present estimates for the TFP growth relations for gross output and real value added data.

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[2] Although a high correlation between two variables is sufficient for multicollinearity it is not necessary (Gujarati, 1995, p. 336).

Table 5.5 Entire Economy TFP Growth Relations – Gross Output[a]

	Coefficients	Buse R^2
Dependent Variable: DEF		
(i). TFP	-0.860***	0.953
	(0.071)	
Dependent Variable: TFP		
(ii). LS	9.198***	0.304
	(2.955)	
(iii). NPLS	0.337	0.125
	(4.273)	
(iv). CS	-6.186*	0.322
	(3.233)	
MS	-9.132***	
	(3.115)	
(v). CS	-27.318***	0.566
	(4.737)	
CSBC	2.884***	
	(0.904)	
CSPMTE	-1.793*	
	(0.933)	
MS	-13.491***	
	(2.933)	
MSDEF	0.268***	
	(0.068)	

[a] Standard errors are in parentheses. The number of observations is sixty, where each observation is a six-year average. During the estimation procedure SHAZAM estimated the error variance-covariance matrix using the number of time-series observations as the divisor because of too few degrees of freedom. In the above results three stars (***) indicate that the coefficient is significantly different from zero at the 1% significance level and one star (*) indicates that it is significant at the 10% level. Time dummy variables were included in the regression model if their coefficients were significantly different from zero at the 10% level.

The first TFP growth relation looks at the relationship between output deflator growth and TFP growth. For the period 1978-95, the sign of the estimate for the coefficient on TFP growth, obtained with gross output data (Table 5.5), indicates that industries with relatively higher average annual TFP growth should exhibit relatively lower annual output deflator growth. This simple linear relationship suggests a relative price decline of 0.86% for industries with 1% faster than average TFP growth. The corresponding result obtained with value added data (Table 5.6) also suggests a negative relationship between output deflator growth and average annual TFP growth, with the point estimate indicating a 0.34% fall in output deflator growth for those industries that experience 1% faster than average TFP growth. In both cases, the high R^2s attest to the explanatory power of TFP growth in accounting for the variation in output deflator growth in this simple linear relationship. The difference between the coefficient on annual average TFP growth for gross output (Table 5.5) and value added (Table 5.6) must be driven by material prices.

Table 5.6 Entire Economy TFP Growth Relations – Value Added[a]

	Coefficients	Buse R^2
Dependent Variable: DEF		
(vi). TFP	-0.343***	0.913
	(0.074)	
Dependent Variable: TFP		
(vii). LS	-3.503**	0.084
	(1.522)	
(viii). NPLS	-9.765***	0.183
	(2.709)	
(ix). CS	4.331***	0.113
	(1.597)	
(x). CS	-6.450**	0.370
	(2.789)	
CSBC	4.323***	
	(0.834)	
CSPMTE	-5.329***	
	(1.009)	

[a] Standard errors are in parentheses. The number of observations is sixty, where each observation is a six-year average. During the estimation procedure SHAZAM estimated the error variance-covariance matrix using the number of time-series observations as the divisor because of too few degrees of freedom. In the above results three stars (***) indicate that the coefficient is significantly different from zero at the 1% significance level and two (**) stars indicate that it is significant at the 5% level. Time dummy variables were included in the regression model if their coefficients were significantly different from zero at the 10% level.

TFP growth relations (ii)-(iv) and (vii)-(x) investigate the relationship between average annual TFP growth and factor shares for gross output and value added data, respectively. Table 5.5 reports a positive coefficient on labour's share, and negative coefficients on capital's and material's share. These point estimates reveal that industries that display high TFP growth are generally relatively less material and capital intensive, and more labour intensive than other industries. For example, the Communications industry's average labour share for the period 1978-1995 was 0.44; more than twice the average for all industries (see Table 5.1). Table 5.1 reports that average TFP growth for all industries over the corresponding period was 1.09%. The Communications industry's average TFP growth was 5.25%. At the other extreme is an industry such as Mining and Quarrying. This industry's labour share was 0.12. Average TFP growth over the same period was 0.99%. The magnitude of the point estimates would also appear to be economically meaningful. For example, if one were to consider the change in the average labour share for the period 1984-1989 to 1990-1995, all else held constant, then TFP growth relation (ii) would predict an increase in the average annual growth of TFP by 0.009%; a realistic prediction.

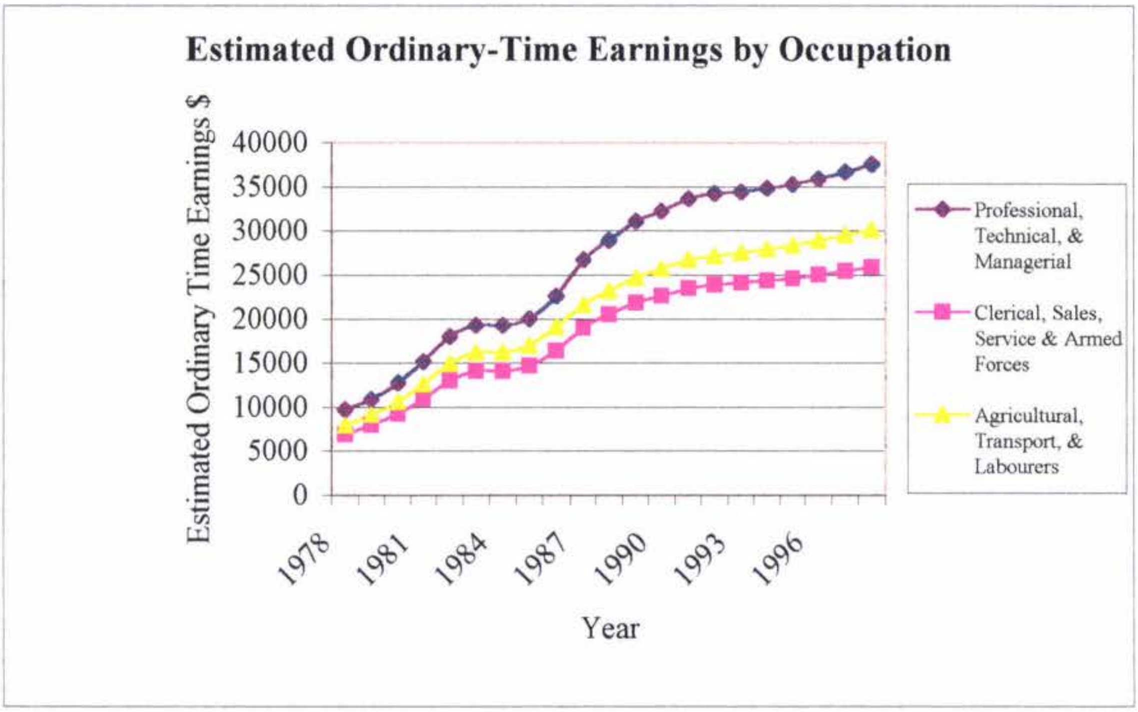
The coefficients on labour's and capital's share for value added results (Table 5.6) are of the opposite sign to those discussed in the previous paragraph. Thus, these results lead to the antithetical conclusion that higher average annual TFP growth is exhibited by those industries that are less intensive in labour and more so in capital.

TFP growth relations (iii) and (viii) probe deeper into the TFP growth facts by investigating the relationship between TFP growth and nonproduction labour's share. Nonproduction labour's share is one measure of industry human capital intensity, based on the assumption that nonproduction workers earn a higher wage relative to production workers due to a higher stock of human capital. As was discussed in Chapter Four, Section 4.2.6 professional, technical, managerial, sales, and service workers are classified as nonproduction workers. Figure 5.3 reveals that the first of these assumptions does not entirely hold true. For while professional, technical, and managerial workers earned a higher wage than did agricultural workers, transport workers, and labourers (i.e. production workers), this was not the case for clerical, sales, and service workers. In addition, a similar problem arises with the second assumption: a greater percentage of professional, technical and managerial workers held post-school qualifications[3], when compared with production workers (see Table 5.7), the opposite was true for clerical, sales, and service

[3] Post-school qualifications (as categorised in the 1996 Census) include skilled vocational qualifications, intermediate vocational qualifications, advanced vocational qualifications, bachelors degrees, higher degrees, and post-school qualifications not specified (Statistics New Zealand, 1997b, p. 39.)

workers. This implies the proxy used for human capital intensity in Klenow's (1998) study is an imperfect one in the New Zealand context, hence, the results need to be treated with some caution. In Section 5.1.4 a further refinement is made on Klenow's proxy in order to obtain a more accurate measure of industry human capital intensity.

Figure 5.3 Estimated Ordinary Time Earnings by Occupation 1978-1998



Source: Diewert and Lawrence (1999, p. 244).

Table 5.7 Distribution of Post-School Qualifications by Occupation

Occupation	Percentage of Post-School Qualifications
Legislators & Administrators	42%
Professionals	85%
Technicians & Associates	50%
Clerks	23%
Service & Sales Workers	22%
Agricultural & Fishery Workers	24%
Trade Workers	49%
Plant & Machine Operators	18%
Elementary Occupations	14%

Source: Statistics New Zealand (1997b, p. 39).

The problems described above are one explanation for the absence of a statistical relationship between TFP growth and nonproduction labour's share (see Table 5.5). In addition, these problems are probably compounded by measurement error, resulting in a biased (and inconsistent) GLS estimator. The other possible explanation for the non-apparent statistical relationship between TFP growth and industry human capital intensity is that no economic relationship exists. On the other hand, value added results (Table 5.6) suggest TFP growth and industry human capital are inversely related. In addition, the magnitude of the coefficient, relative to the coefficients on labour's and capital's share, shows that changes in human capital intensity have a greater impact on TFP growth than do labour and capital intensity (all else held constant).

Finally, TFP growth relations (v) and (x) examine the relationship between TFP and share-weighted factor price changes. After controlling for factor intensities, the point estimates for gross output data indicate that faster than average TFP growth is displayed by those industries that experience slower than average share-weighted plant, machinery and equipment and faster than average share-weighted building and construction and material price increases (for example, the Transport and Storage and the Communications industries). The same is true for share-weighted plant, machinery and equipment and building and construction price changes for value added results (Table 5.6).

5.1.2 Results for Primary & Manufacturing Industries

As discussed in Chapter Four, Section 4.2.7, there are substantial problems associated with measuring outputs and inputs in the service sector industries. One way of overcoming this 'measurement error' predicament is to eliminate service sector industries from the sample. The results gained from re-estimating the TFP growth relations after dropping service sector and support industries are reported in this section. Tables 5.8-5.11 present descriptive statistics and correlation coefficients, for real gross output and real value added data, for primary and manufacturing industries.

Table 5.8 Primary & Manufacturing Industries Descriptive Statistics – Gross Output

Variable	Mean	Std. Deviation	Minimum	Maximum
TFP	1.023	3.854	-7.958	10.193
DEF	7.537	6.133	-5.918	19.106
LS	0.175	0.058	0.063	0.265
CS	0.147	0.093	0.032	0.408
NPLS	0.046	0.020	0.010	0.085
MS	0.678	0.065	0.529	0.807
CSBC	1.469	1.292	0.134	5.816
CSPMTE	0.897	0.982	0.059	4.436
MSDEF	5.699	4.446	0.086	17.404

Source: ONZPRDB

Table 5.9 Primary & Manufacturing Industries Descriptive Statistics – Value Added

Variable	Mean	Std. Deviation	Minimum	Maximum
TFP	1.536	4.241	-8.896	12.607
DEF	7.537	6.133	-5.918	19.106
LS	0.485	0.187	0.130	0.714
CS	0.534	0.183	0.288	0.870
NPLS	0.129	0.062	0.020	0.192
CSBC	5.469	3.833	0.898	14.554
CSPMTE	3.354	3.075	0.396	11.102

Source: ONZPRDB

Tables 5.8 and 5.9 reveal that TFP growth is variable for both gross output and value added data. The same is also true for deflator growth and share-weighted input price changes. Factor shares show less variability.

From Table 5.10 it can be seen that TFP (gross output) is practically uncorrelated with factor shares, the exception being nonproduction labour's share, which is negatively correlated with the growth of TFP. This negative correlation between the growth of TFP and nonproduction labour's share becomes stronger for value added data (Table 5.11), as does correlation between the growth the growth of TFP and the other factor shares. Table 5.10 reveals that capital's share has a strong negative correlation with labour's and material's share. The former is also the case for value added results (Table 5.11). For both gross output data and value added data both labour's share and nonproduction labour's share are positively correlated. In both data groups there is also a negative correlation between nonproduction labour's share and capital's share. This result differs substantially from the correlation calculated in Table 5.3 using gross output data for the entire economy, and would tend to indicate that higher industry human capital intensity is associated with lower capital intensity. This is a somewhat surprising result.

Table 5.10 Primary & Manufacturing Industries Correlation Coefficients – Gross Output

	TFP	DEF	LS	CS	NPLS	MS	CSBC	CSPMTE	MSDEF
TFP	1.00	-0.33	0.04	0.04	-0.34	-0.10	0.36	0.37	0.29
DEF		1.00	0.22	-0.08	0.13	-0.08	0.21	0.22	0.62
LS			1.00	-0.72	0.67	0.13	-0.31	-0.18	0.24
CS				1.00	-0.71	-0.78	0.54	0.43	-0.15
NPLS					1.00	0.21	-0.59	-0.50	-0.27
MS						1.00	-0.50	-0.45	0.00
CSBC							1.00	0.96	0.51
CSPMTE								1.00	0.60
MSDEF									1.00

Source: ONZPRDB

Table 5.11 Primary & Manufacturing Industries Correlation Coefficients – Value Added

	TFP	DEF	LS	CS	NPLS	CSBC	CSPMTE
TFP	1.00	-0.10	-0.27	0.24	-0.43	0.17	0.05
DEF		1.00	0.22	-0.14	0.18	0.37	0.39
LS			1.00	-0.95	0.81	-0.26	-0.14
CS				1.00	-0.83	0.40	0.29
NPLS					1.00	-0.56	0.45
CSBC						1.00	0.95
CSPMTE							1.00

Source: ONZPRDB

Tables 5.12 and 5.13 present estimates for the TFP growth relations for gross output and real value added data respectively.

Table 5.12 Primary & Manufacturing Industries TFP Growth Relations – Gross Output[a]

	Coefficients	Buse R^2
Dependent Variable: DEF		
(i). TFP	-0.894***	0.935
	(0.079)	
Dependent Variable: TFP		
(ii). LS	3.787	0.160
	(3.820)	
(iii). NPLS	-47.366***	0.286
	(15.110)	
(iv). CS	-8.878	0.049
	(6.477)	
MS	-8.540	
	(6.602)	
(v). CS	-39.696***	0.745
	(4.421)	
CSBC	9.028***	
	(1.147)	
CSPMTE	-7.453***	
	(1.330)	
MS	-13.630***	
	(4.484)	
MSDEF	0.375***	
	(0.091)	

[a] Standard errors are in parentheses. The number of observations is thirty-nine, where each observation is a six-year average. During the estimation procedure SHAZAM estimated the error variance-covariance matrix using the number of time-series observations as the divisor because of too few degrees of freedom. In the above results three stars (***) indicate that the coefficient is significantly different from zero at the 1% significance level. Time dummy variables were included in the regression model if their coefficients were significantly different from zero at the 10% level.

The coefficient on output deflator growth for the first TFP growth relation (Table 5.12) is of the same sign and of very similar magnitude to the coefficient on output deflator growth for the entire economy (see Table 5.5). Once again, this reveals that relative price declines are displayed by those industries that exhibit faster than average TFP growth. The point estimate for value added data is approximately half the size (absolute value) of its counterpart in Table 5.6, indicating that service sector and support industries can account for a large proportion of the strength of the signal for the coefficient of TFP growth in Table 5.6. Again, the high R^2s testify to the explanatory power of both of these simple linear regression models.

Table 5.13 Primary & Manufacturing Industries TFP Growth Relations – Value Added[a]

	Coefficients	Buse R^2
Dependent Variable: DEF		
(vi). TFP	-0.170**	0.815
	(0.074)	
Dependent Variable: TFP		
(vii). LS	-5.622**	0.110
	(2.633)	
(viii). NPLS	-29.964***	0.432
	(5.655)	
(ix). CS	6.247**	0.143
	(2.517)	
(x). CS	-9.612***	0.706
	(1.996)	
CSBC	5.074***	
	(0.687)	
CSPMTE	-5.706***	
	(1.019)	

[a] Standard errors are in parentheses. The number of observations is thirty-nine, where each observation is a six-year average. During the estimation procedure SHAZAM estimated the error variance-covariance matrix using the number of time-series observations as the divisor because of too few degrees of freedom. In the above results three stars (***) indicate that the coefficient is significantly different from zero at the 1% significance level and two stars (**) indicate that it is significant at the 5% level. Time dummy variables were included in the regression model if their coefficients were significantly different from zero at the 10% level.

TFP growth relations (ii) and (iv), when compared with the same TFP growth relations for the entire economy (Table 5.5), reveal a break-down in the relationship between TFP growth and factor intensities (coefficients on factor shares are not significantly different from zero at the 10% significance level), except for industry human capital intensity. A possible explanation for this is that service sector and support industries are driving the relationship between TFP and factor shares for the gross output entire economy results. To provide a specific example, labour's share in the Communications industry is very high, as is the industry's TFP growth. In other words, service sector and support industries may be providing a large proportion of the signal on the point estimate for the first TFP growth relation. This, in turn, implies that parameter estimates may be sensitive to individual observations, a point to which this discussion returns later in this chapter. The corresponding coefficients on labour's share and capital's share for value added data, that is, TFP growth relations (vii) and (ix), are of the same sign as their counterparts in Table 5.5, and are of larger absolute value.

The notable exception to the absence of a statistical relationship between TFP growth and factor intensity, as reported in Table 5.12, is the result for TFP growth relation (iii). The estimate for the parameter on nonproduction labour's share is –47.366, considerably larger than the size of the coefficient on nonproduction labour's share for the entire economy result. The coefficient is almost three times as large for the value added data, when compared with the result in Table 5.5 for the entire economy.

The signs of the point estimates on TFP growth relations (v) and (x), are the same as their counterparts in Tables 5.5 and 5.6, however, in all cases the magnitudes of the coefficients are greater in absolute value. The qualitative conclusion, thus, remains the same as for entire economy results, but the impact of share-weighted input prices increases on TFP growth is greater for these sets of results.

5.1.3 Results for Manufacturing Industries

In order to enable comparison with Klenow's (1998) study, estimation of the TFP growth relations was undertaken using data on New Zealand manufacturing industries only. In addition, *a priori* increasing returns would be expected in manufacturing industries, therefore, empirical analysis should be performed on these industries separately. To start, comment is made on Tables 5.14-5.16, which present descriptive statistics and correlation coefficients for gross output and value added data for manufacturing industries.

Tables 5.14 and 5.15, once again, show that TFP growth varies widely across manufacturing industries, as does deflator growth. On the other hand, inter-industry differences in factor intensity are relatively smaller.

Table 5.14 Manufacturing Industries Descriptive Statistics – Gross Output

Variable	Mean	Std. Deviation	Minimum	Maximum
TFP	0.368	2.831	-7.958	9.056
DEF	8.286	6.463	-5.918	19.106
LS	0.203	0.030	0.133	0.252
CS	0.094	0.034	0.032	0.177
NPLS	0.058	0.010	0.040	0.085
MS	0.703	0.045	0.605	0.807
CSBC	0.970	0.706	0.134	3.122
CSPMTE	0.592	0.559	0.059	2.382
MSDEF	5.759	4.644	0.086	17.404

Source: ONZPRDB

Table 5.15 Manufacturing Industries Descriptive Statistics – Value Added

Variable	Mean	Std. Deviation	Minimum	Maximum
TFP	0.573	2.851	-8.896	5.790
DEF	8.286	6.463	-5.918	19.106
LS	0.591	0.085	0.446	0.714
CS	0.427	0.087	0.288	0.554
NPLS	0.167	0.023	0.092	0.192
CSBC	4.394	2.808	0.898	9.769
CSPMTE	2.696	2.321	0.396	7.451

Source: ONZPRDB

Table 5.16 Manufacturing Industries Correlation Coefficients – Gross Output

	TFP	DEF	LS	CS	NPLS	MS	CSBC	CSPMTE	MSDEF
TFP	1.00	-0.38	0.32	-0.31	0.04	0.02	-0.11	0.01	0.22
DEF		1.00	0.22	0.07	-0.36	-0.20	0.72	0.73	0.79
LS			1.00	0.02	0.37	-0.67	0.21	0.29	0.36
CS				1.00	0.21	-0.76	0.48	0.37	-0.18
NPLS					1.00	-0.39	-0.36	-0.30	-0.35
MS						1.00	-0.50	-0.46	-0.10
CSBC							1.00	0.95	0.61
CSPMTE								1.00	0.68
MSDEF									1.00

Source: ONZPRDB

Table 5.17 Manufacturing Industries Correlation Coefficients – Value Added

	TFP	DEF	LS	CS	NPLS	CSBC	CSPMTE
TFP	1.00	-0.24	-0.20	-0.05	-0.31	-0.28	-0.20
DEF		1.00	0.16	0.09	0.09	0.84	0.82
LS			1.00	-0.74	0.21	0.15	0.25
CS				1.00	-0.05	0.24	017
NPLS					1.00	-0.50	-0.39
CSBC						1.00	0.95
CSPMTE							1.00

Source: ONZPRDB

Table 5.16 reports that TFP growth is negatively correlated with capital's share and positively correlated with labour's share. In contrast to the latter, value added statistics (Table 5.17) reveal that labour's share is negatively correlated with TFP growth. When turning to the correlation between factor shares, Table 5.16 shows that material's share is negatively correlated with the remaining factor shares. The negative correlation is particularly strong with capital's share. In addition, nonproduction labour' share is positively correlated with labour's share and capital share. In the case of value added data there is a lack of correlation between nonproduction labour's share and capital's share.

Tables 5.18 and 5.19 present the parameter estimates for the TFP growth relations for gross output and value added data, respectively.

Table 5.18 Manufacturing Industries TFP Growth Relations – Gross Output[a]

	Coefficients	Buse R^2
Dependent Variable: DEF		
(i). TFP	-1.024***	0.966
	(0.149)	
Dependent Variable: TFP		
(ii). LS	20.768***	0.625
	(3.638)	
(iii). NPLS	3.867	0.157
	(20.19)	
(iv). CS	-33.161***	0.300
	(9.948)	
MS	-22.121***	
	(7.408)	
(v). CS	-51.368***	0.712
	(10.540)	
CSBC	5.747**	
	(2.426)	
CSPMTE	-4.513***	
	(2.542)	
MS	-20.250***	
	(4.564)	
MSDEF	0.335***	
	(0.078)	

[a] Standard errors are in parentheses. The number of observations is twenty-seven, where each observation is a six-year average. During the estimation procedure SHAZAM estimated the error variance-covariance matrix using the number of time-series observations as the divisor because of too few degrees of freedom. In the above results three stars (***) indicate that the coefficient is significantly different from zero at the 1% significance level and two stars (**) indicate that it is significant at the 5% level. Time dummy variables were included in the regression model if their coefficients were significantly different from zero at the 10% level.

The coefficient on TFP growth is of the same sign as the point estimate for the entire economy and primary and manufacturing gross output data (Tables 5.5 and 5.12), but exceeds unity in absolute value. This means that the general relationship between output growth and TFP growth continues to hold, but that manufacturing industries that display 1% higher than average TFP growth experience a 1.02% decline in output deflator growth relative to the average. The coefficient on TFP growth for value added results straddles the point estimates for its counterparts in Tables 5.6 and 5.13.

Table 5.19 Manufacturing Industries TFP Growth Relations – Value Added[a]

	Coefficients	Buse R^2
Dependent Variable: DEF		
(vi). TFP	-0.236**	0.964
	(0.010)	
Dependent Variable: TFP		
(vii). LS	-2.472	0.580
	(2.705)	
(viii). NPLS	-36.491***	0.847
	(5.203)	
(ix). CS	-0.754	0.520
	(2.762)	
(x). CS	-1.707	0.570
	(2.760)	
CSBC	2.280**	
	(0.964)	
CSPMTE	-3.920***	
	(1.513)	

[a] Standard errors are in parentheses. The number of observations is twenty-seven, where each observation is a six-year average. During the estimation procedure SHAZAM estimated the error variance-covariance matrix using the number of time-series observations as the divisor because of too few degrees of freedom. In the above results three stars (***) indicate that the coefficient is significantly different from zero at the 1% significance level and two stars (**) indicate that it is significant at the 5% level. Time dummy variables were included in the regression model if their coefficients were significantly different from zero at the 10% level.

The statistical significance or otherwise of the coefficients on the factors shares (at the given significance levels), as well as their signs, are identical to the entire economy results for gross output data. The difference between the two is that the magnitudes of the point estimates for manufacturing industries are considerably greater in absolute value. Like the impact on output deflator growth of changes in TFP growth, changes in factor intensities (with the exception of industry human capital intensity) for the sub-sample of manufacturing industries, have, on average, a greater effect on TFP growth than the average industry comprising the market sector of the New Zealand economy. Conversely, the statistical significance of value added results seem to mirror gross output results when it comes to the relationship between factor intensities and TFP growth. The coefficients of labour's share and capital's share are not significantly different from zero at the 10% significance level, whereas the coefficient on nonproduction labour's share is significantly different from zero at the 1% significance level.

The qualitative relationship between TFP growth and share-weighted input price changes for both gross output and value added results is the same as entire economy results and primary and manufacturing results.

5.1.4 Refining Industry Human Capital Intensity

Given the problems associated with nonproduction labour's share in measuring human capital intensity, this section looks at the relationship between TFP growth and industry human capital intensity using high skilled labour's share (HSLS) as an alternative measure.

High-skilled labour's share is defined as the ratio of compensation to professionals, technical workers, and managerial workers to either gross output or value added data. This is a superior measure of industry human capital intensity because, as Figure 5.3 and Table 5.7 reveals, professional, technical, and managerial workers earned a higher wage than did other workers over the period 1978-1998. In addition, these worker, as a group, hold a relatively greater percentage of post-school qualifications.

Table 5.20 presents the results from regressing high skilled labour's share against TFP growth. According to gross output results there is little sample evidence in support of a relationship between industry human capital intensity and TFP growth. This is also the case for value added results for the entire economy. Value added results for primary and manufacturing industries and manufacturing industries only posit that TFP growth is inversely related to human capital intensity. The results from Table 20, therefore, imply that previous comments in regards to TFP growth and industry human capital intensity still stand.

Table 5.20 TFP Growth and High Skilled Labour's Share[a]

	Entire Economy	Primary & Manufacturing	Manufacturing
Dependent Variable: TFP			
(xi). HSLS (gross output)	-7.294	-32.768	-13.129
	(6.292)	(20.000)	(13.020)
Buse R^2	0.142	0.068	0.202
(xii). HSLS (value added)	-6.922	-50.576***	-36.481***
	(4.855)	(11.44)	(5.207)
Buse R^2	0.034	0.335	0.847

[a] Standard errors are in parentheses. There are sixty observations for the entire economy, thirty-nine observations for primary and manufacturing industries, and twenty-seven observations for manufacturing industries only, where each observation is a six-year average. During the estimation procedure SHAZAM estimated the error variance-covariance matrix using the number of time-series observations as the divisor because of too few degrees of freedom. In the above results three stars (***) indicate that the coefficient is significantly different from zero at the 1% significance level. Time dummy variables were included in the regression model if their coefficients were significantly different from zero at the 10% level.

5.1.5 Gross Output versus Value Added Results

As can be seen from the estimates presented so far in this chapter it is absolutely critical to decide on whether value added results or gross output results should be used in discriminating between alternative growth models for the New Zealand economy. This is because gross output results and value added results are generally the inverse of each other when it comes to the TFP growth relations that investigate the nexus between factor shares and TFP growth. Klenow (1998) emphasises results obtained with gross output data, as opposed to results from value added, although both sets of results are reported. His justification for doing so is that the international literature supports a degree of substitutability between value added and materials. For example, Bruno (1984) estimates an elasticity of substitution of approximately 0.35, using data for ten OECD countries.[4] Jorgenson and Stiroh (1999, p. 113) argue that gross output data is the more appropriate measure of output at the sectoral level, as does Campbell (1984) in his study on the efficiency of New Zealand manufacturing industries. Following the lead of these authors

[4] Canada, the United States, Japan, Belgium, France, Germany, Italy, Netherlands, Sweden, and the United Kingdom.

this study will focus on gross output results. With this view in mind, the following section performs several sensitivity analyses using gross output data.[5]

5.2 Sensitivity Analyses

5.2.1 Outliers

As discussed in Section 5.4, the possibility may arise where some point estimates are very sensitive to the inclusion or omission of individual observations. In order to check whether this was the case, the *dfbetas* index, which evaluates the marginal effect of an individual observation on the point estimate, was computed using the SHAZAM econometric software package. When examining this index there do not appear to be any observations that substantially effect the point estimates to the extent that it changes the sign of any statistically significant coefficients. However, the 1978-1983 observation for the Mining industry and the 1984-1989 observation for the Basic Metals industry could possibly be considered as outliers in the context of the first TFP growth relation. When these observations were dropped from the sample and the first TFP growth relation re-estimated, all coefficients remained of the same sign and were statistically significant at the 1% significance level.

5.2.2 Alternative Estimator

As was discussed in Chapter Four, Section 4.1, *a priori* one would expect autocorrelated error. However, it is futile to test for the presence of autocorrelation because there are only three time-series observations for each cross-section unit. Given this *a priori* expectation, a GLS estimator was selected to correct for the presence of autocorrelation, where the estimate for the autoregressive parameter was restricted to be the same for all cross-sections during the estimation procedure. Yet, it is natural to ask the question: how would the

[5] It should also be noted that gross output versus value added results for manufacturing industries presented in this thesis diverge more than those reported by Klenow (1998). This highlights the importance of material inputs for New Zealand manufacturing industries.

results differ if the *a priori* expectation were incorrect, and if an alternative GLS estimator was used? Table 5.21 presents the parameter estimates from such an estimator, where the estimator corrects for the presence of heteroskedasticity, but not autocorrelation. From Table 5.21 it would appear that the point estimates obtained from the alternative estimator are very similar to those in Tables 5.5, 5.12, and 5.18. Reassuringly, this suggests that the parameter estimates are not critically sensitive to the assumption about autocorrelation.[6]

5.2.3 Alternative Capital Stocks

Diewert and Lawrence (1999, p. 40) argue that their net capital stock "provides a closer approximation to the contribution of capital assets to the production process and better approximates economic depreciation" than do other capital stock series. If this is the case, then it is necessary to calculate TFP using Diewert and Lawrence's net capital stock, and to use these alternative figures for TFP growth in estimating the TFP growth relations. This makes for a good robustness check of the basic results to the capital stock, because the net capital stock provides an upper bound estimate for the growth of TFP, whereas the gross capital stock provides a lower bound estimate. Table 5.22 presents the point estimates of the TFP growth relations, where TFP growth has been calculated using Diewert and Lawrence's net capital stock.

What is apparent when comparing the results in Table 5.22 with their counterparts in Tables 5.5, 5.12, and 5.18 is how similar they are. Coefficients on the different explanatory variables are of the same sign and similar magnitudes. There are, however, two exceptions. The first is the precision of the point estimate on capital's share for entire economy results. As can be seen the coefficient becomes slightly smaller in absolute value, while the standard error standard becomes slightly larger. As such, the coefficient is not significantly different from zero at the 10% significance level. Yet, when consideration is given to the

[6] The TFP growth relations were also estimated using OLS. Generally, the point estimates were of the same sign, and of similar magnitude to their counterparts in Tables 5.5, 5.12, and 5.18. However, the standard errors were relatively larger. This is not surprising, given that in the presence of heteroskedasticity the OLS estimator is no longer efficient, even though it remains unbiased.

Table 5.21 Industry TFP Growth Relations – Gross Output/Alternative GLS Estimator[a]

	Entire Economy	Primary & Manufacturing	Manufacturing
Dependent Variable: DEF			
(i). TFP	-0.855***	-0.900***	-0.992***
	(0.071)	(0.081)	(0.153)
Buse R^2	0.956	0.933	0.955
Dependent Variable: TFP			
(ii). LS	9.264***	3.394	20.855***
	(2.567)	(3.723)	(3.649)
Buse R^2	0.4073	0.183	0.627
(iii). NPLS	2.327	-49.080***	4.129
	(3.920)	(14.710)	(20.060)
Buse R^2	0.194	0.305	0.155
(iv). CS	-4.449	-3.247	-32.610***
	(2.992)	(6.325)	(9.891)
MS	-8.645***	-1.726	-21.968***
	(2.845)	(6.974)	(7.273)
Buse R^2	0.390	0.099	0.299
(v). CS	-27.343***	-38.560***	-50.656***
	(4.682)	(4.997)	(10.360)
CSBC	2.919***	8.713***	5.651**
	(0.909)	(1.370)	(2.403)
CSPMTE	-1.834*	-7.438***	-4.427*
	(0.941)	(1.554)	(2.541)
MS	-13.484***	-13.379***	-20.113***
	(2.925)	(4.169)	(4.398)
MSDEF	0.270***	0.392	0.334***
	(0.068)	(0.086)	(0.075)
Buse R^2	0.565	0.677	0.729

[a] Standard errors are in parentheses. There are sixty observations for the entire economy, thirty-nine observations for primary and manufacturing industries, and twenty-seven observations for manufacturing industries only, where each observation is a six-year average. During the estimation procedure SHAZAM estimated the error variance-covariance matrix using the number of time-series observations as the divisor because of too few degrees of freedom. In the above results three stars (***) indicate that the coefficient is significantly different from zero at the 1% significance level, two stars (**) indicate that it is significant at the 5% level, and one star (*) indicates that it is significant at the 10% level. Time dummy variables were included in the regression model if their coefficients were significantly different from zero at the 10% level.

Table 5.22 Industry TFP Growth Relations – Gross Output/Net Capital Stock[a]

	Entire Economy	Primary & Manufacturing	Manufacturing
Dependent Variable: DEF			
(i). TFP	-0.885***	-0.910***	-1.066***
	(0.070)	(0.074)	(0.145)
Buse R^2	0.955	0.945	0.966
Dependent Variable: TFP			
(ii). LS	8.706***	10.063**	20.931***
	(2.028)	(4.891)	(4.100)
Buse R^2	0.349	0.103	0.587
(iii). NPLS	0.250	-50.191***	3.451
	(4.336)	(13.310)	(20.110)
Buse R^2	0.103	0.358	0.162
(iv). CS	-5.213	-9.229	-33.078***
	(3.298)	(6115)	(10.140)
MS	-9.583***	-9.480	-22.203***
	(3.183)	(6.062)	(7.343)
Buse R^2	0.314	0.063	0.295
(v). CS	-25.565***	-38.055***	-52.298***
	(4.953)	(4.829)	(11.080)
CSBC	2.697***	8.651***	5.518**
	(0.918)	(1.235)	(2.422)
CSPMTE	-1.614*	-6.929***	-4.194*
	(0.938	(1.420)	(2.542)
MS	-13.266***	-12.578***	-20.344***
	(2.997)	(4.629)	(4.719)
MSDEF	0.255***	0.344***	0.308***
	(0.072)	(0.095)	(0.080)
Buse R^2	0.538	0.692	0.694

[a] Standard errors are in parentheses. There are sixty observations for the entire economy, thirty-nine observations for primary and manufacturing industries, and twenty-seven observations for manufacturing industries only, where each observation is a six-year average. During the estimation procedure SHAZAM estimated the error variance-covariance matrix using the number of time-series observations as the divisor because of too few degrees of freedom. In the above results three stars (***) indicate that the coefficient is significantly different from zero at the 1% significance level, two stars (**) indicate that it is significant at the 5% level, and one star (*) at the 10% significance level. Time dummy variables were included in the regression model if their coefficients were significantly different from zero at the 10% level.

coefficient's p-value (0.114), that is, the corresponding exact level of significance, it can be seen that it is only marginally greater than the 10% level that is often set by the statistical decision maker for rejecting the null hypothesis. In other words, there is a 0.114 probability of committing the error of rejecting the null hypothesis (that the parameter value is equal to zero), when it is actually true. Some statistical decision-makers may be willing to take on this risk! Conversely, the point estimate of the coefficient on labour's share for the primary and manufacturing/net capital stock result has greater precision than its counterpart in Table 5.12. The coefficient on labour's share is now significantly different from zero at the 5% significance level, whereas for results obtained using the gross capital stock this was not so (exact p-value corresponding to gross output/gross capital stock was 0.119).

A similar story applies to the results presented in Table 5.23, where the growth of TFP, used in the regression analysis, was calculated using Statistics New Zealand's capital stock series (Statistics New Zealand, 1999). This series (unfortunately) is only available for manufacturing industries.

Table 5.23 shows that the estimated coefficients for each of the five TFP growth relations are of the same sign and similar magnitude to those in Table 5.18. The only difference is that the coefficient on share-weighted plant machinery and equipment price changes is not significantly different from zero at the 10% significance level. Apart from this, overall, the results reported in Table 5.22, as well as those in Table 5.23, tend to confirm the view that the basic results presented in Tables 5.5, 5.12, and 5.18 are robust to alternative capital stock series.

5.2.4 Alternative Time Horizons

In order to check the robustness of the results to growth rates calculated over alternative time horizons, the TFP growth relations were estimated using growth rates calculated over three and nine year time periods. The parameter estimates for growth rates calculated over three years, with the exception of those for the first TFP growth relation, were not

Table 5.23 Manufacturing Industries TFP Growth Relations – Gross Output/Statistics New Zealand Capital Stock

	Coefficients	Buse R^2
Dependent Variable: DEF		
(i). TFP	-1.087***	0.970
	(0.143)	
Dependent Variable: TFP		
(ii). LS	24.630***	0.576
	(5.009)	
(iii). NPLS	8.831	0.271
	(19.290)	
(iv). CS	-33.349***	0.302
	(10.380)	
MS	-22.321***	
	(6.930)	
(v). CS	-49.518***	0.808
	(10.880)	
CSBC	3.764*	
	(2.194)	
CSPMTE	-1.976	
	(2.365)	
MS	-19.678***	
	(4.233)	
MSDEF	0.231***	
	(0.068)	

[a] Standard errors are in parentheses. The number of observations is twenty-seven, where each observation is a six-year average. During the estimation procedure SHAZAM estimated the error variance-covariance matrix using the number of time-series observations as the divisor because of too few degrees of freedom. In the above results three stars (***) indicate that the coefficient is significantly different from zero at the 1% significance level and one star (*) indicates that it is significant at the 1% level. Time dummy variables were included in the regression model if their coefficients were significantly different from zero at the 10% level.

significantly different from zero at the 10% significance level. This is not surprising given the sensitivity of point to point growth rates to the business cycle, especially when calculated over a short period of time. This can be seen from Figure 4.2 in the previous chapter, where annual growth rates vary considerably from year to year. Growth rates calculated over a three-year time horizon are probably too short for calculating *long-run* *growth.*[7] On the other hand, the parameter estimates for the TFP growth relations, calculated over a nine-year time period, run into problems of micronumerosity. Thus, the results based on growth rates calculated over a six-year time horizon seem the most appropriate.[8]

5.2.5 Measurement Error

Given that the data in the ONZPRDB is subject to measurement error, this will affect the point estimates for the TFP growth relations. Assuming that measurement error is 'classical', if the dependent variable suffers from measurement error then the standard errors are larger than if measurement error were not present. Measurement error in the independent variable is more problematic. Not only are standard errors larger than in the absence of measurement error, but the GLS is both *biased* and *inconsistent* (Gujarati, 1995, pp. 468-469). If labour's share is understated, as is most likely the case for New Zealand industries (particularly in primary sector industries), then the growth of TFP will also be understated, due to the fact that capital and material inputs tend to grow faster than the labour input. This implies that there is an upward bias on the point estimates for labour's and nonproduction labour's share[9], and a downward bias on the point estimates for capital's and material's share. This means the biases work in favour of the signs on the coefficients for labour's, capital's, and material's share (that is, TFP growth relations (ii) and (iv), and against the sign of the coefficient on nonproduction labour's share (TFP growth relation (iii)).

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[7] In the literature on long-run growth, a large number of studies that utilise TFP growth in regression analyses, calculate TFP growth over five or more years (see, for example, Dowrick and Nguyen, 1989, Klenow and Rodriguez-Clare, 1997b, and Coe, Helpman, and Hoffmaister 1997). In Klenow (1998) TFP growth is calculated over thirty-two and sixteen year time horizons.

[8] Also recall the discussion in Chapter Four, Section 4.1.3, where it was noted that this author faced the conflicting objectives of maximising the number of time-series observations and removing business cycle effects.

[9] If labour's share is understated so too will nonproduction labour's share because both are positively correlated.

5.2.6 Multicollinearity

Table 5.24 presents results for TFP growth relation (v) when CSBC and then CSPMTE are dropped from the estimated regression equation in an attempt to correct for multicollinearity.

Table 5.24 TFP Growth Relation (v) Corrected for Multicollinearity[a]

	Entire Economy	Primary & Manufacturing	Manufacturing
Dependent Variable: TFP			
(v). CS	-27.277***	-33.854***	-43.828***
	(4.027)	(3.660)	(10.210)
CSBC	1.584***	3.803***	1.585***
	(0.301)	(0.540)	(0.636)
MS	-14.960***	-13.084***	-20.423***
	(2.983)	(2.207)	(4.515)
MSDEF	0.357***	0.429***	0.278***
	(0.078)	(0.059)	(0.070)
Buse R^2	0.568	0.842	0.744
(v). CS	-22.641***	-26.525***	-37.479***
	(4.058)	(5.030)	(9.836)
CSPMTE	1.727***	4.187***	1.326***
	(0.416)	(0.768)	(0.686)
MS	-15.845***	-12.044***	-19.539***
	(3.054)	(4.355)	(4.815)
MSDEF	0.376***	0.421***	0.267***
	(0.091)	(0.105)	(0.076)
Buse R^2	0.503	0.617	0.695

[a] Standard errors are in parentheses. There are sixty observations for the entire economy, thirty-nine observations for primary and manufacturing industries, and twenty-seven observations for manufacturing industries only, where each observation is a six-year average. During the estimation procedure SHAZAM estimated the error variance-covariance matrix using the number of time-series observations as the divisor because of too few degrees of freedom. In the above results three stars (***) indicate that the coefficient is significantly different from zero at the 1% significance level. Time dummy variables were included in the regression model if their coefficients were significantly different from zero at the 10% level.

As can be seen from Table 5.24, when either CSBC or CSPMTE is dropped from the estimated regression equation it can generally be concluded that share-weighted input price changes are positively related to TFP growth for all three sets of results. In contrast to the coefficient on CSPMTE, for all three sets of results (Tables 5.5, 5.12, and 5.18), the coefficient on CSPMTE reported in Table 5.24 is of the opposite sign.

5.3 Summary of Results

Table 5.25 provides a summary of the results. POSITIVE indicates a positive and statistically significant relationship between the dependent variable and the independent variable/s. NEGATIVE indicates a negative and statistically significant relationship between the dependent variables and the independent variable/s. 0 indicates the absence of a statistical relationship. This table will prove to be an invaluable aid in Chapter Six, when comparing the predictions of several growth models with the TFP growth relations.

Table 5.25 Summary of Main Results – Gross Output[a]

TFP Growth Relation	Entire Economy	Primary & Manufacturing	Manufacturing
Dependent Variable: DEF			
(i). TFP	NEGATIVE	NEGATIVE	NEGATIVE
Dependent Variable: TFP			
(ii). LS	POSITIVE	0	POSITIVE
(iii). NPLS	0	NEGATIVE	0
(iv). CS	NEGATIVE	0	NEGATIVE
MS	NEGATIVE	0	NEGATIVE
(v). CS	NEGATIVE	NEGATIVE	NEGATIVE
CSBC	POSITIVE	POSITIVE	POSITIVE
CSPMTE	NEGATIVE	NEGATIVE	NEGATIVE
MS	NEGATIVE	NEGATIVE	NEGATIVE
MSDEF	POSITIVE	POSITIVE	POSITIVE

Note: When either CSBC or CSPMTE are dropped from TFP growth relation (v) the coefficients on the remaining share-weighted capital deflator becomes positive in sign.

Chapter Six

Discussion

Spider, clever and fragile, Cook showed how
To spring a trap for islands, turning from planets
His measuring mission, showed what muskets could do,
Made his Christmas goose of the wild gannets.
Still as the collier steered
No continent appeared;
It was something different, something
Nobody counted on.
(Allen Curnow, The Unhistoric Story)

6.0 Introduction

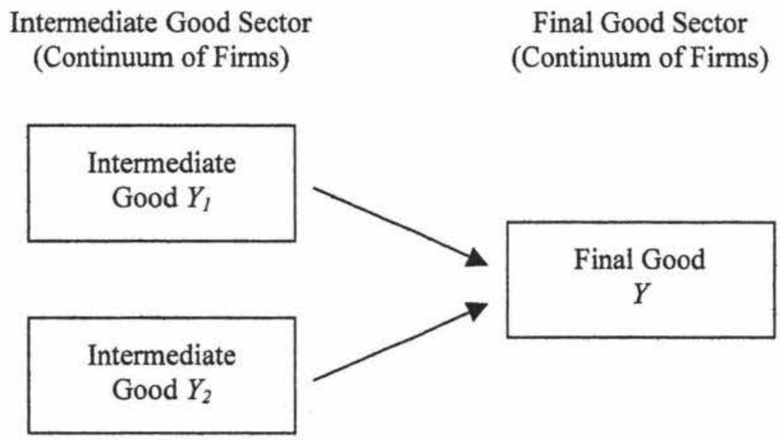
Having reported the estimates for the TFP growth relations in Chapter Five, this chapter attempts to discriminate between three classes of growth models – exogenous growth models, rival human capital models, and idea accumulation models – with a view to determining the most appropriate class for the New Zealand economy. In pursuing Klenow's (1998) methodology and models, this chapter considers variants of Rebelo's (1991) rival human capital model and Romer's (1990) ideas model, in addition to a hybrid exogenous growth model.

This chapter commences by comparing the results of the TFP growth relations with the predictions of the different models, with Section 6.5 summarising the findings of this comparison. Section 6.6 contrasts Klenow's results with results obtained for New Zealand manufacturing industries. Section 6.7 offers a qualitative discussing on open economy models. To end this chapter, policy implications for the two broad classes of endogenous growth models are discussed in the New Zealand context.

6.1 Basic Framework

The basic theoretical framework used by Klenow (1998) when analysing the results of the TFP growth relations is presented in Figure 6.1 below.

Figure 6.1 – The Basic Theoretical Framework



Essentially, Klenow (1998) develops a framework where the production of the final good Y is achieved by combining two intermediate goods Y_1 and Y_2, which in turn are produced using human and physical capital. The three alternative paradigms of economic growth – exogenous growth, rival human capital accumulation, and idea accumulation – are modeled by considering alternative production technologies for the two intermediate goods and alternative accumulation technologies for human and physical capital. The specifications for these alternative production technologies are outlined in Sections 6.2-6.6.

Assuming that the production technology of the final good takes on the Cobb-Douglas functional form, then the production function for Y can be denoted more formally as follows:

$$Y = C + I + M = Y_1^{\theta} Y_2^{1-\theta} \qquad 0 \le \theta \le 1 \qquad (6.1)$$

In addition, it is assumed that final output is produced by a continuum of firms, where final output can be consumed (*C*), invested (*I*), or expended on materials (*M*).

Given (1), each firm producing the final good faces the following maximisation problem:

$$Max \prod_Y = Y_1^{\theta} Y_2^{1-\theta} - p_1 Y_1 - p_2 Y_2$$

where p_1 = price of good 1 and p_2 = price of good 2. The price of the final good is normalised to equal one.

Taking first order conditions, substituting, and finally rearranging, gives the following Cobb-Douglas nominal output shares:

$$\frac{p_1 Y_1}{p_2 Y_2} = \frac{\theta}{1-\theta} \tag{6.2}$$

To aid subsequent analysis it is necessary to find the growth version of (6.2). This can be done by taking the logs of (2) and differentiating with respect to time:

$$g_{Y1} - g_{Y2} = g_{p2} - g_{p1} \tag{6.2a}$$

where g_x denotes the growth rate of *x*.

Given this basic framework, the different growth models are now presented, and their predictions compared with the parameter estimates for the TFP growth relations presented in Chapter Five.

6.2 Exogenous Growth

It is assumed that the two intermediate goods are produced by a continuum of competitive firms with the following Cobb-Douglas production technologies:

$$Y_{1t} = Z_{1t}(L_{1t}H)^{\alpha_1} K_{1t}^{\beta_1} M_{1t}^{1-\alpha_1-\beta_1}$$
$$Y_{2t} = Z_{2t}(L_{2t}H)^{\alpha_2} K_{2t}^{\beta_2} M_{2t}^{1-\alpha_2-\beta_2} \qquad (6.3)$$

where Z is an index of technology, L is the number of labour hours per worker, H is the level of human capital stock per worker, K is the level of capital stock per worker, and the M is the level of material input. In addition, Z is determined exogenously, and grows continuously at the rate of μ_i. This implies that growth in the final good Y is also exogenously determined.

It is also assumed that input markets are competitive, and that the following market clearing conditions are satisfied:

$$L = L_{1t} + L_{2t}$$
$$K = K_{1t} + K_{2t}$$
$$M = M_{1t} + M_{2t}$$

Given the above market clearing conditions, and that labour and human capital do not grow over time, a steady state growth rate implies that Y, C, K, K_1, K_2, M, M_1, and M_2 must all exhibit the same rate of growth. This means the growth version of (6.3) is as follows:

$$g_{Y1} = \mu_1 + (1-\alpha_1)g_Y$$
$$g_{Y2} = \mu_2 + (1-\alpha_2)g_Y \qquad (6.3a)$$

Substituting (6.3a) into (6.2a) yields the following:

$$g_{p2} - g_{p1} = \mu_1 - \mu_2 + (\alpha_2 - \alpha_1)g_Y = g_{Y1} - g_{Y2} \qquad (6.4)$$

Assuming that labour intensity varies exogenously over the two intermediate good industries and is uncorrelated with TFP growth,[1] equation (6.4) implies that if TFP growth is 1% higher in the industry that produces Y_1, relative to the industry that produces Y_2, then the industry that produces Y_1 should experience a relative price decline of 1%. Generalising to N intermediate goods, this model predicts that industry i should experience a relative price decline of 1% for every percentage point of above *average* TFP growth. If the elasticity of substitution between the two intermediate goods in producing the final good is greater than (less than) one, then this model points to a parameter estimate for TFP growth relation (i) that is less than (greater than) one. This model of exogenous growth is, therefore, consistent with the first TFP growth relation for all three samples, dependent on the elasticity of substitution between intermediate goods in final good production.

How does this model of exogenous growth measure up with the other TFP growth relations? Unfortunately, this model gives no explanation as to why TFP growth is related to labour, capital, and material intensity for the entire economy and the manufacturing results (Tables 5.5 and 5.12). It also cannot account for why TFP growth is related to nonproduction labour's share for the primary and manufacturing results. On the other hand, it can be argued that this model is consistent with the absence of a statistical relationship between labour, capital and material intensity because this model does not suggest that these variables should be related.

In addition, this model provides no elucidation of why differences in the growth of input prices are related to TFP growth (after controlling for capital and material factor intensities), because the production technologies for this model reveal that both industries use the same capital and material inputs.

[1] This latter assumption is reasonably true. Tables 5.3, 5.10, and 5.14 reveal a very weak correlation between TFP growth and labour's share.

6.3 Human Capital Accumulation

6.3.1 General Human Capital Accumulation

The growth model presented below is based on Rebelo's (1991) article *Long-Run Policy Analysis and Long-Run Growth.* In this model human capital is general in the sense that it increases the level of production for both intermediate goods by raising the efficiency of labour. Equation (6.5) presents the Cobb-Douglas production technologies for the two intermediate goods:

$$\begin{aligned} Y_{1t} &= (L_{1t}H_t)^{\alpha_1} K_{1t}^{\beta_1} M_{1t}^{1-\alpha_1-\beta_1} \\ Y_{2t} &= (L_{2t}H_t)^{\alpha_2} K_{2t}^{\beta_2} M_{2t}^{1-\alpha_2-\beta_2} \end{aligned} \tag{6.5}$$

with the following market clearing conditions:

$$\begin{aligned} L &= L_{1t} + L_{2t} + L_{Ht} \\ K &= K_{1t} + K_{2t} \\ M &= M_{1t} + M_{2t} \end{aligned}$$

The first market clearing condition reveals that the labour endowment can be allocated between work and human capital accumulation (L_{Ht}). In addition, from (6.5) it can be seen that the growth of human capital is dependent on industry labour intensity and the growth of human capital:[2]

$$g_{TFP_i} = \alpha_i g_H \tag{6.6}$$

where $H_{t+1} = BL_{Ht}^{\gamma} H_t$

[2] Klenow (1998, p. 13) notes that TFP as "conventially measured" (that is, with the human capital input omitted from the production function) does not adjust for labour quality. Hence, human capital accumulation must show up in TFP growth.

By definition, in order to satisfy the market clearing conditions, Y, C, K, K_1, K_2, H, M, M_1, and M_2 must grow at the same rate. Based on this information the following growth version of (6.5) can be obtained:

$$\begin{aligned} g_{Y1} &= g_Y \\ g_{Y2} &= g_Y \end{aligned} \tag{6.5a}$$

Substituting (6.5a) into (6.2a):

$$g_{Y1} = g_{Y2} \tag{6.7}$$

Equation (6.7) reveals that industry output growth is balanced. Therefore, given the property of constant nominal output shares, equation (6.7) predicts that the relative prices of Y_1 and Y_2 are constant over time. Thus this model of general human capital fails to predict that higher than average TFP growth is associated with industries that exhibit relatively lower output deflator growth for the three sets of results, as suggested by TFP growth relation (i).

How does this model of general human capital fit with the other TFP growth relations? The parameter estimate for TFP growth relation (ii) should be the growth rate of human capital according to equation (6.6), thus the positive sign of the coefficient on labour's share for the entire economy and manufacturing results is consistent with this model, although the magnitude of the point estimate for manufacturing results seems very large. It is unlikely that human capital has grown at an average annual compound rate of 24.63% per annum for the period 1978-1995. Having noted this, there are two facts that may alleviate concern over the magnitude of this point estimate. First, if measurement bias could be removed from labour's share it is likely that the point estimate for TFP growth relation (ii) would be smaller. This fact, when viewed alongside a 95% confidence interval for the parameter estimate, may make the consistency of this model with the TFP growth relations more 'believable.' When turning to the results for primary and manufacturing industries (Table

5.8), it can be seen that while the coefficient is of the right sign and a realistic magnitude, it is not significantly different from zero at the 10% significance level.

In order to evaluate the consistency of this model with the remaining TFP growth relations, it is necessary to consider how labour's share is correlated with the other variables. Correlation coefficients for the entire economy (Table 5.3) show that labour's share is positively correlated with nonproduction labour's share and negatively correlated with capital's share and material's share. Labour's share is basically uncorrelated with share-weighted input price changes. Thus, given that this model predicts that TFP growth and industry labour intensity are positively related, and the positive correlation between labour's share and nonproduction labour's share, a positive point estimate is expected for TFP growth relation (iii). While this is the case, the parameter estimate is not significantly different from zero at the 10% significance level. Likewise, given that labour's share is negatively correlated with the remaining factor shares, this model predicts negative coefficients for TFP growth relation (iv), as is the actual outcome.

A similar process can also be worked through for the primary and manufacturing results, as well as the manufacturing results (Tables 5.12 and 5.18). Table 5.10 (Primary and Manufacturing Industries) reveals that labour's share is positively correlated with nonproduction labour's share, thus this model predicts a positive point estimate for TFP growth relation (iii). Table 5.12 shows the opposite is the case. Analogously, this model can not account for the absence of a statistical relationship for TFP growth relation (iv). For manufacturing results (see Table 5.18), this model is unable to explain the point estimate for TFP growth relation (iii), but is able to account for TFP growth relation (iv).

Once again, this model cannot explain why input price changes effect TFP growth given that both industries utilise the same capital and material inputs. However, the coefficient on TFP growth relation (v), for manufacturing results (Table 5.18), can be reconciled with this model. If it is assumed that multicollinearity is a problem, and that an attempt is made to rectify this by dropping either CSBC or CSPMTE during the estimation of TFP growth relation (v) (see Chapter Five, Section 5.2.6 for details), then given that labour's share is positively correlated with share-weighted input price changes, the coefficients on TFP growth relation (v) are of the expected sign. This is not the case for the entire economy or the primary and manufacturing industries results.

6.3.2 Industry-Specific Human Capital Accumulation

In an effort to improve the predictive power of Rebelo's human capital growth model, Klenow (1998) modifies the general human capital model to make allowance for human capital that is industry-specific. The following is a brief presentation of the industry-specific human capital model, as well as a discussion of how this model marries with the TFP growth relations.

In this model the first intermediate good, Y_1, is produced by workers who posses a higher level of human capital (skilled workers) relative to the workers who produce the second intermediate good, Y_2 (unskilled workers). The production technologies for these two goods are given as follows:

$$\begin{aligned} Y_{1t} &= (L_{1St}H_t)^{\alpha_1} K_{1t}^{\beta_1} M_{1t}^{1-\alpha_1-\beta_1} \\ Y_{2t} &= L_{2Ut}{}^{\alpha_2} K_{2t}^{\beta_2} M_{2t}^{1-\alpha_2-\beta_2} \end{aligned} \qquad (6.8)$$

where L_S and L_U are the number of hours worked by skilled and unskilled workers, respectively. In addition, the human capital of unskilled workers is constant and is normalised to equal one in the production function. Skilled workers can allocate their time between working and accumulating human capital, where human capital accumulation follows:

$$H_{t+1} = BL_{SHt}^{\gamma} H_t$$

The market clearing conditions for this model are as follows:

$$L = L_{Ut} + L_{St} + L_{SHt}$$

$K = K_{1t} + K_{2t}$

$M = M_{1t} + M_{2t}$

In addition the growth of TFP is determined as follows:

$$g_{TFP_i} = \alpha_i g_{H_i} \qquad (6.9)$$

Klenow (1998, p.15) notes that when Y, C, K, K_1, K_2, H, M, M_1, and M_2 all grow at the same rate, this model does not converge to a balanced growth path because the growth rate of human capital is greater than the growth rate of the final good. This is because the accumulation of human capital is specific to the industry that produces the first intermediate good.

Finding the growth version of equation (6.8) and substituting into (6.2a) yields the following:

$$g_{Y1} - g_{Y2} = \alpha_1 g_H + (\alpha_2 - \alpha_1) g_Y = g_{P_2} - g_{P_1} \qquad (6.10)$$

Equation (6.10) shows that industries with faster than average TFP should exhibit relative price declines, since TFP growth and human capital growth are positively related. Therefore, this model is consistent with TFP growth relation (i) for the three sets of results.[3] Equation (6.9) suggests that TFP growth and industry labour intensity can be positively related. This is consistent with TFP growth relation (ii) for the entire economy and the manufacturing results (Tables 5.5 and 5.18). In addition, because labour's share is negatively correlated with material's share and capital's share for entire economy and manufacturing results (Tables 5.3 and 5.16) negative coefficients were expected on capital's share and material's, as was the case for TFP growth relation (iv) (Tables 5.5 and 5.18).

[3] Based on the assumptions that labour intensity varies exogenously across industries and that the covariance between labour intensity and human capital intensity is zero.

Equation (6.9) indicates that the parameter estimate for TFP growth relation (iii) should be the growth rate of human capital. This is clearly at odds with the results for the primary and manufacturing industries (Table 5.12), and can not account for the absence of a statistical relationship between TFP growth and nonproduction labour's share for the entire economy and the manufacturing results (Tables 5.5 and 5.18).

A similar story applies to TFP growth relation (v) as it did for the General Human Capital Accumulation Model (Section 6.3.1). While the General Human Capital model can not explain TFP growth relation (v), the signs of the coefficients on share-weighted input price changes can be reconciled with the manufacturing industries results (Table 5.18) because labour's share is negatively correlated with the growth of input price deflators. On the other hand, this does not hold true for the entire economy and the primary and manufacturing industries results (Tables 5.5 and 5.12).

6.4 Idea Accumulation

6.4.1 General Idea Accumulation

Consideration is now given to the second class of endogenous growth models – idea accumulation models. The first of these models is a general idea accumulation model, which is based on Romer's (1990) article *Endogenous Technological Change*. The model is general in the sense that new ideas are general to both industries that produce the two intermediate goods – where new ideas are embodied in new types of equipment.

The two intermediate goods are produced by the following production technologies whereby firms combine varieties of physical capital with human capital:

$$Y_1 = H_{Y_1}^{\alpha_1}\left(\int_0^A x_1(i)^{\frac{\sigma-1}{\sigma}}\,di\right)^{\frac{\sigma(1-\alpha_1)}{\sigma-1}}$$

$$Y_2 = H_{Y_2}^{\alpha_1}\left(\int_0^A x_2(i)^{\frac{\sigma-1}{\sigma}}\,di\right)^{\frac{\sigma(1-\alpha_2)}{\sigma-1}} \qquad (6.11)$$

where A is the number of capital varieties, x is the quantity of each capital good used in production, and σ is the elasticity of substitution. It is assumed that the elasticity of substitution is less than infinity, meaning that the capital varieties are imperfect substitutes. Human capital is held constant.

Following Romer (1990), a single firm produces each capital variety. The firm has obtained its monopoly position by purchasing a production license from the research firm that designed the capital variety. Each of the research firms holds an infinitely lived patent for the capital variety that they designed. The stock of capital varieties follows:

$$A_{t+1} = \delta H_A A_t$$

where δ is the research productivity parameter and H_A the level of human capital devoted to research.

In this model, ideas (or knowledge), embodied in capital varieties, are a "partially excludable nonrival input" (Romer, 1990, p. S72). Ideas are nonrival because the research sector has access to the current stock of capital varieties, when designing further capital varieties. Ideas are partially excludable because research firms obtain infinitely lived patents for their capital designs.

Klenow (1998 p.18) notes that when capital good varieties are assumed to be symmetric, equation (6.11) can be written as follows:

$$Y_1 = A^{\frac{1-\alpha_1}{\sigma-1}} H_{Y_1}^{\alpha_1} K_1^{1-\alpha_1}$$
$$Y_2 = A^{\frac{1-\alpha_2}{\sigma-1}} H_{Y_1}^{\alpha_2} K_1^{1-\alpha_2} \tag{6.12}$$

Given (6.12) it can be established that TFP growth can be measured as follows:

$$g_{TFP_i} = (1-\alpha_i)\frac{g_A}{\sigma - 1} \tag{6.13}$$

That is, TFP growth is a function of the growth of capital varieties, scaled by a 'substitutability adjusted' capital share.

A balanced growth path means that Y, C, K, K_1, and K_2 all grow at the same rate. H_{Y1}, H_{Y2}, and H_A are assumed to be fixed.

Substituting the growth version of (6.12) into (6.2a) yields the following:

$$g_{Y1} - g_{Y2} = (\alpha_2 - \alpha_1)g_Y + g_{TFP_1} - g_{TFP_2} = g_{P2} - g_{P1} \tag{6.14}$$

In words, when (6.14) is generalised to N industries, those industries that exhibit faster than average TFP growth should experience relative output price declines. This is consistent with TFP growth relation (i) for all three sets of results (Tables 5.5, 5.12, and 5.18).

In this model, equation (6.13) predicts that capital's share should be inversely related to TFP growth. Clearly this is at odds with all three sets of results for TFP growth relation (iv). Once again, both industries use the same capital and material inputs. This model cannot account for why differences in input deflator growth help to explain inter-industry TFP differences.

6.4.2 Industry-Specific Idea Accumulation[4]

The fifth and final model that Klenow (1998) considers in his paper is an industry-specific idea accumulation model. In this model, research firms design capital goods with a particular industry in mind. In other words, capital goods are exclusive to either one of the two industries, and cannot be used by the other. In this case, research firm j chooses to specialise in the production of designs for exclusive use by one of the two intermediate goods, with one of the following research technologies:

$$A_{1t+1} = \frac{\delta_1 H_{A1}(j)}{H_{A1}^{1-\gamma}} A_{1t}$$
$$A_{2t+1} = \frac{\delta_2 H_{A2}(j)}{H_{A2}^{1-\gamma}} A_{2t} \qquad (6.15)$$

where $\gamma < 1$ implying diminishing returns to scale for the research industry.

Klenow (1998, p.20) notes that in this model, if the variety of inputs for a particular industry is not fully reflected in the factor prices, then TFP growth for industry i is determined as follows:

$$g_{TFP_i} = (1-\alpha_i)\frac{g_{A_i}}{\alpha - 1} \qquad (6.16)$$

Klenow, however, goes on to state that the price deflators utilised in his study do not capture all the improvements in variety. Therefore, industry i's price deflator needs to be weighted by some proportion, ω_i, in order to measure the actual improvement in variety. If this is the case equation (6.16) becomes:

$$g_{TFP_i} = (1-\omega_i)(1-\alpha_i)\frac{g_{Ai}}{\alpha - 1} \qquad (6.16a)$$

[4] A more comprehensive account of this model is provided in Klenow (1996).

In this situation industries with relatively faster input price declines will exhibit faster TFP growth, since rising input quality is not fully being captured by the input price deflators. This is not entirely consistent with TFP growth relation (v) (for all three sets of results), where TFP growth tends to be positively related to share-weighted input price changes, especially if CSBC or CSPMTE is dropped from TFP growth relation (v). In addition, this model is inconsistent with TFP growth relations (ii)-(iv).

6.5 Comparison of Growth Models with TFP Growth Relations – A Summary

Tables 6.1-6.3 provide a summary of Sections 6.2-6.4 that aids in discriminating between the alternative growth models.

Table 6.1 Theoretical Growth Models versus TFP Growth Relations – Entire Economy

TFP Growth Relations	Theoretical Growth Models				
	Exogenous	General Human Capital	Specific Human Capital	Idea Accumulation	Specific Idea Accumulation
(i)	✓	✗	✓	✓	✓
(ii)	✗	✓	✓	✗	✗
(iii)	✓	✗	✗	✗	✗
(iv)	✗	✓	✓	✗	✗
(v)	✗	✗	✗	✗	✗

A '✓' indicates that the growth model can explain the TFP growth relation point estimate/s. A '✗' indicates that the growth model cannot explain the TFP growth relation point estimate/s. The numbers (i) to (v) correspond to the TFP growth relations presented in Chapter Four, Section 4.1.1.

Table 6.1 reveals that while the exogenous and idea accumulation growth models are able to explain the empirical relationship between output deflator growth and TFP growth, they are unable to explain TFP growth relations (ii)-(v) for the entire economy results, with the exception of the exogenous growth model for TFP growth relation (iii). In contrast, rival human capital models do a better job at explaining why TFP growth is positively related to labour intensity, and inversely related to material and capital intensity. On the other hand, these models cannot account for why input price deflators behave differently across industries, and why there is no positive relationship between TFP growth and nonproduction labour's share. In addition, the general human capital cannot explain TFP growth relationship (i).

It could be argued that the absence of a statistical relationship between TFP growth and industry human capital intensity is because nonproduction labour's share is too crude a measure for industry human capital intensity. In Chapter Five, Section 5.1.4, an attempt was made to further investigate the relationship between TFP growth and industry human capital intensity, by regressing high skilled labour's share (a superior measure of industry human capital intensity) against TFP growth. As can be seen from Table 5.20, a statistically significant relationship could still not be established.

Table 6.2 Theoretical Growth Models versus TFP Growth Relations – Primary and Manufacturing Industries

		Theoretical Growth Models				
TFP Growth Relations		Exogenous	General Human Capital	Specific Human Capital	Idea Accumulation	Specific Idea Accumulation
	(i)	✓	✗	✓	✓	✓
	(ii)	✓	✗	✗	✗	✗
	(iii)	✗	✗	✗	✗	✗
	(iv)	✓	✗	✗	✗	✗
	(v)	✗	✗	✗	✗	✗

A '✓' indicates that the growth model can explain the TFP growth relation point estimate/s. A '✗' indicates that the growth model cannot explain the TFP growth relation point estimate/s. The numbers (i) to (v) correspond to the TFP growth relations presented in Chapter Four, Section 4.1.1.

When turning to primary and manufacturing results, Table 6.2 shows that the exogenous model is most consistent with the TFP growth relations. However, this model cannot account for why human capital intensity is inversely related to TFP growth, and why input price deflators behave differently across industries. In relation to the former empirical relationship, Hazeldine (1998) has hypothesised that a fall in managerial productivity has substantially detracted from TFP growth for the New Zealand economy; TFP growth relation (iii) for the primary and manufacturing industries is consistent with this hypothesis. In addition, when this result is contrasted with its counterpart for manufacturing industries, it appears that a substantial proportion of the signal for this coefficient is coming from primary sector industries.

Table 6.3 Theoretical Growth Models versus TFP Growth Relations – Manufacturing Industries

TFP Growth Relations	Theoretical Growth Models				
	Exogenous	General Human Capital	Specific Human Capital	Idea Accumulation	Specific Idea Accumulation
(i)	✓	✗	✓	✓	✓
(ii)	✗	✓	✓	✗	✗
(iii)	✓	✗	✗	✗	✗
(iv)	✗	✓	✓	✗	✗
(v)	✗	✗	✗	✗	✗

A '✓' indicates that the growth model cannot explain the TFP growth relation point estimate/s. A '✗' indicates that the growth model can explain the TFP growth relation point estimate/s. The numbers (i) to (v) correspond to the TFP growth relations presented in Chapter Four, Section 4.1.1.

Table 6.3 for manufacturing industries is identical to Table 6.1 for the entire economy. This suggests that manufacturing industries conform most closely to the rival human capital class of endogenous growth models. In addition, even though the rival human capital model cannot explain TFP growth relation (iii), it can be reconciled with TFP growth relation (v) given the correlation between labour's share and input price changes.[5]

[5] TFP growth relation (v), for both rival human capital models, still receives a cross in Table 6.3 because these models have no explanation as to why input price changes differ over industries because both intermediate goods industries use the same material and capital inputs. If these models were being evaluated on their consistency with the TFP growth relations, rather than on the basis of being able to provide economic explanations for the parameter estimates, TFP growth relation (v) would receive a tick rather than a cross for both rival human capital models for manufacturing industries.

As can be seen from Tables 6.1-6.3 above, none of the models are able to explain why share-weighted input price changes are positively related to TFP growth (after correcting for multicollinearity). This result is particularly puzzling given that output and input price deflators are positively correlated.

6.6 Results for United States Manufacturing Industries

Tables 6.4 and 6.5 are the analogous tables for 449 US manufacturing industries. These tables are taken from Klenow (1998, pp. 6 and 13). Before comparing these results with the manufacturing results for the New Zealand economy, comments are made in relation to the interpretation of some of the results.

When commenting on the signs of the point estimates for the TFP growth relations in the context of the general human capital model, Klenow (1998, p.14) states:

> Moreover, the model gives no reason for share-weighted materials and capital goods prices to decline more rapidly in fast TFP growth industries (Regression 6) [this is analogous to TFP growth relation (v)] since labour's share is negatively correlated with these variables (-0.65 and p-value = 0.0001 for each).

The general human capital model predicts that labour's share should be positively related to TFP growth, therefore, as an industry becomes relatively more intensive in labour, its TFP growth increases, and it tends to experiences a slowing (or even a decrease) in input price changes, given the negative correlation between labour's share and share-weighted input price changes. Thus, according to this model, share-weighted input price changes *should be* negatively related to TFP growth – consistent with the point estimates for United States manufacturing industries. While agreeing with Klenow (1998, p. 14) that this model cannot explain why input price deflators behave differently across industries, in antithesis to the conclusion reached by Klenow, the signs of the coefficients on share-weighted input prices changes are reconcilable with the general human capital model.

Table 6.4 United States Manufacturing Industries TFP Growth Relations – Gross Output[a]

Time Period	1959-1991	1959-1991	1959-1975	1975-1991
Dependent Variable: DEF				
i. TFP	-0.88***	-0.82***	-0.72***	-0.87***
	(0.03)	(0.03)	(0.04)	(0.03)
Dependent Variable: TFP				
ii. LS	-1.87***	-2.15***	-0.31	-3.24***
	(0.66)	(0.58)	(0.75)	(0.97)
iii. NPLS	-0.89	-3.03**	-2.30	-4.76**
	(1.45)	(1.29)	(1.70)	(2.00)
iv. CS	3.45***	3.50***	3.39***	1.78
	(1.08)	(0.95)	(1.26)	(1.46)
MS	1.80***	1.98***	0.72	2.27**
	(0.65)	(0.58)	(0.74)	(0.95)
v. CS	13.6***	9.74***	11.3***	7.33***
	(2.1)	(1.95)	(3.9)	(2.10)
MS	6.04***	4.90***	2.39**	4.45***
	(0.81)	(0.75)	(0.94)	(0.95)
CSCD	-2.28***	-1.38***	-1.92*	-1.24
	(0.45)	(0.43)	(1.01)	(2.10)
MSMD	-1.01***	-0.71***	-0.35***	-0.74***
	(0.14)	(0.14)	(0.12)	(0.12)

Source: Klenow (1998, p. 6).

[a] CSCD = Share-weighted capital deflator growth. MSMD = Share-weighted material deflator growth. OLS estimates are obtained using data from the National Bureau of Economic Research (NBER) database. Standard errors are in parentheses. The number of observations for results in columns one, three, and four is 449. The number of observations for column two results is 447, where the computer industries (SIC 3572 and SIC 3674) have been dropped because price deflators are calculated using hedonic methods. In the above results three stars (***) indicate that the coefficient is significantly different from zero at the 1% significance level, two stars (**) that it is significant at the 5% level, and one star (*) that it is significant at the 10% level.

A similar case can be made for point estimates on share-weighted input price changes in relation to the prediction of the industry-specific human capital model. In contrast to Klenow's (1998, p. 17) conclusion – that Regression 6 [the equivalent of TFP growth relation (v)] is "the opposite of what this 'H_i' model [that is, the industry specific human capital model] predicts" – this models suggests that share-weighted input price changes should be positively related to TFP growth, given the negative correlation between nonproduction labour's share and share-weighted price changes.[6]

Table 6.5 Theoretical Growth Models versus TFP Growth Relations – United States Manufacturing Industries

	Theoretical Growth Models				
TFP Growth Relations	Exogenous	General Human Capital	Specific Human Capital	Idea Accumulation	Specific Idea Accumulation
(i)	✓	✗	✓	✓	✓
(ii)	✗	✗	✗	✓	✓
(iii)	✗	✗	✗	✓	✓
(iv)	✗	✗	✗	✓	✓
(v)	✗	✗	✗	✗	✓

Source: Adapted from Klenow (1998, p. 13). A '✓' indicates that the growth model cannot explain the TFP growth relation point estimate/s. A '✗ ' indicates that the growth model can explain the TFP growth relation point estimate/s.

These corrections do not change the main conclusions of Klenow's (1998) paper, as both rival human capital models still cannot explain why input price changes behave differently across industries. However, they do show that the signs of the coefficients on material's and capital's share can be reconciled with these models.

In contrast to the findings for the New Zealand manufacturing industries (Table 6.3), Table 6.5 indicates that the 'ideas' class of endogenous growth model seems most appropriate for the United States manufacturing industries.[7] Yet, in reaching this conclusion, Klenow (1998, p. 22) notes that "[r]ival human capital accumulation and idea accumulation are not

[6] I am grateful for the comments provided by Klenow (1999) when queried about some of his conclusions. He acknowledges that "sign errors" were made in regards to the relationship between share-weighted input price changes and TFP growth when discussing both rival human capital models in Klenow (1998).

[7] When comparing United States manufacturing industries results with New Zealand manufacturing industries results it should be borne in mind that Klenow's (1998) conclusions are based on data for a longer time period (1959-1991 compared with 1978-1995 for New Zealand manufacturing industries) and more disaggregate data (observations at the 4-digit level instead of the 2-digit level).

mutually exclusive and both surely contribute to growth." A similar argument can be made in relation to New Zealand manufacturing industries. For example, the Minister for Information Technology's IT Advisory Group (1999, p. 28) notes industry clusters are "a way of promoting and focussing new business activity... as businesses learn from one another through joint research ventures and shared best practices." In other words, as firms and industries work together 'knowledge spillovers' occur – consistent with the 'ideas' class of endogenous growth model. At the same time, Lucas (1988, p.19) highlights the positive human capital externalities that are generated as people work together.[8] In addition, Klenow (1998, p.5) points out the a hybrid model of idea and human capital accumulation would show up in the empirics as a rival human capital model, and yet would basically have 'idea' model policy prescriptions.

6.7 Open Economy Models

The models considered in Sections 6.2-6.4 were closed economy models. Given that New Zealand is a small open economy it is appropriate to examine the TFP growth relations using the open economy versions of Romer's (1990) and Rebelo's (1991) models (see Aghion and Howitt, 1998, Chapter 11, pp. 372-375). In the Romer (1990) model the effect of opening up the model to international trade is twofold. First, assumming that economies specialise in producing different capital goods, the stock of capital varieties available for manufacturing Y_1 and Y_2 will increase. Second, the stock of knowledge that is available to research firms in designing new capital varieties will also increase. Thus, when the general idea model and the industry specific idea models are opened up to international trade, the qualitative predictions remain the same, however, the quantitative implications change. In other words, the open economy version of the 'ideas' class of endogenous growth model would still predict that TFP growth should remain positively related to industry capital and material intensity, especially given that a large proportion of New Zealand imports are capital goods (see Birks and Chatterjee, 1992, Chapter 12, Table 12.1, p.226). Moreover,

[8] Strictly, Lucas' (1988) model is not a *rival* human capital model because benefits to human capital accumulation accrue to others, as well as to those who have invested in it. It is, however, a variant of this class of model, and has similar policy implications.

when one considers the point estimate from regressing manufacturing industries' import share against TFP growth (Table 6.6), open economy 'ideas' models are still unable to be reconciled with the empirics, given that New Zealand manufacturing industries import a large number of capital goods.

Analogous to the increase in the stock of capital varieties and 'ideas,' is the increase in the available stock of human capital when Rebelo's (1991) model is opened up to international trade. Deardorff and Lattimore (1999, p. 83) show that the importables sector of the New Zealand economy, which is basically comprised of manufacturing industries, is *generally* more intensive in high skilled workers than is the exportables sector. Knowing this, and the fact that labour's share is negatively correlated with manufacturing industries' import share, the point estimate in Table 6.6 appears more consistent with the rival human capital models than the 'ideas' models.

Table 6.6 – TFP Growth and Manufacturing Industries' Import Share[a]

	Coefficient	Buse R^2
Dependent Variable: TFP		
Import Share	-1.743***	0.350
	(0.593)	

[a] The standard error is in the parenthesis. The number of observations is twenty-seven, where each observation is a six-year average. During the estimation procedure SHAZAM estimated the error variance-covariance matrix using the number of time-series observations as the divisor because of too few degrees of freedom. For the above result three stars (***) indicate that the coefficient is significantly different from zero at the 1% significance level. Time dummy variables were included in the regression model if their coefficients were significantly different from zero at the 10% level.

6.8 Policy Implications

One of the major reasons for discriminating between different classes of growth models is that they have different policy implications. For example, Romer (1990, p. S94) notes that the early models that attempted to endogenise technical progress (Arrow, 1962; Romer, 1986) supported policies that favoured capital accumulation in order to raise the growth rate of output.[9] The growth models of Romer (1990) and Rebelo (1991), presented in the

[9] Romer (1990) gives the example of an investment tax credit.

first part of this chapter, have different policy implications from the early endogenous growth model, as well as from each other.

As noted previously, the empirical results for New Zealand give some support in favour of the rival human capital class of endogenous growth models. In Rebelo's (1991) model the decentralised equilibrium is Pareto optimal, therefore, no economic justification is provided for intervention. In terms of policy implications, this class of models tends to focus around education and training, and the effect that subsidies and taxes have upon them. For example, Rebelo's model suggests "that the growth rate should be low in countries with high income tax rates and poor property rights enforcement" (ibid., p. 519). This hypothesis has found some empirical support. For example Kocherlakota and Yi (1996, p. 129) find "that a temporary reduction of tax rates by 10% points would lead to a permanent 0.4% increase in GNP" for the United States' economy. As part of New Zealand's economic reforms successive governments have sought to lower marginal income tax rates, with a view to improving market signal in the economy, while simultaneously trying to broaden the tax base in an attempt to raise tax revenue (Evans et al., 1996, p.1869).

Romer's (1990) model differs from Rebelo's (1991) in that there is a divergence between the social and market equilibrium. In order to rectify the divergence, this calls for a subsidy to the R&D sector. Romer (1990, p.S96) justifies this subsidisation for two reasons. First, research generates a positive externality, both in the present and future, which is not reflected in the market pricing, leading to a sub-optimal level of research and growth. Second, too little human capital is devoted to research because those firms that manufacture producer durables engage in monopoly pricing. Romer (1990, p.S99) also notes that in the absence of policies to raise research levels to the social optimum, the 'second best' policy is to subsidise human capital accumulation.

New Zealand's expenditure on R&D, as a percentage of GDP, is almost half the OECD average. In 1997/98 1.09% of New Zealand's GDP was spent on R&D, compared with the

OECD average of 2%.[10] This was a 'record high' of an estimated $1,107.4 million for the New Zealand economy (MORST, 1999, p. 1). New Zealand's low R&D expenditure is primarily due to low private sector expenditure.[11] This fact, in addition to the low number of researchers per 1000 members of the labour force,[12] could be used to argue that New Zealand's R&D expenditure is sub-optimal. This is interesting in light of the government's industry policy. Since the commencement of the reforms in 1984 successive New Zealand governments have sought to maintain 'industry neutrality', reflecting a view "that the government's major role in industry should be to establish an economic environment that is conducive to business" (Evans et al., 1996, p.1884), rather than providing direct assistance to industry.[13] In relation to R&D, at the time of writing, the government allows a 100% tax right off for research, but not for development (Bennett, 1999). This stance in part reflects some of the excesses of the past. It also reflects the view of Barro and Sala-i-Martin (1995, p. 230), which is also endorsed by some New Zealand policy makers, that:

> A successful subsidy policy is nevertheless difficult to implement because it requires the government to identify promising areas of research that have substantial spillover benefits, and it assumes that the necessary public finance will not have distorting influences that outweigh the benefits from the internalization of spillovers.

A lot of the apprehension that some policy makers have to a proactive government R&D policy is with the notion of 'picking winners'. Yet as Stiglitz (1999, p. 22) contends, the objective of a industrial policy is "not to pick winners, but to identify externality-generating innovations."[14] In this direction, some New Zealand commentators have called for

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[10] This excludes defence spending on R&D. If defence spending were included these figures would become 1.12% and 2.17%, respectively. A comparison can also be made with a series of New Zealand reference countries, known as the 'Science Envelope'. These countries are Australia, Denmark, Finland, Ireland, Norway, and Sweden. Their expenditure of R&D in 1997/98 was 2.07% (excluding defence).

[11] Private R&D is probably somewhat understated due to perverse tax incentives (Minister for Information Technology's IT Advisory Group, 1999, p. 25).

[12] 4.5, compared to the OECD average of 5.1.

[13] As a reflection of this policy stance, Evans et al. (1996, p. 1884) highlight the "massive reduction in direct government assistance to industry from 16.2% of government expenditure (nondebt) to 4% in 1993/94."

[14] Although, Stiglitz (1999, p. 23) also points to the "proclivity" of governments for "fancy projects."

government assistance to be made available to businesses for R&D (for example, Philpott, 1999, p. 19).

New Zealand's low level of R&D expenditure could also explain why the economy struggles to absorb knowledge-spillovers from overseas. For example, Engelbrecht (1997a, p. 318) notes that foreign R&D spillovers have had a negative impact on New Zealand's TFP growth. He argues that New Zealand (as well as other economies) may need to increase its domestic level of R&D in order to raise its capacity to absorb foreign R&D. Engelbrecht and Darroch (1999) also highlight New Zealand's poor absorptive ability. In the framework of the 'National Innovation System' the authors consider a whole range of factors in an attempt to measure innovation, and knowledge absorption and diffusion, concluding that New Zealand is weak in these areas relative to other OECD economies. As discussed in Chapter Two, given that knowledge/technology transfer may be one factor in driving convergence, absorptive capacity is very important. This, as well as some other factors discussed above, suggests that New Zealand has a way to go before it becomes a 'knowledge-based' economy.

6.9 Concluding Comments

This chapter has compared the predictions of several models of economic growth against the empirical results reported in Chapter Five. The major conclusion to be taken from this chapter in that there is some evidence, from entire economy and manufacturing results, that the empirical evidence conforms most closely with the rival human capital class of endogenous models. In relation to results for manufacturing industries, the conclusion reached contrasts with US manufacturing results, which conform more closely with idea accumulation models.

Chapter Seven

Conclusion

> *We can never completely rule out the possibility that these findings are also consistent with other models... or that they have been 'contaminated' by various data or methodological problems.* (Maloney, 1998, p. 3)

Using data on twenty industries comprising the market sector of the New Zealand economy, this thesis has provided an *indirect* test of two classes of endogenous growth models, in addition to an exogenous growth model, in order find the most appropriate class for the New Zealand economy. The empirical evidence, reported in Chapter Five, reveals that industries with higher average annual TFP growth tend to exhibit low or declining output prices. When compared with the predictions of alternative growth models, this empirical relationship runs into problems of observational equivalence, given that all bar one of the growth models posit that this relationship should be displayed by the data. A more decisive test is to investigate the relationship between TFP growth and industry factor intensities. Rival human capital models suggest that high TFP growth industries should be more intensive in labour and human capital, whereas 'idea' models point to high TFP growth industries being more intensive in physical capital – the opposite of rival human capital models. The empirical relationships between TFP growth and industry factor intensities, for the entire economy and manufacturing results, *tend to support* rival human capital models, however some anomalies remain. In particular, the inability to establish a positive statistical relationship between TFP growth and industry human capital intensity is of concern. In addition, the positive relationship between TFP growth and input deflator growth is somewhat puzzling, as are some of the dubious results for primary and manufacturing industries. Opening up the model to international trade did not help in reconciling these results to any of the models. While not wishing to lay blame totally on 'data problems,' given the inherent difficulties with collecting, classifying, and measuring data at the industry level in the New Zealand economy, this must be a major factor.

In noting that the empirical evidence tends to conform more closely with the rival human capital models, it is also important to recognise that a hybrid model would exhibit the same empirical relationships that are consistent with rival human capital models, but that would follow idea accumulation models in policy prescription. This should be borne in mind when considering the policy implications that flow from these models.

In Klenow's (1998) study on 449 United States manufacturing industries the empirics conform totally with the industry-specific ideas model. In discussing this finding, Klenow (1998, p. 21) notes that "the facts documented might be peculiar to US manufacturing industries. They may not extend to nonmanufacturing industries or to other countries." The results contained in this thesis tend to support this view.

This thesis suggests a number of future research avenues. First, it would be desirable to calculate the growth of TFP using alternative (more flexible) functional forms. In this thesis a Cobb-Douglas production function was chosen, because traditionally this has been the one used in New Zealand studies. However, it would be useful to explore different functional forms to see whether they change the parameter estimates for the TFP growth relations. Second, it would be advantageous to carry out this study at a more disaggregate level (3 or 4 digit). Chiefly, this would increase the spread for the independent variables, thus providing more precise point estimates. This would serve to provide more conclusive statistical evidence in supporting economic policy. Third, more direct testing of different classes of endogenous growth models is required. It is necessary to develop a methodological basis to carry out this testing. Finally, it necessary to consider in more detail why New Zealand may lack the capacity to absorb knowledge spillovers.

Appendix One
Testing for Heteroskedasticity

Table A.1.1 Breusch-Pagan-Godfrey Statistics – Gross Output/1978-1983[a]

	Breusch-Pagan-Godfrey Statistics
Dependent Variable: DEF 1. TFP	9.690***
Dependent Variable: TFP 2. LS	2.675*
3. NPLS	1.972
4. CS/MS	7.200**
5. CS/CSBC/CSPMTE/MS/MSDEF	15.871***

[a] The number of observations on which the test statistic is computed is twenty. Three stars (***) indicate that the null hypothesis would be rejected at the 1% significance level, two stars (**) indicate that it is significant at the 5% level, and one star (*) indicates that it is significant at the 10% level.

Table A.1.1 reports the Breusch-Pagan-Godfrey test statistics associated with the TFP growth relations (gross output, 1978-1983). The null hypothesis is that the variance of the error term is homoskedastic. The alternative hypothesis is that the variance of the error term is heteroskedastic. Rather than reporting the Breusch-Pagan-Godfrey test statistics for eighteen sets of results,[1] this Appendix only reports gross output results for the period 1978-1983. They are very similar to the other seventeen sets.

[1] Given that there are three time-series observations the Breusch-Pagan-Godfrey test needs to be computed three times for the entire economy, primary and manufacturing industries, and manufacturing industries only, both for gross output and value added data.

Appendix Two

Testing for Structural Breaks

Chapter Four, Section 4.1.3, provides an *informal* justification as to why six year averages for the periods 1978-1983, 1984-1989, and 1990-1995 are used in the regression analysis. As discussed in footnote 13, Chapter 4, this appendix provides details on the linear spline test, used to test for the presence of structural breaks in 1984 and 1990.

In order to test for structural breaks in the years 1984 and 1990 the following statistical model was estimated using OLS:

$$LogGDP_t = \beta_1 + \beta_2 Year_t + \beta_3 S_{1t} + \beta_4 S_{2t} + \varepsilon_t \qquad \varepsilon_t \sim N(0, \sigma^2) \qquad \text{(A2.1)}$$

$t = 1978, \ldots, 1995.$

where $LogGDP$ = Log of GDP

$Year$ = Year

$S_{1t} = 0$ if $t = 1978, \ldots, 1984$
$= 1, \ldots, 11$ for $t = 1985, \ldots, 1995$

$S_{2t} = 0$ if $t = 1978, \ldots, 1990$
$= 1, \ldots, 5$ for $t = 1991, \ldots, 1995$

(Note: The linear series commences the year after the hypothesised structural break).

The parameter estimates for this model and the associated R^2 and adjusted R^2 are presented below (standard errors in parentheses):

$$LogGDP_t = \underset{(8.248)}{-39.879} + \underset{(0.004)}{0.026}Year_t - \underset{(0.007)}{0.016}S_{1t} - \underset{(0.008)}{0.005}S_{2t}$$

$R^2 = 0.931$ Adjusted $R^2 = 0.916$

Setting a significance level of 5%, the above results reveal that the coefficient on S_{1t} is statistically different from zero, whereas the coefficient on S_{2t} is not. This implies sample evidence of a structural break in 1984 but not 1990.

Appendix Three
TFP Growth 1978-1995

The following are the TFP calculations for gross output and value added data for the periods 1978 – 1983, 1984 – 1989, and 1990 – 1995.

Table A.3.1 Average Annual Compound Growth Rates – Gross Output 1978-1983

Industry	Output	Labour Share	Labour	Capital Share	Capital	Material Share	Materials	TFP
Agriculture	8.07	0.08	1.49	0.33	1.81	0.59	-0.76	7.79
Fishing and Hunting	19.99	0.09	2.93	0.23	3.67	0.68	18.23	6.48
Forestry and Logging	11.81	0.26	-1.96	0.20	1.17	0.53	3.56	10.19
Mining and Quarrying	-2.63	0.13	-2.32	0.21	4.28	0.66	2.25	-4.72
Food and Tobacco	1.93	0.19	0.49	0.03	5.41	0.78	1.46	0.53
Wood and Wood Products	4.01	0.24	0.87	0.08	1.21	0.68	3.10	1.59
Pulp and Paper Products, Printing, and Publishing	2.83	0.23	-0.18	0.09	0.98	0.68	1.37	1.84
Basic Metal Products	-0.09	0.17	0.43	0.10	10.32	0.73	1.44	-2.27
Textiles, Clothing, and Footwear	1.57	0.25	-0.20	0.08	0.80	0.67	1.06	0.85
Petroleum, Chemical, Plastics, and Rubber Products	-1.11	0.19	-0.38	0.08	18.07	0.73	-5.51	1.52
Non Metallic Mineral Products	4.93	0.22	-3.38	0.18	2.37	0.60	6.50	1.31
Machinery and Equipment	4.42	0.24	-0.48	0.07	2.18	0.69	3.90	1.69
Other Manufacturing	3.65	0.24	1.72	0.10	-1.15	0.65	2.44	1.76
Electricity, Gas, and Water	3.64	0.14	0.33	0.28	2.24	0.57	0.30	2.80
Construction	-1.63	0.19	-5.43	0.09	0.60	0.73	-2.52	1.15
Trade, Restaurants, and Hotels	-0.59	0.20	0.59	0.12	3.57	0.68	-0.99	-0.46
Transport and Storage	3.58	0.33	-2.45	0.10	2.41	0.57	-1.55	5.05
Communicatons	5.06	0.59	-1.29	0.18	2.23	0.23	0.62	5.29
Finance, Insurance, Real Estate, and Business Services	4.17	0.25	2.19	0.31	4.36	0.44	5.27	-0.04
Community, Social, and Personal Services	2.75	0.25	0.78	0.19	-0.39	0.56	1.46	1.80

Table A.3.2 Average Annual Compound Growth Rates – Gross Output 1984-1989

Industry	Output	Labour Share	Labour	Capital Share	Capital	Material Share	Materials	TFP
Agriculture	3.70	0.09	-1.34	0.30	-0.50	0.61	-3.40	6.05
Fishing and Hunting	4.37	0.06	-12.43	0.23	4.42	0.71	5.02	0.61
Forestry and Logging	-1.42	0.16	-17.52	0.27	-1.83	0.56	2.21	0.72
Mining and Quarrying	7.08	0.11	-0.81	0.15	2.85	0.74	-3.56	9.36
Food and Tobacco	1.44	0.16	-0.95	0.07	2.29	0.77	8.23	-4.89
Wood and Wood Products	-2.79	0.22	-2.76	0.09	2.94	0.68	-2.83	-0.52
Pulp and Paper Products, Printing, and Publishing	2.33	0.22	1.82	0.10	3.37	0.68	3.32	-0.66
Basic Metal Products	8.51	0.18	-1.49	0.05	4.06	0.78	-0.61	9.06
Textiles, Clothing, and Footwear	-1.18	0.22	-3.44	0.07	0.37	0.71	-1.69	0.76
Petroleum, Chemical, Plastics, and Rubber Products	-4.60	0.16	-3.16	0.14	3.38	0.71	4.79	-7.96
Non Metallic Mineral Products	1.00	0.19	0.45	0.14	0.41	0.68	-0.61	1.28
Machinery and Equipment	-4.34	0.21	-2.08	0.08	3.25	0.71	-3.54	-1.62
Other Manufacturing	-0.86	0.18	-2.81	0.13	-0.84	0.68	0.11	-0.31
Electricity, Gas, and Water	2.16	0.14	3.01	0.28	-0.13	0.58	3.06	0.01
Construction	1.19	0.15	-1.59	0.10	-1.19	0.75	2.77	-0.52
Trade, Restaurants, and Hotels	1.03	0.19	-0.06	0.12	2.92	0.69	0.21	0.53
Transport and Storage	3.29	0.28	-2.24	0.10	-0.58	0.61	5.82	0.40
Communicatons	9.80	0.43	-1.54	0.26	1.32	0.32	20.33	3.70
Finance, Insurance, Real Estate, and Business Services	7.12	0.22	8.06	0.29	8.39	0.48	8.73	-1.36
Community, Social, and Personal Services	-1.60	0.26	1.38	0.20	1.97	0.54	0.05	-2.37

Table A.3.3 Average Annual Compound Growth Rates – Gross Output 1990-1995

Industry	Output	Labour Share	Labour	Capital Share	Capital	Material Share	Materials	TFP
Agriculture	3.22	0.10	0.33	0.28	-1.47	0.62	1.70	2.54
Fishing and Hunting	0.43	0.07	3.06	0.24	7.39	0.69	1.38	-2.52
Forestry and Logging	2.31	0.06	5.31	0.41	1.87	0.53	11.49	-4.87
Mining and Quarrying	2.49	0.11	9.28	0.33	3.07	0.57	3.82	-1.66
Food and Tobacco	4.35	0.13	-0.22	0.06	1.86	0.81	5.23	0.04
Wood and Wood Products	10.26	0.22	6.91	0.08	2.98	0.71	8.11	2.79
Pulp and Paper Products, Printing, and Publishing	0.40	0.22	-1.70	0.12	-0.67	0.66	0.08	0.81
Basic Metal Products	2.54	0.21	-1.14	0.05	-0.88	0.74	1.37	1.80
Textiles, Clothing, and Footwear	0.70	0.21	-2.82	0.08	-1.20	0.71	1.51	0.33
Petroleum, Chemical, Plastics, and Rubber Products	4.22	0.17	2.34	0.11	2.40	0.72	5.02	-0.05
Non Metallic Mineral Products	3.19	0.19	-2.58	0.10	-0.66	0.71	3.12	1.53
Machinery and Equipment	0.26	0.22	3.98	0.11	-0.22	0.67	0.59	-0.96
Other Manufacturing	-0.61	0.20	-1.66	0.16	0.06	0.64	0.04	-0.30
Electricity, Gas, and Water	4.00	0.11	-6.26	0.28	-1.05	0.61	6.24	1.17
Construction	-0.94	0.15	-0.68	0.07	-2.68	0.78	0.30	-0.88
Trade, Restaurants, and Hotels	0.71	0.22	2.71	0.13	0.90	0.65	0.59	-0.37
Transport and Storage	6.54	0.25	-0.65	0.12	0.68	0.63	2.99	4.74
Communicatons	9.62	0.30	-2.09	0.24	1.63	0.46	6.77	6.76
Finance, Insurance, Real Estate, and Business Services	1.73	0.22	2.43	0.26	4.39	0.52	3.94	-1.99
Community, Social, and Personal Services	3.83	0.26	3.40	0.25	4.37	0.48	3.87	-0.05

Table A.3.4 Average Annual Compound Growth Rates – Value Added 1978-1983

Industry	Output	Labour Share	Labour	Capital Share	Capital	TFP
Agriculture	5.61	0.18	1.49	0.81	1.81	3.88
Fishing and Hunting	9.30	0.24	2.93	0.83	3.67	5.56
Forestry and Logging	6.28	0.55	-1.96	0.62	1.17	6.64
Mining and Quarrying	-4.25	0.28	-2.32	0.74	4.28	-6.76
Food and Tobacco	3.24	0.65	0.49	0.50	5.41	0.22
Wood and Wood Products	3.28	0.70	0.87	0.36	1.21	2.23
Pulp and Paper Products, Printing, and Publishing	1.93	0.62	-0.18	0.41	0.98	1.63
Basic Metal Products	1.65	0.56	0.43	0.30	10.32	-1.64
Textiles, Clothing, and Footwear	2.34	0.71	-.209	0.29	0.80	2.26
Petroleum, Chemical, Plastics, and Rubber Products	0.86	0.66	-0.38	0.55	18.07	-8.90
Non Metallic Mineral Products	4.12	0.50	-3.38	0.49	2.37	4.67
Machinery and Equipment	3.19	0.68	-0.48	0.37	2.18	2.71
Other Manufacturing	1.18	0.61	1.72	0.50	-1.15	0.71
Electricity, Gas, and Water	4.45	0.30	0.33	0.72	2.24	2.75
Construction	-1.30	0.64	-5.43	0.44	0.60	1.90
Trade, Restaurants, and Hotels	0.26	0.46	0.59	0.56	3.57	-2.00
Transport and Storage	0.11	0.70	-2.45	0.39	2.41	0.89
Communicatons	4.97	0.71	-1.29	0.46	2.23	4.86
Finance, Insurance, Real Estate, and Business Services	2.80	0.38	2.19	0.64	4.36	-0.80
Community, Social, and Personal Services	2.01	0.51	0.78	0.49	-0.39	1.81

Table A.3.5 Average Annual Compound Growth Rates – Value Added 1984-1989

Industry	Output	Labour Share	Labour	Capital Share	Capital	TFP
Agriculture	7.41	0.19	-1.34	0.81	-0.50	8.07
Fishing and Hunting	9.55	0.17	-12.43	0.83	4.42	8.07
Forestry and Logging	0.95	0.38	-17.52	0.62	-1.83	8.73
Mining and Quarrying	14.49	0.26	-0.81	0.74	2.85	12.61
Food and Tobacco	0.72	0.50	-0.95	0.50	2.29	0.05
Wood and Wood Products	-3.40	0.64	-2.76	0.36	2.94	-2.69
Pulp and Paper Products, Printing, and Publishing	3.20	0.59	1.82	0.41	3.37	0.75
Basic Metal Products	0.06	0.70	-1.49	0.30	4.06	-0.09
Textiles, Clothing, and Footwear	-3.00	0.71	-3.44	0.29	0.37	-0.66
Petroleum, Chemical, Plastics, and Rubber Products	1.36	0.45	-3.16	0.55	3.38	0.90
Non Metallic Mineral Products	-3.26	0.51	0.45	0.49	0.42	-3.69
Machinery and Equipment	-2.37	0.63	-2.08	0.37	3.25	-2.28
Other Manufacturing	0.92	0.50	-2.81	0.50	-0.84	2.74
Electricity, Gas, and Water	1.69	0.28	3.01	0.72	-0.13	0.93
Construction	-1.03	0.56	-1.59	0.44	-1.19	0.39
Trade, Restaurants, and Hotels	-0.07	0.44	-0.06	0.56	2.92	-1.67
Transport and Storage	3.14	0.61	-2.24	0.39	-0.58	4.73
Communicatons	8.06	0.54	-1.54	0.46	1.32	8.29
Finance, Insurance, Real Estate, and Business Services	6.11	0.36	8.06	0.64	8.39	-2.17
Community, Social, and Personal Services	0.64	0.51	1.38	0.49	1.97	-1.04

Table A.3.6 Average Annual Compound Growth Rates – Value Added 1990-1995

Industry	Output	Labour Share	Labour	Capital Share	Capital	TFP
Agriculture	2.21	0.21	0.33	0.79	-1.47	3.30
Fishing and Hunting	0.65	0.17	3.06	0.83	7.39	-6.00
Forestry and Logging	4.41	0.13	5.31	0.87	1.97	2.09
Mining and Quarrying	2.39	0.17	9.28	0.83	3.07	-1.73
Food and Tobacco	2.74	0.45	-0.22	0.55	1.86	1.80
Wood and Wood Products	7.12	0.65	6.91	0.35	2.98	1.60
Pulp and Paper Products, Printing, and Publishing	1.20	0.55	-1.70	0.45	-0.67	2.44
Basic Metal Products	7.22	0.60	-1.14	0.40	-0.88	8.26
Textiles, Clothing, and Footwear	-0.16	0.67	-2.82	0.33	-1.20	2.12
Petroleum, Chemical, Plastics, and Rubber Products	3.95	0.47	2.35	0.53	2.40	1.58
Non Metallic Mineral Products	4.13	0.52	-2.58	0.48	-0.66	5.79
Machinery and Equipment	0.55	0.59	3.98	0.41	-0.22	-1.69
Other Manufacturing	-0.15	0.51	-1.66	0.49	0.06	0.67
Electricity, Gas, and Water	1.13	0.24	-6.26	0.76	-1.05	3.42
Construction	-3.46	0.59	-0.68	0.41	-2.68	-1.97
Trade, Restaurants, and Hotels	2.09	0.50	2.71	0.50	0.90	0.28
Transport and Storage	5.30	0.52	-0.65	0.48	0.68	5.32
Communicatons	7.96	0.44	-2.09	0.56	1.63	7.95
Finance, Insurance, Real Estate, and Business Services	0.78	0.37	2.43	0.63	4.39	-2.89
Community, Social, and Personal Services	4.68	0.46	3.40	0.54	4.37	0.76

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