Singapore's Growth Sectors : The Manufacturing and Services Sectors

Renuka Mahadevan

A thesis submitted for the degree of Doctor of Philosophy at The Australian National University

May 1998

Dedicated in loving memory to my late grandfather,

Mr.T.Chellappah,

Who has been and will always be the source of my inspiration.

Declaration

This dissertation was written while I was studying at the Department of Economics, Research School of Pacific and Asian Studies at the Australian National University. The opinions expressed are my own, unless otherwise indicated.

Renuka Mahadevan
May 1998

Acknowledgments

In completing this dissertation I have incurred debts both intellectual and otherwise to so many people that these acknowledgments are bound to be incomplete.

First, I am greatly indebted to my supervisor, a specialist in the study of production frontiers, Dr. K.P.Kalirajan, who has patiently guided me and provided excellent insight and advice in academic research. I am very grateful that he was concerned and supportive in my personal matters as well. Working and interacting with him has taught me a great deal and has contributed significantly to my professional and personal development.

I also wish to thank Dr. Satish Chand, my academic advisor, and a good friend, who always made time for me. My other academic advisor, Dr. Cheah Hock Beng, also kindly commented on my drafts whenever possible. Dr. Cezary Kapuscinski was particularly helpful in the applied econometrics work in this thesis. I also greatly appreciate Dr. Ric Shand's efforts in his meticulous manner of correcting the drafts which served to greatly improve the quality of the thesis.

I am also thankful for the discussions, both academic and otherwise, I had with my fellow Ph.D. friends, KK Tang, Amy Liu and Hsiao-Chuan. They were also very supportive and patiently put up with me during my days of depression. These people made my life as a Ph.D. student less painful. Whenever possible, Wen-Thuen, Xiao-Lu, Elliot Gilbert and Ross Worthington were also supportive. Moral support from my dear and close friends afar, Hau Wah, Bee Peng, Jenny and Radha Krishnan also deserve mention. In particular, my deep gratitude goes to Pang Chai Ping who was extremely willing to help me, and did so efficiently, whenever I needed to check on data in Singapore.

I wish to thank Professor Warwick Mckibbin, the head of the Economics Division, Research School of Pacific and Asian Studies of the Australian National University, as well as my supervisor, Dr. Kali Kalirajan, for providing me with financial support. The helpful and friendly academic and administrative staff of the department made it possible for me to work in a very pleasant environment. I would also like to thank the

Economics Department of the National University of Singapore for having me as a visiting scholar during my fieldwork. I am especially grateful to my mentor and ex-teacher at the National University of Singapore, Associate Professor G.Shantakumar, who was very encouraging and supportive throughout my thesis. He showed me love and concern, and advised me in my pursuits in life.

I must also acknowledge the very special person in my life, my aunt, Navarani, who is responsible in many countless ways for what I have achieved so far, for without her, my life would have been very unfulfilling. I am also much obliged to my dear parents for their kind support. However, he who would be most proud at this occasion would be my beloved grandfather, who instilled in me at a very young age, the value of education. In his blessed memory, I continue to draw inspiration from the very successful and fruitful life he led.

Last, but most importantly, I wish to thank God, who has given me strength and seen me through difficult times and made it possible for me to complete this dissertation.

Abstract

Despite its miraculous economic growth, Singapore has been singled out as having low or insignificant total factor productivity (TFP) growth. An interesting question is: has Singapore lost its productivity growth? If so, when and in which sector? If not, what are the factors responsible for such a question? This thesis compares the structure and performance of the manufacturing and services sectors in order to address the issue of each sector's contribution to TFP growth.

The analysis is undertaken in two steps. First, the study focuses on measures of partial productive performance, in particular labour productivity and employment generation of both sectors. The issue of the hollowing out effect on manufacturing output and employment which was evidenced in developed countries, such as the OECD, are also investigated for Singapore. With employment determinants, the exercise is undertaken using two-stage least square estimation of various factors, based on a theoretical framework for a labour demand model.

Second, the comparative performance of the growth sectors is examined in terms of total factor productivity measures. TFP growth is first measured by the conventional growth accounting method to compare the results with existing studies. TFP growth is then estimated using the technique of the stochastic production frontier method. The latter method is an improvement over the standard method of calculating TFP growth from production functions, in that, it decomposes output growth into changes in technical efficiency in addition to technological progress and input growth. Technical efficiency refers to movements towards the technology frontier; while technological progress is defined as the shifting of the technology frontier over time, stemming from Romer's (1986) endogenous growth models.

Unlike the conventional approach, the stochastic frontier approach does not calculate TFP growth as a residual. Thus, it is a pure measure which does not include measurement errors, technical efficiency changes and other forms of X-inefficiency. Furthermore, the stochastic frontier approach relaxes the important assumption of the conventional approach that all firms are efficient and operate on the production frontier. Hence, TFP growth from the stochastic frontier estimation could emanate not just from technological progress (as will be the case under the growth accounting method) but

also from improvements in technical efficiency. This allows for the design of more accurate policy measures to improve TFP growth, depending on the source of this growth. The model used is also an improvement over existing models because the rigid assumption that the rate of technical change over time is constant among industries is discarded.

It was found that TFP growth of the manufacturing and services sectors has remained low, at less than 1% over various time periods within 1975-1994. Both the conventional and stochastic frontier approaches showed that the manufacturing sector's TFP growth has declined in the late 80s and was negative in the early 90s. For the services sector, both approaches also showed a decline in TFP but with a positive growth rate.

Using the stochastic frontier approach, an important policy conclusion emerges. Although Singapore experiences technological progress, it is not reaping the full potential of the chosen technologies. This does not mean that Singapore should not go for further technological progress. What is crucial is Singapore should improve its technological progress and at the same time improve its realisation of the potential of their technologies. The former can be achieved by attracting multinational companies (MNCs) and increasing research and development (R&D) expenditure and the latter can be achieved by improving the comprehension of the chosen technologies to workers through careful selection of MNCs to provide training to workers, and greater efforts to diffuse knowledge among local firms.

Regarding the use of resources and technology, this study also shows that industries dominated by foreign firms were not more efficient than those dominated by local firms. However, improvements in technical efficiency are ensured for both the manufacturing and services sectors if increases in capital intensity are accompanied by increases in the quantity and quality of labour. Manufacturing industries operating with small number of firms allowed for economies of scale and hence higher technical efficiency; while for the service industries, economies of scale were not a significant feature for efficiency gains.

Contents

Chapter 3

Chapter 4

Chapter 5

Chapter 6

Chapter 7

List of Tables

List of Figures

Chapter 1

Introduction

1.1 Introduction

Singapore obtained full internal self-rule from Britain in 1959 and the period of 1959-65 corresponds to Singapore's self-government within Malaysia. In August 1965, when Singapore separated from the Federation of Malaya to become a fully independent country, the only viable economic strategy was to shift the industrialisation policy from import-substitution (which was undertaken with the aim of serving the Malaysian market) to an outward-looking strategy. However, there was a major problem with unemployment, which was further aggravated by the withdrawal of British troops in July 1967, to ease its military presence in the region.

Given the absence of a large internal market, its heterogeneities and diversities in ethnicity, religion and language, Singapore went on to capitalise on its strategic economic location. It embarked on developing labour intensive manufacturing activities like textile and garment, food and beverage, printing and publishing, and metal and engineering industries. And not having the resources, Singapore actively started to attract foreign direct investment (FDI) in these activities by granting various fiscal incentives and rapidly reducing its import trade barriers. Because of its small domestic market, these FDI activities were inevitably export-oriented. The programme was successful and the unemployment rate was reduced to about 4 % by 1974 from between 10% and 15 % during 1959-65.

In the late 1970s, given the tight labour market conditions and the desire to seek high value added output, Singapore embarked on capital intensive manufacturing activities with the help of the government's high wage policy and provision of attractive incentives for firms to automate. After the recession in 1985/86, Singapore further encouraged the move to more capital intensive manufacturing operations activities and the 1990s have seen yet another structural shift to high technology intensive manufacturing operations and the push to regionalise (i.e. relocate abroad due to loss of comparative advantage in labour intensive activities).

With the absence of an agricultural sector in Singapore's early development, not surprisingly, the services sector was also significant in its economic development. As early as the 1960s, having started out as a port city, port services were important for Singapore. In the early 1970s, commerce and transport services were developed to support tourism as well as the export-oriented manufacturing industries. Financial and business services too increased as trade expanded and by the mid 1980s, the services sector had grown significantly enough to be identified as another engine of growth. In fact, it has been selected to be the lead sector in the 1990s.[1]

Singapore is a city-state with a resident population of about 3.2 million. Within the past two decades, Singapore has transformed itself and has achieved consistent high economic growth and joined the ranks of 3 others (Taiwan, Hong Kong and South Korea) to be known as a newly industrialised economy (NIE) and in 1993, was one of the 'East Asian miracle' economies. The average real GDP growth rate for the decade of the 70s was 9% and for the 80s, it was 7.3%. After double digit growth rates for 1993 and 1994, Singapore managed to grow at 8% and 7% in 1995 and 1996 respectively. Singapore has also enjoyed low inflation rates and since 1988 has had a positive current account balance. If anything, Singapore is the first NIE to be upgraded to the status of an 'advanced developing nation' by the OECD at the end of 1995 and had a per capita income of US$ 23 924 in 1996.

While Singapore has sustained its high growth so far, is it possible to continue sustaining the growth momentum in the 21st century? The answer to this question depends on what type of development strategy Singapore embarks on. Various targets have also been set out - the aim now is to catch up with, on a moving target basis, the GNP per capita of the Netherlands by 2020 or the US by 2030 and the total factor

[1] See The Straits Times (Singapore) 13 February 1988.

productivity (TFP)[2] growth target is now set to reach at least 2% annually in order to sustain (labour) productivity growth of 4% and GDP growth of 7%.[3]

In the past, Singapore has benefited from its open trade regime but its average annual growth rate of manufactured exports has declined from 22% over 1974-82 to 18.4% over 1986-90 and to about 12% in the early 1990s. With an increasing awareness of the processes of globalisation in many countries, it would be extremely difficult to depend on merchandise trade as the sole engine of growth, due to the slow erosion of earlier comparative advantage. Further, there may be limits to the extent of expansion in the manufacturing sector due to competition for FDI from the reforming countries. Competitiveness is essential for Singapore's economic growth and according to Baumol (et al., 1989) and Porter (1990), the most useful definition of competitiveness is one which is synonymous with productivity.

Although Singapore has enjoyed impressive levels of economic growth, Porter (1990) and Young (1992, 1994, 1995) claim that economic growth in the 70s and 80s has been only factor-driven. For instance, in the manufacturing sector, Tsao (1985) has shown that the rapidly growing output in the 70s was merely due to growth in factor inputs and there has been negligible TFP growth during this period. Young (1992) has convincingly argued that Singapore has, on average, experienced slightly negative TFP growth for the period 1970-1990. Thus, although an 'economic miracle', using Young's (1994) evidence, Krugman (1994) singled out Singapore as the only high-performing Asian economy to lack the ability to keep pace with the world's shifting technological frontier.[4] The consensus among numerous TFP studies on Singapore is that output growth has been contributed mainly by accumulation of factor inputs rather than TFP growth. But it is the latter that would enable growth to be sustained in the long-run.

Lim (1986:5) commented that, "if a country can raise its standard of living so spectacularly with a very low TFP growth, does it then matter whether TFP growth is

---

[2]TFP growth measures changes in technical progress, improvements in organisational structure and worker-management relations as well as the diffusion of technology across firms.

[3] See The Straits Times (Singapore) 2 Nov 1995.

[4] See World Bank (1993:57). The high-performing Asian economies include Japan, Hong Kong, South Korea, Taiwan, Singapore, Indonesia, Malaysia and Thailand.

low?"[5] Peebles and Wilson (1996: 203) replied that an important point is missed in this comment which only looks at the benefits resulting from high growth and ignores the cost of achieving such growth. Such a cost in the form of a lack of gains from learning-by-doing has been identified in some discussions but this has yet to be empirically proven or quantified.

Thus, Singapore's long term economic growth is of great concern. Is its TFP growth mainly factor-driven for both the manufacturing and services sectors? Does Singapore incur a high cost for achieving high growth? If so, what is the cost and how can it be measured?

1.2 Issues

To the extent that the Asia-Pacific region is committed to maintaining itself as one of the fastest growing regions in the world, Singapore cannot afford to slow down its growth process which is dependent on the performance of its manufacturing and services sectors.

In the light of the recent comments on the sources of Singapore's output growth (discussed above), the important issues that arise are as follows:

1) What are the structural and performance characteristics of the manufacturing and services sectors?

2) What are the similarities and dissimilarities of performance measures between the sectors?

3) What are the sources of output growth in both sectors?

4) Are there any differences in sources of growth between these sectors?

5) Do both sectors apply technology efficiently?

6) If not, what are the factors that determine the efficient use of technology at industry level in both sectors? Are the factors different for the sectors?

---

[5] Peebles and Wilson (1996:204) report that Singapore's chosen role model, Switzerland, in Young's (1994) study registered zero TFP growth and being the richest country in the world, this resurrects Lim's question.

7) What policy implications emerge from the economic performance of the manufacturing and services sectors?

The central focus of this thesis is TFP growth because it has been identified as an important way to secure economic growth beyond the limits of population growth and capital accumulation. A particular question that becomes imperative is, what is the services sector's contribution in terms of TFP growth, in light of the growing argument (Tsao 1982, Young 1992, Krugman 1994, Kim and Lau 1994, Leung 1997) that the Singapore economy suffers from insignificant TFP growth in the aggregate economy and the manufacturing sector?

In analysing the above issues, the partial measure of productive performance (labour productivity) and employment generation in manufacturing and services are given particular attention. Performance is also examined in terms of total factor productivity measures. First, the conventional growth accounting method with a new set of data (panel data) is used to compare the results with the existing studies. Next, using the stochastic production frontier method, TFP growth is estimated by relaxing the restrictive assumptions of the conventional growth accounting method enabling a comparison of results. The former method is an improvement over the commonly used latter method, because it decomposes output growth into not just technological progress (TP) and input growth, but also changes in technical efficiency. Technical efficiency (TE) is defined as the ability and willingness of the economic decision making unit to operate on the technology frontier. Though the concept of TE dates back to Farrell (1957), Romer's more recent (1986) endogenous growth models draw on this concept. Thus, the use of the stochastic frontier model allows further investigation of the determinants of the components of TFP growth, thereby providing some important policy implications.

This study is the first attempt to use the frontier methodology to investigate the TFP growth of the services sector in Singapore. Also, with manufacturing, though previous studies of Tay (1992), Cao (1992), and Wong and Tok (1994) have used the stochastic frontier model, an improved version of their model is developed in this study.

1.3 Data

For partial productivity analysis, data on output (measured as GDP in 1985 market prices) as well as labour employed and weekly hours worked were obtained from the *Singapore Yearbook of Statistics.*

For the analysis of employment determinants of the manufacturing sector, data were mainly obtained from the *Report on the Census of Industrial Production,* the International Monetary Fund's *International Financial Statistics* and the *Singapore Yearbook of Statistics.*

For the employment determinants on services, data were from the *Singapore Yearbook of Statistics,* the *Report on the Survey of Services* (for various years), *The Service Sector* 1990-93 and *Census of Services 1994.*

Lastly, for TFP growth estimation and the determinants of technical efficiency, in addition to the above mentioned sources, separate *Economics Survey Series* published on Wholesale and Retail, Transport and Communication, Financial and Business Services as well as data on workers employed by occupational groups and average weekly hours worked by these occupational categories were obtained from the *Singapore Yearbook of Labour Statistics* and the *Report on the Labour Force Survey of Singapore* (various issues).

1.4 Organisation of Thesis

The thesis is structured as follows:

Chapter 2 gives an overview of Singapore's manufacturing and services sectors. First, it highlights some definitional issues of services and measurement problems of service output in the Singapore context. Second, the overall performance of the growth sectors in terms of output and employment is discussed. Third, evidence of a bidirectional causality relationship between the growth of the manufacturing and services sectors is established. Finally, the underlying inter-industry linkages between the two sectors are discussed using input-output tables.

Chapter 3 sheds light on the partial measure of productivity performance (labour productivity) of the aggregated and disaggregated manufacturing and services sectors. The evidence of lagging services sector labour productivity growth, relative to the manufacturing sector, leads to an investigation this has on the expansion of services sector employment; followed by a discussion of the issue of hollowing out of manufacturing employment.

Chapter 4 analyses the determinants of employment growth in both sectors. First, a theoretical framework of a labour demand model is set out. Second, empirical evidence and a discussion on the factors that affect the manufacturing sector is reviewed. This is followed by the analysis of the Singapore case, assessing the foreign worker policy in the manufacturing sector. Next, a similar analysis of the services sector employment growth is undertaken and finally, the sustainability of employment in these growth sectors is briefly discussed.

Chapter 5 examines the total factor productivity measure, providing an overview of some of the theories and methodologies underlying TFP studies. Limitations of the various approaches are highlighted, leading to the choice of the estimation for this study, the stochastic frontier approach. Then an improved theoretical framework of the model for use in this study is developed, along with data sources and the construction of variables for use in the estimation.

Chapter 6 highlights the importance of TFP for Singapore and reviews critically, the often-cited cross-country and inter-temporal studies related to this measure concerning Singapore.

Chapter 7 provides a comparative analysis of the empirical estimates of TFP growth for the manufacturing sector using the conventional growth accounting and the stochastic frontier approaches with new data (panel data of 28 industries from 1975-1994).

Chapter 8 gives a comparative analysis of the services sector using the growth accounting and stochastic frontier approaches with new data (panel data of 17 industries from 1975-1994).

Chapter 9 takes up the finding from the above two chapters where the stochastic frontier approach identified technical inefficiency as a cause for low TFP growth for both the manufacturing and services sectors. This chapter examines the technical efficiency levels of the growth sectors and then using an analytical model identifies the determinants of technical efficiency in these sectors.

Chapter 10 summarises the major findings and draws conclusions from the quantitative and qualitative analyses of the study. It outlines the limitations of the study and suggestions for further research.

Chapter 2

The Growth Sectors in Singapore

2.1 Introduction

Until the late 80s, Singapore's growth was mainly dependent on the manufacturing sector and its exports.[1] However, after the 1984/85 recession, the services sector was identified as an equally important engine of growth.[2] Thus, both sectors are identified as important elements for economic growth in Singapore. This chapter sets out to provide an overview of the performance of these sectors to demonstrate their role in the economy. As the definition of services and measurement of service output has been, and still is, a contentious area for research, a brief review is first given to explain 'services' in the Singapore context. Then the output and employment performances of the growth sectors are evaluated and, using empirical evidence, the interdependence between the sectors is highlighted.

2.2 Some Issues in Services

Levitan (1985:30) states that, to some extent, the determination of what is a service and what is not is a statistical artifact. This is particularly pronounced with the development of computer technology that can be used both for manufacturing work and for the provision of services. The term 'services' is often used loosely to mean an intangible good, or defined as all economic activities that are not agriculture, mining or manufacturing. There is no universally acceptable definition or classification of 'services' or consensus as to what constitutes 'services' yet, and there are almost as many answers as there are researchers that have written on the subject.[3]

Definition of Services

Hill's definition (1977:318) of a 'service' stems from an industrial organisation view:

---

[1]The correlation between GDP growth rate and the growth rate of manufactured exports was 0.67 between 1971-87 but this correlation decreased to 0.56 since the 90s.

[2] See Report on the Economic Committee (1986).

[3] See Marshall (et al. 1988), Singlemann (1978), Fuchs (1968), Stanback (1979).

"A service may be defined as a change in the condition of a person, or of a good belonging to some economic unit, which is brought about as the result of the activity of some other economic unit, with the prior agreement of the former person or economic unit."

Thus, he stresses that service transactions take place between separate economic organisations and that they add value to goods belonging to other people or to those people themselves. Hirsch (1989) on the other hand, focuses on the "simultaneity factor" which derives from the interaction between supplier and user of services. He grades services according to the proportion of their total costs incurred by the producer and user during their interaction. He also distinguishes between services and tangible and intangible goods. For example, he argues that information itself is an intangible good that can be stored but the transmission of information is a service. But intangible goods must be accompanied by services before they can be used.

Dowrie (1970:227) argues in favour of a definition based on the tangibility of an industry's output. But not all nontangibles are services. For instance, a movie on a cassette if purchased is a good but it is a service when rented. This example draws attention to the analytical significance of the distinction between a good and a service.

Stern and Hoekman (1988) characterise services as non storable because service producers do not produce output that is tangible. This inability to store output means that the production and consumption of services take place simultaneously. Another view is that the capacity to provide a service is however storable and this has implications for the nature of scale economies.

But on the grounds of a need for physical proximity of producer and receiver, Bhagwati (1984:139) has pointed out that the electronic transfer of information and some forms of entertainment is enabling the separation of provider and receiver to develop rapidly.

Thus, definitions of services have been varied to suit the context in which they are discussed. In this study, in addition to the general characteristics of intangibility and non storability, Hill's definition of 'services' is adopted.[4]

The Classification of Services

There are many ways of subdividing the divergent range of service activities. Most approaches consider services as those products defined in the four major divisions 6, 7, 8 and 9 of the International Standard Industrial Classification (ISIC) outlined as follows:

(6) wholesale and retail trades, hotels and restaurants;
(7) transport, storage and communications;
(8) finance, insurance, real estate and business services;
(9) community, social and personal services.

There is sometimes a degree of haziness regarding the classification of transport and communications, because which certain authors compare these services to the production of goods. Much more exceptional is Colin Clark (1957), who regards construction, including repair activities, as services. There are still others who classify services as production, consumption or function based.[5] For example, Singer (1971) proposed a consumption-based classification where he distinguished between consumption by industries and institutions, and consumption by the public and individuals. But under this method, the same service activity, for example transportation, could fall simultaneously into all three categories.

The divergent services sector is also often broadly divided into consumer and producer services. The former type of services is related to final demand and the latter to intermediate demand. Daniels (1993:4) rightfully argues that such groups are not mutually exclusive as some services like banking and financial can fulfil both final and intermediate demand. He suggests that a third group of 'mixed' services be created or a service activity should be grouped according to which kind of output (using input-output tables) predominates. Allen (1988:18), too, claims that some services are neither producer nor consumer services but are circulation services as they are services produced within the process of circulation and for circulation.

[4] Hill's definition has been quite successful in the literature and is presented as the definition of services in the 'New Palgrave of Economics'.
[5] See Riddle (1985:14) for details.

Browning and Singlemann (1975) have identified 4 main types of services as:

Distributive Services: Transportation, Communication, Commerce

Producer Services: Finance, Professional

Social Services: Health, Education, Defence

Personal Services: Domestic, Hotels, Restaurants, Leisure

Baumol categorises the services sector according to its degree of technological 'progressiveness' in the following manner (with some examples)[6] :

Stagnant Personal Services : Healthcare, Haircuts, Teaching and Live Performances

Progressive Impersonal Services : Telecommunications

Asymptotically Stagnant Impersonal Services : Broadcasting, Computing, R&D

However, in this study, the classification used is found in the Singapore Standard Industrial Classification (SSIC) which follows that of the ISIC very closely. It is generally in line with Hill's definition on services. Thus, services would be taken to constitute

(6) Commerce (Wholesale, Retail Trade, Restaurants and Hotels)

(7) Transportation (Air, Land and Water transport), Storage (Warehousing) & Communication (Postal and Telecommunication)

(8) Real Estate, Financial (Banking, Insurance), & Business Services (Professional and Technical Services)

(9) Other services (Community, Social and Personal Services)

As this thesis does not dwell on services trade, a review of the terminology in the area of international transactions in services is not presented here.

Measuring Services Output[7]

Another question still outstanding is that of the measurement of the volume of service activities which is less readily identifiable and quantifiable. This is partly due to data problems but more importantly it is a conceptual problem. Another problem is due to the constant changes in the number and type of services available. Petit (1986:12) explains that the use of volume indicators, obtained by comparing production at

---

[6] For more details on his classification, see Inman (ed.1985:302-303).

[7] This section draws heavily on existing literature. See Mark (1982), Petit (1986), Leveson (1986) and Griliches (ed. 1992).

constant prices, is only a partial solution to the problem, since it requires product stability and an identification of unit prices which are largely illusory. As a result, it becomes necessary to work on ad-hoc hypotheses.[8]

In a rapidly changing environment, where new products are constantly introduced, present methods are incapable of taking product benefits into account. For instance, faster transport, more effective communication systems and an increased array of financial services are not considered in terms of quality changes, which leads to an underestimation of real output in services. Besides, changes in product prices are considered after the products have established a place in the market, but the effective decline in the price of accomplishing a task made possible by the new product's use is ignored.

In the case of an industry producing a number of heterogeneous services, the various units in which output is measured must be expressed in some common basis for aggregation. For example, the output of franchised new-car dealerships should be a combination of the number of cars sold and the repair activities of the dealers, with appropriate weighting, but such an effort is not practical.

The measurement of service outcomes is especially intractable. For instance, there is very little information on the contribution of services to health, learning or utility. Health outcomes from developments are not included in the output of the health care industry, even when changes in health status are clearly the result of resources devoted to and actions taken by that industry. As with government services, the difficult problem of valuation has led to a largely underestimated measure of output in these areas by the common use of the cost of inputs that go into the production of such services. There is also substantial uncertainty in measuring 'true' output in other services like legal or business consulting, administrative services, advertising, maintenance and engineering services.[9] Griliches (1994) emphasises that economic activity has shifted towards the 'hard-to-measure' sector which includes the wholesale and retail trade, financial and

---

[8] See Kenderick (1982), Kutscher and Mark (1983) for use of such hypotheses to analyse US data on services.

[9] See Hill (1971:1977), Eurostat (1981) and De Bandt (1987) for elaboration.

business services, government and personal, social and community services, thus possibly increasing the seriousness of measurement difficulties. With wholesale and retail trade, and financial intermediations, gross output/sales are often measured by gross margins[10] on the assumption that gross margins are a constant percentage of sales. Although Leveson (1986:82) says that studies have shown stability in gross margins over time, he claims that improvements in efficiency and changes in the demand for services could shift margins dramatically. Also, modest differences in margins between periods can imply rather substantial variations in annual rates of output growth. Even more important is the idea that constant margins may reflect opposing trends.[11] If the sector is competitive, then the margin should reflect the opportunity cost of 'owned' factors of production in use. But it is likely that this sector is imperfectly competitive such that the margins reflect rent accruing to operators.

Giersch (1988:52) sums up the general feeling that different definitions of services give rise to different measures of services output and there is a need to unify the various studies in order to treat services adequately. The most common service output measure is that using the 'double deflation' method which is the constant price output estimates. This involves revaluing, separately, the outputs and inputs of each industry at base year prices and then taking the difference as the constant price estimate of value added. But it does not take into account changes in quality of those inputs used.

The volume measures in terms of GDP or employment can vary because of differences in capital and labour intensities in service activities even within a certain group of activities or within the same service activity over time. Petit (1986:15) suggests that a relative homogeneity of productive combinations of labour and capital in service activities can alleviate the problem, but even a clear distinction between the capital and labour intensive services does not exist and there is instead a great diversity of productive combinations within service activities fulfilling similar functions.

In this study, the following measures of service output are adopted.

---

[10] Margin is the difference between the value of the goods sold by traders and the value of the goods bought for resale.

[11] Leveson (1986:82) provides the following example. While increases in efficiency of providing the service could reduce the spread between retail sales and cost of inputs, increases in the demand for services could provide an offsetting increase in spread, thereby leading to constant margins.

Measuring Service Output In Singapore[12]

The 'double deflation' method, although ideal, has not been adopted as it would require voluminous and detailed data. Instead, the 'single deflation' method is used. This involves deflating current estimates of value added or net output by appropriate price indices. The underlying assumption in this method is that prices of output and inputs change by the same proportion and in the same direction. This of course is not true in many cases. Hence actual physical quantities of output or relevant indicators of real output are used whenever they are available. Bailey and Gordon (1988:386) claim that even using base-period price is still flawed because relative prices are likely to have changed and this overweights the growth of service commodities in years following the base year and underweights them in years preceding the base year.[13]

Output of the components of commerce are valued in different ways. For entrepot trade, the value added at current prices is obtained by taking the difference between the estimated gross margin on re-exports less intermediate costs such as transport and rental costs. The gross margin on re-exports is the difference between the value of re-exports at f.o.b. and the corresponding imports at c.i.f. Then the current-price series is deflated by the relevant subgroup indices of the import price index. For domestic trade, it is similar but the gross mark-ups on retained imports and production are used. Deflation is then undertaken using appropriate price indices. For hotels and restaurants, value added is operating surplus, deflated using suitable subgroup indices of the CPI and hotel-room days occupied.

For transport and communications, volume indicators like seaborne cargo handled, passenger-kilometres and tonnage-kilometres of airborne cargo, volume of postal articled handled, number of international telex and telephone calls transmitted, number of bus tickets sold, number of registered taxis and number of boats licensed are used to estimate the value added at constant prices.

For financial services, value added is the sum of actual and imputed bank service charges (the latter is an estimate of net interest income which is the excess of interest income received from loans and advances over interest paid) less purchases of goods

[12] See Singapore National Accounts 1987.

[13] However, the use of shifting base years in Singapore does increase the accuracy of the relative price structure used to aggregate the output and price index, according to Gordon (1996).

and services for intermediate consumption and the overall GDP deflator is used for converting current prices to constant prices.[14]

For insurance companies, value added is the excess of premium income over claims paid and less any intermediate expenses for general insurance and for life insurance, net additions to actuarial reserves are also included. Where appropriate, volume indicators or premium rates are used for deflation.

For business services, value added is obtained from detailed income and expenditure accounts and constant price estimates are obtained by the extrapolation method using employment data.

For real estate activities, like real estate agents, value added is the value of properties transacted and deflated by an index of property prices. For real estate developers, value added is estimated on the volume of work done on residential buildings. With ownership of dwellings, value added is obtained from actual rentals and imputed owner-occupied dwellings, less the estimated cost of maintenance and repairs.

For public administration and defence, value added is taken as the cost of providing such services and is essentially wages and salaries paid to government employees less wage increases due to increased rates of pay. For community, social and personal services, it is calculated separately for the public and the private sector. The same method as above is used for the public sector.[15] As for the private sector, employment and gross earnings are used and deflators are supplemented from employment data, professional bodies and other indicators.

Improvements Required in Service Output Measure

First, in order to perform double deflation, there must be sufficient data on outputs and inputs and their appropriate deflators. This would enable the use of gross product originating estimates. Furthermore, the price of various service components are not available, let alone the existence of a single service price measure.

Second, census or survey data on purchase of producer services must be carried out and

[14] See Fixler and Zieschang (1992) for a discussion on the output measure of banks.
[15] See Murray (1992) for a discussion on measurement of public-sector output.

there is also a need to differentiate between imported and local producers services, as this has implications for relative factor prices. Currently, only input-output tables, which are published every five years, contain some of such information.

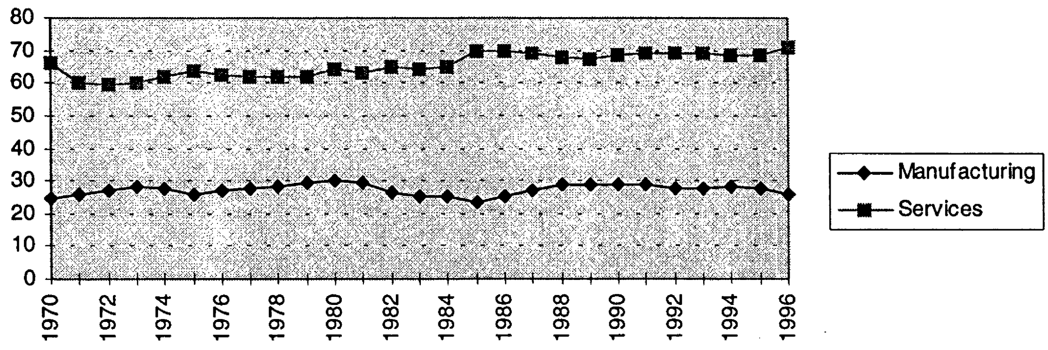
Third, Griliches (1992:19) suggests that the household sector be included in the national income accounts as some of the primary effect of technical change is not in terms of the items themselves, but in what they accomplish when used in the household sector and how they substitute for consumer time and other purchased inputs.

2.3 Performance of the Manufacturing and Services Sectors

Output Trends

In the absence of an agricultural sector, the services sector has thrived alongside the manufacturing sector since the early 1970s. There have been no major changes in the GDP shares of these sectors over time, as shown in Figure 2.1.

Figure 2.1 : GDP Share by Sector (Percent)



Source: Singapore Yearbook of Statistics, various issues

In the 1970s, when Singapore was in its initial stage of development, to solve the unemployment problem, FDI was encouraged in the labour intensive manufacturing sectors like the textile and garment industries, food and beverage, printing and publishing, and metal and engineering industries. The most prominent industry in the manufacturing sector in the 1970s was petroleum, which was established by virtue of locational advantages in serving the surrounding region endowed with oil reserves.

In the early 1980s, the manufacturing share decreased slightly. This could be due to the structural changes that were taking place, particularly in the manufacturing sector where the high-wage policy of 1979-81 was implemented by the government to gear the manufacturing sector towards capital intensive operations. The chemical process, metal engineering and machinery, heavy engineering, and electrical and electronics industries were then selected for priority development.[16]

The Economic Committee Report (1986:160) then decided that "a strong and viable manufacturing sector is important and services cannot plausibly expand sufficiently to replace this." Besides focusing on the electronics industry, other new growth industries in manufacturing were identified in biotechnology, pharmaceutical and medical products. The aerospace industry today is a key aviation hub and service centre. Singapore is also a base for aircraft repair and maintenance, component manufacturing, product design and development, and regional sales and supporting activities.

The electronics sector, however, has been the key manufacturing sector since the late 70s. In the 80s, the items produced by the electronics sector included computer peripherals, integrated circuits, semiconductor devices, printed circuit boards, audio and video equipment. In the 1990s, the electronics industry was into design and wafer fabrication, which is close to the advanced end of the production. Singapore today produces almost half of the world's hard-disk drives and 90% of all sound cards. High-technology exports (covering bio-technology/life science, opto-electronics, flexible manufactures, information and communication, electronics, advanced materials and, aerospace) grew 16% each year between 1990 and 1995 and accounted for the largest share of all such goods exported by the four Asian tigers between 1990 and 1995.[17] Thus, although the GDP share of manufacturing has not changed much except for the fall in 1996, the composition of the manufacturing sector has changed significantly.

---

[16] See Lim (1984:41).

[17] See Southeast Asia Business Times (Singapore) 11 June 1997.

The share of the services sector seems to have gradually increased. After the 1985/86 recession, the share has increased due to the boost given by the government through incentives. The 'supply-pull' elements were also well in place and this referred to the growing need for producer services like distribution and infrastructure services which were key ingredients for the manufacturing activities. At the same time, Singapore was gearing up towards being a major financial centre and business hub of the region.

Table 2.1 shows the breakdown of various service industries' GDP within the services sector.

Table 2.1 : Breakdown of Services Sector's GDP (Percent)

Service Industry	1970	1976	1982	1988	1992	1996
Commerce	36.0	35.6	30.0	26.2	26.1	25.7
Transport & Communication	11.9	17.4	11.3	20.0	20.1	20.8
Financial & Business Services	27.7	25.4	32.6	36.8	37.8	38.7
Other Services	24.4	21.5	18.4	17.0	15.4	14.7

Note: Figures may not add up to 100 due to rounding up.

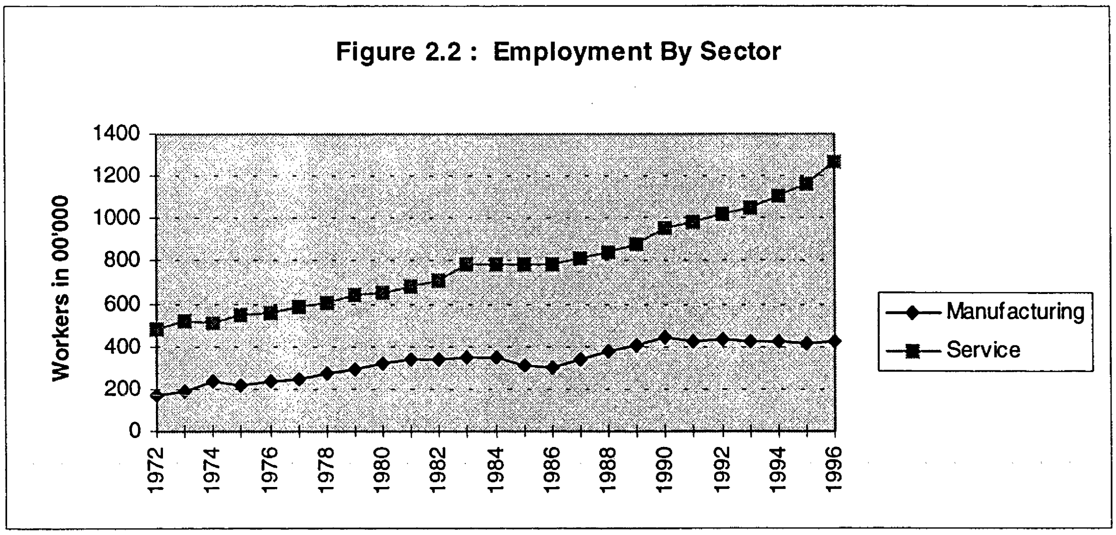
Source: Singapore Yearbook of Statistics, various years

In the 1970s, the commerce sector's share of GDP increased due to strong demand for entrepot trade but this role has diminished over time and tourism has now become a larger component of commerce. But the lead sector is clearly the financial and business services sector which grew, in part, to the timely promotional efforts of the government in making Singapore a major financial centre and a total business hub of the region. This is expected to continue as neighbouring countries deregulate their financial sectors and the growing information technology industry becomes increasingly able to support the growth of this sector.

The transport and communication sector's share increased in the 1970s due to large investments in infrastructure designed to support and attract the large FDI that was coming in. Since the 80s, this share has stabilised. The 'other services' component, which comprises community, personal and social services, consistently declined in its share as other sectors have taken on increasing importance.

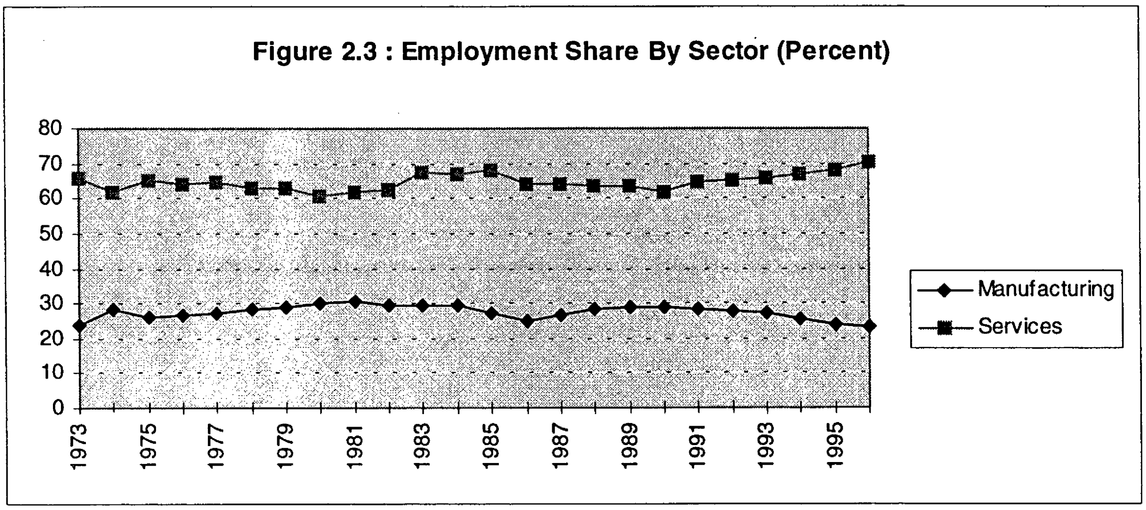
Employment Trends

The service sector has always had more workers than the manufacturing sector (Figure 2.2) and the services sector employment is increasing while the manufacturing sector has stabilised after 1990.



Source: Singapore Yearbook of Statistics, various years

The employment shares of these sectors (Figure 2.3) show that services have consistently absorbed two-thirds of the total employment, rising to around 70% in the 1990s.



Source: Singapore Yearbook of Statistics, various years

The manufacturing sector's employment share increased in the 70s, because of the FDI in labour intensive manufacturing, strongly encouraged by the government. The electronics sector has always been the largest employer in the manufacturing sector since the late 70s. In the 80s, the two oil price shocks, as well as a wage correction policy to encourage the shift to capital intensive manufacturing, reduced the employment share of the manufacturing sector but the share picked up in the late 80s before decreasing in the 90s, by which time, the services sector had been identified as an engine of growth, resulting in knowledge and information intensive service industries and increased demand for financial and business services, which have caused service employment to increase. In the 90s, not only was the Singapore port the world's largest port in terms of shipping tonnage, it was also the second busiest container port.[18] In 1995, Singapore was the top bunkering port and the 10th biggest tourism earner in the world.[19] The growth of the manufacturing sector in the past two decades has also created the need for producer services. The expanding Asia-Pacific region will also increase the demand for Singapore's financial and business services.

Table 2.2 enables a closer look at employment shares of the various components of the services sector .

Table 2.2 : Employment by Industry in the Economy (Percent)

Service Industry	1970	1976	1982	1988	1992	1996
Commerce	23.5	23.1	22.2	22.9	22.6	22.5
Transport & Communication	12.1	11.7	11.4	9.7	10.0	10.8
Financial & Business Services	3.5	6.5	7.9	9.6	10.9	13.6
Other Services	27.2	24.5	20.6	21.3	21.5	20.4

Note: [1] Data prior to this refers to persons aged 10 years and over. After 1984, figures refer to persons aged 15 years and over.
Figures do not add up due to 100 as the other sectors on the economy have been excluded.

Source: Singapore Yearbook of Statistics, various years

The commerce sector's employment share declined until the late 80s and picked up slightly after that. The extensive use of information technology (IT) in commerce and

[18] See Straits Weekly Edition (Singapore) 30 March 96.
[19] See Straits Weekly Edition (Singapore) 23 March 96.

the emphasis on promoting tourism since the late 80s may have caused this increase in employment. The move to 'electronic commerce'[20] can also be expected to affect employment in this sector. The transport and communication sector's employment share also has a similar pattern of employment to the commerce sector. The financial and business services sector's share, on the other hand, has consistently increased over the entire period in line with its increasing GDP share, due to its operations as a major financial centre and business hub of the region.

Table 2.3 investigates the resilience of the services sector during recession times by studying the GDP and employment trends of services and manufacturing.

Table 2.3 : GDP and Employment Growth Rates of the Growth Sectors

	GDP Growth Rate		Employment Growth Rate	
	Services	Manufacturing	Services	Manufacturing
1974	9.9	3.8	-2.4	23.3
1975	6.5	-1.6	6.3	-6.9
1976	6.2	10.9	2.8	7.3
1984	8.9	7.5	0.14	-0.14
1985	5.5	-7.3	-0.04	-9.7
1986	1.7	8.4	-0.95	-2.4

Source: Singapore Yearbook of Statistics, various years.

The common notion that services are resilient has been noted by many studies for various countries.[21] The amplitude and severity of recessions in the goods-producing sector of the economy are moderated by the service-producing sector. The evidence can be seen in the above table during the first oil price shock in the mid 70s and the world-wide recession in the mid 80s.

Unlike the services sector, during both recessions the manufacturing sector's GDP

[20]Electronic commerce refers to trade over the internet and the Singapore government has set its sights on being an international hub for such activities. A legal framework for internet transactions is being proposed and the government will introduce measures such as a 10 % concessionary tax for foreign firms deriving income from internet transactions operating in Singapore. See The Australian Financial Review 15 April 1998.

[21] See Nusbaumer (1987), Elfring (1989) and Wieczorek (1995:215).

growth rate experienced large fluctuations. In employment, services are less sensitive to variations than manufacturing. Thus, the services sector has a softening effect and cushions the economy from the drastic and harmful effects that filter from the vulnerable manufacturing sector - which are more pronounced due to Singapore's openness. Several reasons have been put forth to explain the resilience of the services sector.

One is that service output cannot be stored and thus the services sector is spared the effects of swings in inventory investment. Elfring (1989:435) gives two other reasons for the relatively limited cyclical responsiveness of market services. First, there is more disguised unemployment in services, especially among the self-employed. Second, the flexibility of compensation systems is higher in services because of a) commission payments in many sales activities b) flexibility of the incomes of the self-employed and c) limited presence and influence of labour unions. Nusbaumer (1987:66) claims that the linkage function played by services between physical production and the market in all economies is not likely to vary in proportion with the volume of physical output, and this would serve to explain their smaller cyclical variability.

But studies show that the composition of the services sector is of importance too. For instance, producer services which are closely linked to industrial production are said to be volatile to business cycles. Should the producer services share increase, then the services sector may not be as resilient as expected. Also, if the income elasticity of services is high, then the demand for services would be affected by business cycles, thereby reducing resilience.

2.4 Causality Between the Manufacturing and Services Sectors' Growth

Here we examine if growth in one sector causes growth in the other. The direction of causality of growth has important policy implications.

In the absence of an agricultural sector, a common notion is that an economy in its initial developmental stage would receive a larger share of its GDP from the industrial sector than from its services sector. But as it develops, the services sector becomes an increasingly significant contributor to GDP.[22] The implication here is that the growth of the industrial sector causes the services sector to grow. This is what Bhagwati (1984) termed as the 'splintering effect' where services grow due to increased production of manufactured goods.[23] Such a trend has already been identified for Singapore by Toh and Low (1988, 1994). This is the case when shipping services, advertising, marketing and commerce thrive because of the need to sell manufactured goods locally or abroad. Also, with increasing specialisation, or technological progress allowing for standardisation of services or relatively lower transactions costs, industrial firms may choose to contract out their 'in house' services, thereby increasing the link from the manufacturing to the services sector.

But services sector growth could also influence growth in the manufacturing sector. Bhagwati (1984) explains this as the 'disembodiment effect' where goods splinter off from services due to a technical revolution in information and communication technology. For instance, R&D activities could result in improvement in manufacturing technology and thus an increase in industrial output. When banks provide low borrowing rates, there is an incentive for manufacturers to borrow and produce more. The existence of trading companies and their worldwide network can be seen to encourage greater exports of manufactured goods as producers now increasingly rely on such middlemen (who have specific knowledge) to conduct their trade for them. However, these examples seem to suggest that the causality from services to the industrial sector is likely to take place in the later stages of an economy's development.

A causality study by Kalirajan and Kapuscinski (1993) on the experience of selected Asian countries provides some evidence for uni-directional causality running from the industrial sector to the services sector. This is the case for Philippines, Thailand, Japan, India and Malaysia which show that the pattern is similar for countries at varying levels of economic development.

The objective here is to investigate whether such causal links between the

[22] It is however acknowledged that in some developing countries, labour surplus tends to be absorbed in service occupations as domestic servants and government employment to a significant amount.
[23] But not all services grow from the industrial sector. For instance, public administration, law and order, education and health are quite independent of the growth of manufacturing.

manufacturing and services sectors exist in Singapore. The testable hypothesis, following Bhagwati's 'splintering effect' is then formulated as:

Growth in the manufacturing sector causes growth in the services sector.[24]

Methodology of the Causality Tests

Drawing on Kalirajan and Shand (1992), consider the following simple structural model of Jacobs (et al., 1979).

$$x_t = \alpha\ y_t + \alpha_{11} x_{t-1} + \alpha_{12} y_{t-1} + w_{1t}$$

$$y_t = \beta\ x_t + \alpha_{21} x_{t-1} + \alpha_{22} y_{t-1} + w_{2t}$$

where x and y are two time series variables and w_{1t} and w_{2t} are independent, serially uncorrelated random variables distributed as N(0, σ_1^2) and N(0, σ_2^2) respectively. The aim is to examine the causality between x and y.

The reduced form for the structural system above is as follows:

$$\begin{pmatrix} x \\ y \end{pmatrix}_t = (\pi) \begin{pmatrix} x \\ y \end{pmatrix}_{t-1} + \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \end{pmatrix}_t$$

where $(\pi) = (1-\alpha\beta)^{-1} \begin{pmatrix} \alpha_{11} + \alpha\alpha_{21} \alpha_{12} + \alpha\alpha_{22} \\ \alpha_{11} + \beta\alpha_{11} \alpha_{22} + \beta\alpha_{12} \end{pmatrix}$

and $\begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \end{pmatrix} = (1-\alpha\beta)^{-1} \begin{pmatrix} 1 & \alpha \\ \beta & 1 \end{pmatrix} \begin{pmatrix} w_1 \\ w_2 \end{pmatrix}$

The extent to which y influences x is described by three hypotheses:

1) $H_0 : \alpha = \alpha_{12} = 0$
This hypothesis is that, neither the current nor the past effect of y is transmitted to x, that is, y does not cause x.

2) $H_0 : \alpha = 0$
This hypothesis is that the current influence of y does not affect x.

3) $H_0 : \alpha_{12} + \alpha\alpha_{22} = 0$

[24] This is to say that any negative growth in the manufacturing sector would cause negative growth in the service sector as well.

This is often referred to in Granger's sense as y does not cause x. It is equivalent to testing if π_{12} is zero. If π_{12} is not equal to zero, then y causes x. However if π_{12} is equal to zero, then it is impossible to conclude that y does not cause x. This is due to the fact that both α and α_{12} may not be equal to zero.

As the structural model is not identified, its parameters cannot be estimated and so, α and α_{12} cannot be estimated either. Thus, only the third hypothesis can be tested. For this exercise, it is appropriate for the methodology to be based on a bivariate case. Then the implicit assumption is that all variables except the rate of growth of services and the manufacturing sectors may be excluded from the analysis without giving rise to spurious causality.

For Granger's causality, the following linear models are estimated:

Serv = f { Manu, Manu (-1), Serv (-1) } (1)

Manu = f { Serv, Serv (-1), Manu (-1) } (2)

A uni-directional causality from Manu to Serv requires that coefficient estimates of Manu or Manu (-1) is significantly different form zero in Equation (1) and that Serv and Serv (-1) in Equation (2) is not significantly different from zero.

However, the literature indicates that when different methods of testing are used to investigate the same relationship, results tend to vary.[25] Thus, another method by Sims (1972) is applied to test the above causality relationship. Sims uses a two-sided distribution method while Granger uses a one-sided distributed-lag method.

Sims's Forward-Backward Regression Model

Serv = f { Manu, Manu (-1), Manu (+1) } (3)

Manu = f { Serv, Serv (-1), Serv (+1) } (4)

If causality runs from Manu to Serv only, then Manu (+1) would not be significantly different from zero.

All 4 equations above were then estimated by the ordinary least-squares method with a time trend and a constant using the computer software, Shazam.

---

[25] See Hsiao (1979) and Jacobs (et al.,1979).

Data

Empirical testing is done using the real (measured in 1985 market prices) annual GDP growth rates of the two sectors over 1960-1994 and the data is drawn from various issues of the *Singapore Yearbook of Statistics*.

Testing Stationarity of Series

The empirical evaluation of causality is dependent on the stationary properties of the two sectoral growth rates series. Non-stationarity of time series may contribute to spurious regressions and thus can significantly alter tests of the causal relationships between the sectors. Although growth rates are used to induce stationarity, it is still necessary to check on the autocorrelation properties of these series.

To do so, the unit root test of Dickey and Fuller (1981) is used. Consider the following 'augmented Dickey-Fuller (ADF)' regression:

$$\Delta x(t) = \gamma + \delta t + \zeta x(t-1) + \sum_{i=1}^{k} \beta_i \Delta x(t-i) + \varepsilon(t)$$

The test statistics Φ_1, Φ_2 and Φ_3 are designed to test the following:

a) $H_0 : \zeta = 0$

b) $H_0 : \gamma = \delta = \zeta = 0$ (presence of drift)

c) $H_0 : \delta = \zeta = 0$ (presence of deterministic trend)

with the alternative hypothesis in each case being the stationarity of the series.

To ensure that the series is uncorrelated, the lag structure was selected based on minimising the Akaike Information Criterion (AIC). It was found that the optimal number of lags identified by Shazam for both series was zero. The results of the unit root tests are reported in Table 2.4 below.

Table 2.4 : Stationarity Test Results

Test	Manufacturing	Services	Critical Values (5% level of significance)
Φ_1	-3.628	-3.708	-3.6
Φ_2	4.408	4.591	5.68
Φ_3	6.610	6.879	7.24

Note: Critical values for the tests are taken from Fuller (1976:373), and Dickey and Fuller (1981:1063).

For Φ_1, the test values (in absolute terms) are above the critical value and therefore statistically significant, indicating that the null hypothesis of non-stationarity cannot be accepted. Hence, for the causality testing, the growth rates of the series can be used in their levels. However for tests Φ_2 and Φ_3, the conclusion is that the series is non-stationary. Furthermore, as the test values for Φ_1 are very close to the critical values, it was decided to test for the stationarity of the first differences of the series.

This then requires the estimation of the following ADF regression:

$$\Delta^2 x(t) \ = \gamma_1 \ + \ \zeta_1 \ \Delta x(t-1) \ + \ \sum_{i=1}^{k} \beta_i' \ \Delta^2 x(t-i) \ + \ \varepsilon_1(t)$$

The null hypothesis tests whether $\zeta_1 = 0$. The test values for the manufacturing and services sectors are - 4.217 and -5.459 respectively while the critical value for 5% level of significance is -3.6 . Thus the results indicate that both the series are stationary of order one or I (1).

The causality tests were then performed on both series when they are stationary of order zero or I (0), and I (1). As similar results were obtained in both cases, only the test results of the series used at their levels are reported.

Empirical Results of Causality Tests

A summary of the results of Equations (1) to (4) are tabulated below and the significance of the test statistics at the 5% level is indicated with an asterisk, *.

In Table 2.5, both the Granger and Sims tests show that Manu (t) is significantly different from zero and Manu (t+1) is statistically insignificant as expected. Thus, causality is seen to run from the manufacturing sector to the services sector.

In Table 2.6, both tests show that Serv (t) is significant and the Sims test shows that Serv (t+1) is not significant as would be expected. Thus, causality is seen to run from the services sector to the manufacturing sector.

Table 2.5 : Causality from Manufacturing Sector to Services Sector

Variable	Granger Test (*t*-Test Statistics)	Sims Test (*t*-Test Statistics)
Manu (t)	3.417*	3.323*
Manu (t-1)	0.007	0.713
Manu (t+1)	-	0.059
Serv (t-1)	1.447	-

Table 2.6 : Causality from Services Sector to Manufacturing Sector

Variable	Granger Test (*t*-Test Statistics)	Sims Test (*t*-Test Statistics)
Serv (t)	3.417*	3.397*
Serv (t-1)	-0.825	-0.063
Serv (t+1)	-	0.749
Manu (t-1)	1.392	-

In all of the above tests, there were no problems with serial correlation or heteroscedasticity. The $\overline{R}^2$, which ranges from 0.3 to 0.4, is small but not of great concern, as the tests here are merely looking for the existence of a relationship and not for the major determinants of the dependent variable. The stability of the regression coefficients was also tested using the Chow test with a structural break in 1980. There was no evidence of such a break, and thus the above regressions hold for the period of 1960-1994.

Interpretation of Results

The above analysis shows that there is bidirectional causality between the growth of the services and manufacturing sectors, indicating the presence of Bhagwati's 'splintering' as well as 'disembodiment' effects. More interestingly, the feedback is immediate as its influence takes place within the same period.[26] This further reinforces the common notion of 'servicised' industrial and 'industrialised' service activities, but in reality the

[26] However, if the feedback occurred within months, it would not be picked up as the data used was annual. Since the sample size of 34 is small, results of the tests should be treated with caution.

difference between the two sectors is blurred. Such a stand is not taken in this study, as the blurring is not proven to be significant in most areas.

The causality running from the manufacturing sector to the services sector highlights the importance of producer services, which is to be expected given the emphasis on industrialisation and the huge presence of foreign investment in manufacturing since the early 70s. The increase in regional headquarters operations in Singapore by foreign MNCs in manufacturing is certainly proof of service sector growth as a by-product of long-term investment in manufacturing.

Basically, there are two reasons for the two-way relationship between the growth of the services and manufacturing sectors. First, Singapore is unique as the agricultural sector is barely significant, and this has partly accelerated the path to bidirectional causality. This is in line with the empirical evidence given by Kalirajan and Kapuscinski (1993) on the uni-directional causality running from the industrial sector to the services sector for Asian countries which have had a significant agricultural sector in the past. It takes time for the manufacturing sector to grow in importance and a link to be established to the services sector. Thus, the structural change which brings about a link from services to manufacturing has yet to take place (if at all it does) for some of these countries.

Second, as discussed earlier, the two-way relationship reflects the fact that Singapore is a highly developed economy and, in particular, manufacturing can be said to have reached a mature stage. Given that more sophisticated production techniques in manufacturing rely heavily on service industries, there are more opportunities for a link to be established from services to manufacturing. Besides serving as inputs which are demanded when manufacturing increases, the level of sophistication of the services sector could also encourage the production of manufactured goods.[27]

---

[27]For example, the extensive use of information technology and the use of advanced technology in the services sector might be an incentive to increase production of manufactured goods if the demand for the latter type of goods exist. In fact, Murinde and Eng (1994) give evidence of a causal relationship from financial development to economic growth and find no evidence of real output growth being induced by financial development.

Implications of Causality Result

First, there is little opportunity for significant de-industrialisation or 'hollowing out' of the manufacturing sector to take place.[28] This phenomenon refers to a long-term decline in the share of manufacturing output with a corresponding rise in service output.

Second, although both manufacturing and service sectors will continue to be the twin engines of growth, any government policy biased towards either sector should not be a major concern due to these two-way causality effects. As long as one sector grows, the other sector will also grow. Thus, Singapore's commitment to retaining a manufacturing base of at least a quarter of GDP or to ensure a growth rate of 7% for the manufacturing sector until the year 2000[29] is in no way worrying. Lastly, in effect, the emphasis on nurturing either sector or an expansion of one sector at the expense of the other would only matter in terms of growth in the short run.

However, the above tests are unable to indicate the strength of the causality (that is, whether the relationship from manufacturing to services or that from services to manufacturing is stronger). Despite criticisms on the econometric testing of causality,[30] it still remains a useful tool for empirical testing. One can rely on the input-output tables for the measurement of the extent of interdependence between the growth sectors as identified by the causality results above.

2.5 Inter-Industry Linkages of the Growth Sectors

The above causality study using time-series data lends clear support to the 'snapshot' analysis of Singapore's Input-Output Tables which have identified increasing interdependence of the two sectors over the years 1973, 1978, 1983 and 1988.[31]

---

[28] The issue of 'hollowing out' of employment in the manufacturing sector is taken up in Chapter 3.
[29] See The Straits Times (Singapore) 2 Nov 1995.
[30] See Wu (1985) for a detailed discussion on these criticisms.
[31] The 1993 Input-Output Tables were not published at the time of writing.

Table 2.7 : Interdependence of the Services and Manufacturing Sectors (Percent)

	1973	1978	1983	1988
Share of value added of services attributed to non-oil manufacturing activities	5.6	5.1	6.5	7.4
Share of value added of non-oil manufacturing attributed to service activities	5.7	5.8	5.7	4.3

Source: Toh and Low (1994)

The first row in the table above shows increasing dependence of services on manufacturing over the years. The second row shows that in the 70s, the non-oil manufacturing sector seemed to have depended on services more as it shows how much of services was used to produce non-oil manufactured goods. However in the 80s, this dependency was lower. But this does not necessarily diminish the role of producer services. Petit (1986:31) claims that low transfers of value added is only an accounting identity and it is conceivable that certain services have a strategic importance as far as competitiveness is concerned.

Given the industrial structure in 1988, Toh and Low (1994:17) found that the manufacturing industries have high backward linkages, while those that have high forward linkages are predominantly service-oriented enterprises.[32] But some services, like commerce and financial and business services, have an above average backward linkage as well.[33]

Table 2.8 provides more information on the composition of industrial output of the manufacturing and services sectors over time.

[32] A backward linkage is used to indicate the kind of interconnection of a particular sector to those sectors from which it purchases inputs and a forward linkage is the interconnection of a particular sector to those sectors to which it sells its output. It is a measure of potential stimulus as a result of investment in a particular activity and is given by the output multiplier. The output multiplier is the total amount of output generated when one unit of the final demand of the sector of interest is materialised.

[33] An above average backward linkage means that the measure is greater than one.

Table 2.8 : Composition of the Value of Industry Output (Percent)

	Manufacturing				Services			
	1973	1978	1983	1988	1973	1978	1983	1988
Final Output*	83.6	82.6	83.4	82.1	78.1	75.8	62.8	64.8
Intermediate Input	16.4	17.4	16.6	17.9	21.9	24.2	37.2	35.2

Note: * This includes exports which may be used as intermediate inputs in another country.

Source: Absorption Matrix from Singapore I-O Tables, various years

It can be seen that over the years, the share of manufacturing output used as intermediate input was fairly stable at around 17%, while a greater share of services sector output was sold as intermediate input to other sectors until 1983. Toh and Low (1994) also show that in general, services are large users of services themselves while the transport and communications, and the financial and business services are increasingly used by the industrial sector as producer services.

The role of the growth sectors can be also be viewed through its employment generating capacity as seen below.

Table 2.9 : Employment Multiplier (no/milS$)

Industry	1973	1978	1983	1988
Manufacturing	-	-	10.5	7.7
Services	-	-	25.2	17.6
Finance	21	24	13	-
Business	21	25	16	-
Government Services	104	61	44	-

Note: - means information is not available.

Source: Toh and Low (1994)

The employment multiplier has been higher for the services sector as seen above. In 1983, the service sector created 15 more jobs than the manufacturing sector for every million dollars worth of final demand in service output. In 1988, this figure was 10. In terms of actual numbers, services accounted for more than 70% of the 475 000 additional jobs created by the economy from 1980 to 1993.[34]

The above can be reinforced by employment elasticities calculated as

$$\text{Employment Elasticity} = \frac{\text{Growth in Employment}}{\text{Growth in Output}}$$

where Employment refers to number of workers employed
Output is given by Real GDP.

Table 2.10 : Employment Elasticities

Sector	1973-1983	1983-1993
Services	0.40	0.30
Manufacturing	0.94	0.21

Source: Calculated from Singapore Yearbook of Statistics, various issues.

It can be seen that the elasticity values for both sectors are less than one, indicating that the growth in the product trend is lower than that of the labour force trend (Table 2.10). This is similar to Baer and Samuelson's (1981) finding for a wide range of developed countries. The fall in the employment elasticities of both sectors over the two periods shows that both the sectors have become less labour intensive, especially manufacturing. In the last decade, it is the services sector which has generated greater employment growth (per unit of output growth) than the manufacturing sector.

2.6 Conclusion

It was shown that in the absence of an agricultural sector, both the manufacturing and services sectors played a critical role in the economy, whereby growth in one sector induced growth in the other (in the same direction) and vice versa. This bidirectional interdependence between the sectors is reflective of how highly developed Singapore's economy is, with little opportunity for hollowing out of the manufacturing sector's output. Under these conditions, there is little need for concern if policies are biased towards any one sector due to the two-way feedback effect of the growth between the

[34] See National Productivity Board (1994:43).

sectors. Input-output tables further served to show the interdependence between these sectors.

With the services sector, financial and business services showed an increasing employment share, reflecting Singapore's role as an emerging regional financial centre. As expected, the services sector was also more resilient than the manufacturing sector in terms of employment and output changes during recessions. Furthermore, the employment multiplier and employment elasticities values show that the services sector has greater employment generating capacity than the manufacturing sector. This then leads to the issue of hollowing out of the manufacturing sector employment which is examined in the next chapter in light of the partial productive performance of the growth sectors.

Chapter 3

Productivity Performance of the Growth Sectors : A Partial Measure

3.1 Introduction

According to the literature, the productive performance of the manufacturing and services sectors is measured in a number of ways. Here it is measured by labour productivity, which is the traditional partial productivity measure. Baumol and McLennan (1985:3) claim that labour productivity is probably the most significant determinant of a nation's standard of living. The productivity issue is of major concern in Singapore and the new Productivity and Standards Board, which was established in early 1996 is currently mapping out a 10-year national productivity plan in order to 'steer Singapore into the next millennium'.

This chapter looks at the trends of aggregated manufacturing labour productivity levels and growth rates and compares them with those of services at a disaggregated level. The existence of Verdoon's law is then investigated and finally, the implications of the finding of lagging service labour productivity growth, relative to manufacturing, on the issue of hollowing out of manufacturing employment is analysed.

Labour productivity is the value of output per unit of labour input and is given by:

$$= \frac{\text{Value added GDP of Sector}}{\text{Number of Workers Employed in Sector}}$$

Data

The output measure used is value added GDP in 1985 market prices.

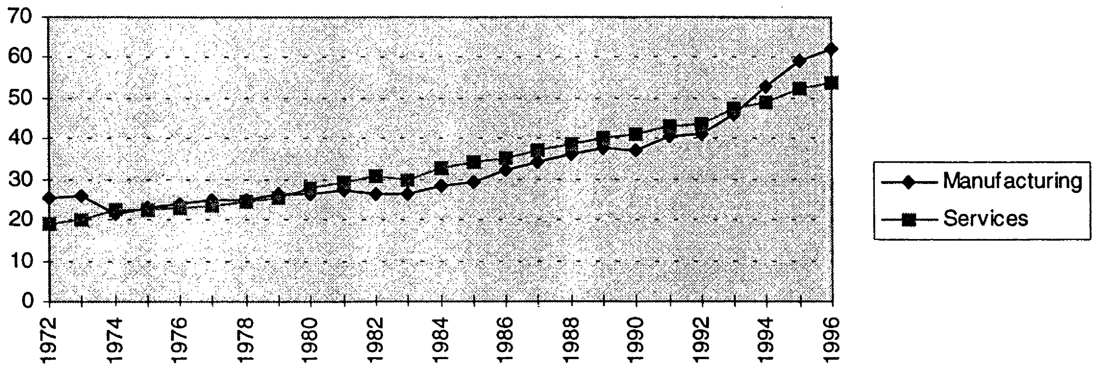
The employment figures (data are available annually from 1972 onwards) refer to persons who, during the reference week, worked for one hour or more, thus including part-time workers. As such, the services sector, which is more favourable for engaging part-timers would register lower productivity levels than the manufacturing sector. Perhaps a better measure is hours worked per week, which is the sum of standard and overtime hours worked during the reference week for both full-timers and part-timers. But overtime hours would not always be the same for every week. An alternative measure is to convert hours worked to full-time equivalents, however, consistent time series data on part-time workers were not available to do this.

Also, prior to 1988, the coverage included both private and public sector establishments with at least 10 workers, whereas from 1988, only establishments with at least 25 workers are included. Thus, the data for the two periods are not strictly comparable. The *Singapore Yearbook of Statistics* is the main source of data. All units of productivity are reported in thousands of Singapore dollars of output per man and per man hour.

3.2 Aggregated and Disaggregated Labour Productivity Levels

Services sector labour productivity was lower than that of the manufacturing sector from 1972 to 1979 and 1994 to 1996 but from 1980 to 1993, it exceeded that of the manufacturing sector (Figure 3.1). A similar trend was obtained when the weighted sum of services sector (comprising of various service industries) labour productivity was used with employment shares as weights.

Fig 3.1 : Labour Productivity (S$'000 Per Man)



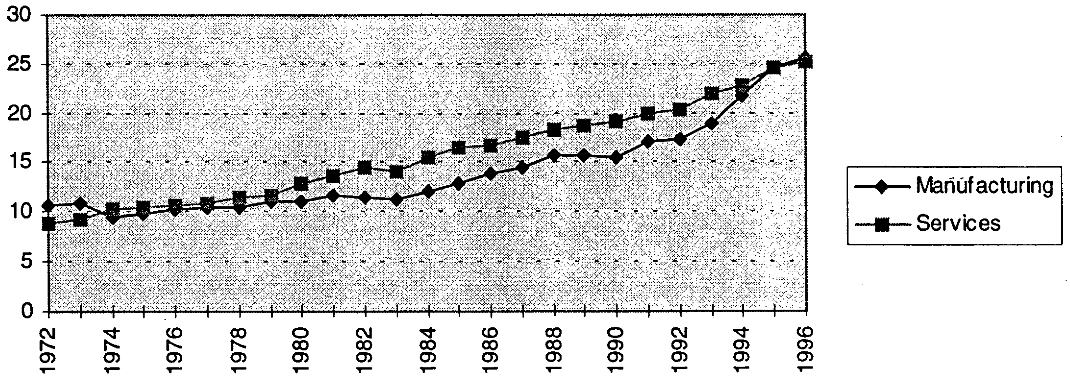
Source: Calculated from Singapore Yearbook of Statistics, various issues

Some suggested factors to explain inter-sectoral gaps in productivity are measurement problems, disparity in efficiency or wages, differences in structural characteristics of the sectors such as labour and capital intensity of activities, educational and skill level of workers, and predominance of small enterprises or the market structure of the sector.

When service industries 'mature', they use more sophisticated inputs, apply new technologies, expand firm size and exploit economies of scale - what Levitt (quoted in Stanback (et al., 1981:126) calls "industrialisation" of services. In particular, it is hypothesised (Stanback, op cit.) that the productivity gap between producer services and manufacturing will gradually diminish and that the productivity gap between manufacturing and consumer and public services will continue to increase.

Somewhat similar results were obtained when labour productivity was measured on a per man-hour basis (Figure 3.2). Here, total hours worked per year is given by multiplying average weekly hours by 49 (that is, 52 weeks per year minus 3 non work weeks, due to public holidays and an average of two weeks no-pay leave per employee) and by the number of workers employed. Also, since weekly hours data were available for the service industries within the services sector, the weekly hours for services was obtained as a weighted sum of each service industry's weekly hours worked using employment shares as weights. The trend was similar to the one below and there were no significant differences.

Fig 3.2 : Labour Productivity (S$'000 Per Man Hour)



Source: Same as Fig 3.1

The services sector's labour productivity was higher than that of the manufacturing sector's over a longer period from 1974 until 1995.

Sectoral Labour Productivity

Since the services sector is a very heterogenous group, the labour productivity levels of the various components of the services sector are compared to the manufacturing sector (Table 3.1). True to Baumol's (et al., 1985:816) claim, the services sector does seem to contain some of the most progressive as well as most stagnant industries.

Table 3.1 : Sectoral Labour Productivity Levels (S$'000 Per Man)

Year	Manu.	Commerce	Transport & Communication	Financial & Business	Other Services
1972	25.35	18.56	13.94	102.35	11.18
1977	24.85	20.98	25.69	69.88	13.88
1983	26.51	22.44	33.11	82.52	15.90
1988	36.33	28.08	52.54	95.67	18.40
1992	41.21	33.03	60.09	98.76	19.46
1996	61.97	40.08	69.52	104.58	27.22

Source: Same as Fig 3.1

The commerce and other services categories (the latter comprising of community, social and personal services) have consistently been less productive than the manufacturing sector. The National Productivity Board (1994:18) reported that these two domestic sectors have productivity levels which are only 70-75% of the national average. Possible reasons for this are that they have not been exposed to international competition, and there may be a need for deregulation. Also, Kuznets (1981: 249) explains that these sectors often deal with processes and functions that could not be standardised and mechanised as easily as those of manufacturing, because they deal with the needs of a population of final consumers, and of other economic agents, who exercise choices in the market. Other reasons would be measurement problems in the retail trade.[1]

The financial and business sector, on the other hand, has not only recorded higher productivity levels than the manufacturing sector but has always registered the highest productivity levels as well. The aim of making Singapore into a major financial sector since the early 70s, and this being realised by the late 80s, might be a cause for this. To

[1] For example, Bailey and Gordon (1988:414) explain that in retail trade, 24-hour convenience stores reduce productivity as they spread food shopping over a greater amount of labour input.

remain internationally competitive, this sector has always had up-to-date technology and has used its resources efficiently.

Transport and communications have improved their productive performance over the manufacturing sector since the 80s. It has always had the highest capital and fixed assets investment among all the service industries and this allowed for high labour productivity levels. Buoyant export market conditions also helped boost its strategic port activities. Since the mid 80s, Singapore has been one of the three busiest ports in the world (in terms of shipping tonnage). Changi Airport has had great success with international awards, reinforcing Singapore's importance as a regional air traffic hub. Singapore has taken great efforts to improve its telecommunication services, complementing its role as a regional business hub. [2]

3.3 Aggregated Labour Productivity Growth Rates

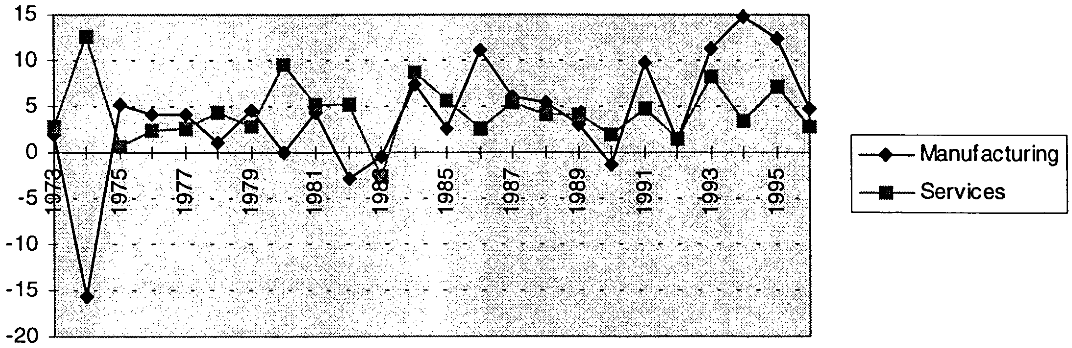
The need to distinguish 'levels' from 'rates of changes' in any discussion of productivity has been emphasised by many, and in particular, Stanback (et al.1981:128) and Baumol and McLennan (1985:171). Stanback states that the level of productivity is likely to be understated, while the rate of change is likely to be overestimated. On the other hand, Baumol and McLennan explain that sectoral patterns of productivity levels and growth rates are not necessarily related. In theory, both studies examine equally important but different questions. However, in practice, productivity levels suffer from what is called, 'fallacy of levels comparisons', while productivity growth rates can produce unambiguous results.

Manufacturing and services sector's labour productivity growth rates using the per man measure are shown in Figure 3.3. The manufacturing and services sector's labour productivity growth rates are seen to move in opposite directions from 1974 to 1981, after which they move roughly in unison. There can be three possible reasons for this.

---

[2] There are two satellite earth stations links Singapore with more than 50 countries and Singapore is the first in the world to have a public photo videotex system. By 1984, Singapore was using fibre optics, digital transmission networks and had teleconferencing facilities. In 1989, there was a nation-wide Integrated Service Digital Network in operation. In 1991, World Competitiveness Report gave Singapore 96.67 out of 100 for overall quality of its telecommunications infrastructure.

Fig 3.3 : Rate of Labour Productivity Increase (Percent)
(Per Man Measure)



Source: Same as Fig 3.1

One is that perhaps, since the early 80s, the bidirectional causality[3] between the growth of the two sectors took effect in the close relationship between the rates of productivity changes in the sectors. Second, and relatedly, is the consequence of economic restructuring in 1979 as a reinforcing factor. The National Wages Council recommended that wages be increased to induce movement from labour intensive manufacturing to capital intensive manufacturing activities. This caused the manufacturing sector to gear up towards higher value-added activities, which can be expected to increasingly require the support of the services sector. Third, both services and manufacturing have tended to become more capital intensive over time as labour shortages since the late 70s have caused labour costs to increase.

In general, services sector labour productivity growth showed smaller fluctuations than that of manufacturing. Elfring (1989:435) gives two reasons for the relatively limited cyclical responsiveness of services. First, it is likely that there is more disguised unemployment in services, especially among the self-employed. Second, the flexibility of the compensation system is higher in services because of commission payments in many sales activities and flexibility of incomes of the self-employed. As Singapore is involved very significantly in tradeable goods, it is very vulnerable to external demand and hence manufacturing output can be expected to fluctuate. Although Singapore's export of services is also significant, there is often a tendency to hoard labour in the services sector as firms are reluctant to lose workers who have firm-specific knowledge.

---

[3] Section 2.4 of this study showed that there was bidirectional causality between the growth of the services and manufacturing sectors over 1960-1994.

A summary of the per man labour productivity growth rates (Table 3.2) shows that in the earlier periods, especially 1973-80, the services sector productivity growth was higher than that of manufacturing. There was however, a minor slowdown in the productivity growth rate in the service sector; whereas, that of the manufacturing sector showed continued acceleration.

Table 3.2 : Average Annual Growth of Labour Productivity Per Man (Percent)

Time Period	Manufacturing	Services
1973-1980	0.65*	4.72
1981-1988	4.24	4.30
1989-1996	7.04	4.26

Note: * This low value is due to the very low productivity growth rates in a number of years, e.g. 1973, 1974, 1978 and 1980.

Source: Same as Fig 3.1

The productivity slowdown in services identified above is similar to that found in developed countries like the US, the UK and Canada. But Sabolo (1975:96-108) is less convinced and argued that labour productivity in the services sector can grow rapidly, and provides detailed evidence relating to a large number of countries. Leveson (1985:100) also gives evidence of accelerating productivity growth in services. Illeris (1989:46), on the other hand, states that it is subject to discussion as to whether labour productivity has really shown a slower increase in services than in goods production.

As the services sector is very heterogenous, a breakdown in terms of service industries is examined (Table 3.3).

Table 3.3 : Service Industries' Average Annual Growth of Labour Productivity Per Man (Percent)

Time Period	Commerce	Transport & Communication	Financial & Business	Other Services
1973-1980	3.55	9.52	-3.25	3.91
1981-1988	2.27	7.96	3.47	2.57
1989-1996	4.83	3.57	1.49	5.14

Source: Same as Fig 3.1

Transport and communications showed a substantial slowdown in its labour productivity growth rate; while that of financial and business services slowed down in the 90s. Commerce and other services industries' labour productivity growth seem to have risen in the 90s. The recovery from the mid 80s recession, the promotional efforts in tourism and a shake out in retail trade, where neighbourhood grocery stores are giving way to chain-store alliances, which are computerised and more organised, may have led to improvements in labour productivity in the commerce sector. The move towards 'electronic commerce' to promote borderless transactions for conducting retail trade on the Internet, and Singapore's step towards building the infrastructure in information and communication to enable this move, can also be expected to lead to productivity gains for the commerce industry.

3.4 Implications of Labour Productivity Growth Rates

Here two issues are examined using the labour productivity growth rates obtained earlier. One is to find out if Verdoon's law exists for Singapore and the other is to examine if manufacturing employment is hollowed out.

Verdoon's Law

This law postulates a positive relationship between output growth and labour productivity growth. In particular, it states that as output increases, economies of scale enable productivity to increase, so that higher output growth leads to higher productivity growth.

However, it is difficult to check the existence of the law on statistical and theoretical grounds. The main problem is that of causality because it is unclear whether output growth causes productivity growth or vice versa. Thus, regressing output growth on labour productivity growth would provide a spurious estimation. Cornwall (1977) provides suggestions to get around the causation problem.

As a preliminary step, the correlation coefficient between the two variables is first examined; although correlation offers no explanation as to causation. The results showed a very low correlation coefficient of not more than 0.37 for the relationship between output growth and labour productivity growth for the manufacturing and services sectors. In cases when output growth has been high, productivity growth has, in general, been low. Given such low correlation, it adds little value to use Cornwall's (ibid) suggestions to establish any causation for interpretation. It is clear however, that if causation was found to run from output growth to labour productivity growth, then output growth is an insignificant determinant of labour productivity growth.

The Hollowing Out of Manufacturing Employment?

In an important paper, Baumol (1968) was the first to describe the productivity consequences of unbalanced growth among sectors of differing productivity growth. According to Baumol, the differential productivity growth rates in the services and manufacturing sectors would affect wages in both sectors. Often the services sector is the slower growing labour productivity sector, but eventually, the wage increase in the manufacturing sector would be matched by wage increase in the services sector. Since the wage increase in the services sector is not due to an increase in productivity, the increase in cost would be passed on to consumers and the relative price of services would increase. Producers in the services sector would then have a greater incentive to produce more and this would result in a labour flow to services and hence a rise in the services sector employment share.[4] Dowrie (1970) and Faulhaber (et al., eds. 1986) also attribute services sector employment growth to trends in comparative costs due to high rates of technological change in the manufacturing sector.

Sufficient evidence in the literature exists to suggest that productivity growth differential in favour of the manufacturing sector is one of the main causes for the growth of employment in the services sector.[5] This relates to the following concern of the senior minister of Singapore, Mr. Lee Kwan Yew, when he claimed in 1995 that Singapore is "... hollowed out ... and has only services - which is a dangerous position, as Hong Kong has found."[6] A Department of Statistics study (Singapore, 1995a) on the other hand, dismisses such fears.

[4] Fuchs (1981) and Leveson (1986), on the other hand, explain that the rise in the relative price of services (due to slower productivity growth in services) would slow down consumption of services, but in the face of relatively strong demand for services based on rising income, this would result in rising services sector employment growth.
[5] See Fuchs (1969:8), Briscoe (1972), Haig (1975), Baumol (1985),Wieczorek (1995) and Rowthorn and Ramaswamy (1997).
[6] See Economist 14th-20th October 1995.

Table 3.4 indicates that manufacturing employment share has hollowed out and that of services employment share has increased especially since the 1990s.

Table 3.4 : Employment Share By Sector (Percent)

	1970	1975	1980	1985	1990	1996
Manufacturing	22.0	26.2	30.1	25.4	29.1	23.5
Services	66.3	65.3	60.7	63.9	62.1	70.3

Source: Singapore Yearbook of Statistics, various issues.

Also, as was experienced by OECD countries, the labour productivity growth of the services sector in Singapore was found to be lagging behind that of the manufacturing sector in the late 1980s (see Table 3.2).

The Department of Statistics study (Singapore, 1995a) reports that increasing shortage of labour, rising business costs, and an increasing number of manufacturing companies relocating to the neighbouring countries, due to an erosion of comparative advantage in labour intensive operations, have been the reasons for such a trend. In addition to detecting if hollowing out has occurred in Singapore, another question of importance is: if it is so, is there cause for concern?

To shed light on the hollowing out issue, the correlation coefficient between the services sector employment share relative to the manufacturing sector and that of the labour productivity growth differential (labour productivity growth of the manufacturing sector minus labour productivity growth of the services sector) between the two sectors was examined (see Table 3.5).[7]

[7] An alternative method is to include the labour productivity growth differential as a regressor in determining the relative service sector employment share or growth. But the fact that labour supply is not fixed in Singapore (due to inflow of foreign workers) did not allow for the theoretical derivation of the labour demand function to be a function of other variables and this factor. See Section 4.2 of this study for the theoretical framework of the labour demand function used for empirical estimation.

Table 3.5 : Correlation Coefficient between Relative Employment Shares and Labour Productivity Growth Differential

Time Period	Correlation Coefficient
1973-80	0.49
1981-88	0.53
1989-96	0.67

Source: Calculated from Singapore Yearbook of Statistics, various issues.

For all periods, the relationship is positive and is relatively higher in the later periods. In 1989-1996, the correlation coefficient was highest and the services sector's labour productivity growth was lagging relative to manufacturing in this period as can be seen from Table 3.2. The correlation coefficient of 0.67 is not very high, but it is highly likely that the productivity effect on manufacturing employment is understated since there is a ready pool of foreign workers that the manufacturing sector can draw on, masking any possible reduction in manufacturing sector employment due to the shift to service employment. This makes the following evidence possible.

The Department of Statistics study (Singapore, 1995a) and the Business Times (Singapore) 23 Feb 96 provide evidence of no hollowing out in the manufacturing sector in terms of employment and claim that such a shift is yet to be seen unlike OECD countries. They substantiate their claim stating that, " the top job provider between 1980 and 1994 was the high growth electronics industry in the manufacturing sector. Although the manufacturing sector produced the smallest gain in employment, it was still the largest employer in the economy compared to each of the service industries in the service sector. Overall, both the services and manufacturing sectors continued to record net gains. This is not to say that there has not been a loss of jobs in the manufacturing sector, but these have been in the labour intensive and less technologically-based industries and were more than compensated by the creation of jobs in the higher value-added and more technologically-based industries and the service sector."

But since data on foreign workers in Singapore is not published, no definite conclusion can be drawn on the issue of hollowing out of employment in the manufacturing sector.

Even if there is a hollowing out effect, there may be little reason to worry. If the markets dictate that there is high growth potential in services, then Singapore's move towards a more service-oriented economy would create higher growth.[8] Hong Kong is an excellent example in this respect, as its manufacturing sector is hollowed out because most of its manufacturing activities have been relocated to China.

In fact, Singapore's regionalisation drive of the 1990s, which the government has been strongly encouraging, ought to lead to hollowing out as in Hong Kong's case. This would also help Singapore reduce its dependency on foreign unskilled workers. Even if hollowing out were to take place (presuming that the Department of Statistics 1995 study is right in saying that it has not happened yet), it can be expected to be a gradual process if the Singapore government keeps to its commitment to retain a manufacturing base of at least a quarter of GDP.

Perhaps the more important concern should be that the hollowing out of manufacturing employment is not caused by a lagging services sector labour productivity growth rate. If that is so, the latter would have a damaging effect on the overall economy in the long run and that would clearly be an issue that needs to be addressed.

<u>How serious is the labour productivity growth decline in the services sector?</u>

Denison (1973:20),as well as an OECD 1991 report on technology and productivity, claim that the difficulties of measuring output cause increases in productivity in the service industries to be understated relative to increases in commodity-producing industries. Denison (1973:32) has argued that for any unmeasured quality change (in the number of commodities and amenities associated with services) occurring in intermediate products, the productivity gain in any producer services is often credited to some manufactured industry which uses it to produce the end product, thereby showing greater increase in its manufacturing productivity.[9]

Also, the consumer price index (which applies to final purchases of consumer goods and services is shown by Gordon (1996) to have an upward bias. This would bias

[8] Section 2.4 of the thesis provides empirical evidence of growth in the services sector causing growth in the manufacturing sector.

[9]One must also not totally dismiss that the reverse holds for any productivity gain in the manufactured goods used as intermediate inputs in services, although this can be expected to be relatively insignificant.

productivity performance downwards, and if more consumer services than goods are purchased, this would further bias service output downwards.[10]

But the fundamental question is how accurate is this measure on productivity?[11] This in turn relies on the accuracy of the input and output measures themselves. As variations exist in the output and input measures, the resulting partial productivity measure has many drawbacks.

First, Denison (1973:21) points out that the choice of the numerator and denominator as well as the base year for valuation influences the results. The numerator can be measured using gross or net figures, valued at market price or factor cost, in the selected base year.[12] Kendrick (1991:153) reports that although economists generally agree that unit factor cost weights for output are preferable to market prices for productivity analysis, tests for Canada and US suggest that there is minimal effect when alternative sets of weights were used. In this study, although real output was used, the use of inappropriate deflators to obtain this value is itself subject to criticism.[13] There also exists a vast literature on how, in general, service output measures are inaccurate.[14]

Second, the denominator can be measured using employment figures, full-time employees, or hours worked (productive number of hours versus number of hours paid for). The problem of self-employed and unpaid family workers has also been highlighted.[15]

Third, a frequent criticism is that the partial productivity measure does not take into account labour efficiency and quality, such as work improvements in work standards due to better education and training.

Unfortunately, there are insufficient disaggregated data on educational attainment and the age-sex mix of the workforce for all sectors of the Singapore economy. The lack of

---

[10] See Gordon (1996) for an explanation as to why the CPI has an upward bias.
[11] For a detailed discussion, see Kendrick (1985), Griliches (1987) and Gordon (1995).
[12] See Baumol and McLennan (eds. 1985:30) for a discussion on the merits and demerits of each measure.
[13] See Bailey and Gordon (1988).
[14] This has been discussed briefly in Chapter 2.
[15] In the last decade, the proportion of self-employed in Singapore remained stable at about 13%, but the shift towards service-oriented industries was more pronounced among self-employed who operated their own business without any paid help. See Department of Statistics (Singapore, 1993).

such information greatly distorts productivity measures. But another view as well as some empirical evidence show that mismeasurements could not have accounted for such a common phenomenon in so many developed countries.[16] However, Gordon (1995), in reassessing the seriousness of measurement errors, is convinced that his 1988 study with Bailey has very significantly understated the importance of the measurement issues.[17] Thus, whether the slowdown is a statistical mirage is still an unresolved matter.

More and more authors are questioning the traditional productivity indicators in services, especially in the most modern and complex services dealing with information and knowledge. Noyelle and Stanback (1990:193) claim that about 60% of the services in US are characterised by such complexities and thus such productivity measurements are "seriously distorted or largely meaningless". Bailey and Gordon (1988:391) put forth the idea that computers have made it harder to measure service output and Nordhaus (1988:421) explains that computers, being intermediate products, further allows the output and input components of services to be easily mismeasured. Stanback (et al., 1981:122) claims that for years, economists have relied upon a static framework for productivity measurements and that a dynamic framework is sorely needed even if the initial attempts are crude and unsatisfactory.

But as Nordhaus (1988:421) pointed out, there should be nothing automatic about having a certain percentage of annual growth in labour productivity and if this phenomenon is a common experience to many developed countries, why worry? More interesting is Solow's (1982:459) dismissal of the productivity decline by suggesting that what is being experienced now could possibly be the normal productivity growth and that the early periods, for a variety of reasons, including random errors, saw above average productivity growth rates. There is little evidence to suggest that the experience of the 70s is the right benchmark.

[16] See Bailey and Gordon (1988:348), and Nordhaus (1988:425). These studies made such adjustments and found that it contributed little to understanding the productivity slowdown.

[17] But Gordon (1995:152) notes that his discussion of the measurement problems are relatively complex and some of them may not apply to other countries.

3.5 Conclusion

The labour productivity of services was found to be higher than that of manufacturing, and given the high possibility of understatement of measurements in services, it is likely to be higher than that reported here. However, since 1993, the trend has reversed and an interesting study for future research is to try and understand what has caused these trends over the period 1970-96. The determinants of labour productivity growth is also another area worth looking into and the puzzle that output growth is not a significant determinant of this measure makes it even more interesting. Moreover, due to the numerous limitations on the partial productivity measure, this study focuses on the total measure of productivity in the following chapters.

As was found in other countries, the labour productivity growth of services was seen to slow down and it was found to be lagging in the early 90s, relative to the manufacturing sector. But the implication of this finding on the hollowing out of manufacturing employment could not lead to any definitive conclusion due to insufficient data on foreign workers. Nevertheless this unresolved issue remains interesting.

The next question is, what drives the employment determinants in the services and manufacturing sectors? This is the focus of the next chapter.

Chapter 4

Employment Growth Performance of Sectors : Analysis of Determinants

4.1 Introduction

Unemployment has hardly been an issue for Singapore since the mid 70s. Lim (et al., 1988) estimated the unemployment rate for the period of 1959-65 to be between 10% and 15% but it was soon resolved by the significant FDI that went into labour intensive manufacturing activities. With the exception of 1985-87, Singapore's unemployment rate has never been higher than 4% since the late 1970s, and since the early 1990s it has been lower than 3%.

While the previous chapter examined the hollowing out issue of manufacturing employment, this chapter focuses on the employment determinants of both the manufacturing and services sectors. First, a theoretical framework of the labour demand model is set out. Second, empirical evidence and a discussion of the factors that affect the manufacturing sector is reviewed. This is followed by an analysis of the Singapore case. Next, a similar analysis of services sector employment growth is undertaken and finally, the sustainability of employment in these growth sectors is briefly discussed.

Basically, there are two alternative perspectives of employment measurement - the industrial and the occupational approaches. Employment by industry records workers according to the industries to which they belong, while the occupational approach is based on the activity of the individual. Here, the conventional industrial approach is chosen due to the availability of time-series data on employment and its determinants, based on such a categorisation. But such data may include a proportion of strictly non-service workers for the services sectors, and/or 'service workers' may be engaged in the manufacturing or other non-service sectors.

4.2 Theoretical Framework of Labour Demand Model

Consider the following production function of a firm:

$$Y = f(n, k, T)$$

where Y= Output
n = Number of Workers
k = Capital Stock
T = State of Technology

Let w = wage rate of a single unit of labour
r = price of a single unit of capital

Minimising the cost of production, wn + rk, subject to $Y = f(n, k, T)$ would then give rise to the following Lagrangian, L :

$$L = wn + rk - \lambda[Y - f(n, k, T)]$$

Taking the first derivative of L with respect to n, k and λ, and equating them to zero gives rise to:

$$r = \lambda f_k \qquad \text{....... (1)}$$

$$w = \lambda f_n \qquad \text{....... (2)}$$

$$Y - f(n, k, T) = 0 \qquad \text{....... (3)}$$

where f_k and f_n represent the first derivatives of $f(n, k, T)$ with respect to k and n and are the marginal product of k and n respectively.

From (1) : λ = shadow price of Y $\equiv$ P .... (4)

Let P be endogenous to the industry such that it is affected by the demand for industry's output Q , and it is negatively related to Q.

$$P = P(Q) \qquad \text{....... (5)}$$

Substituting (4) into (2) : $f_n = \dfrac{w}{\lambda} = \dfrac{w}{P}$

Integrating the above : $n = n(w/P)$

This is the firm's demand for labour expressed as a function of real wage. It can also be interpreted as a positively sloped labour supply expressed as a function of real wage.

Inverting the above: $w = w(n)$ .... (6)

Since P is exogenous to the firm, it is a constant and thus ignored from the perspective of the individual firm. Hence, the cost minimisation problem for the firm is given by substituting (4) and (6) into the Lagrangian L:

$$L = w(n)\,n + rk - P\,[\,\overline{Y} - f(n, k, T)\,]$$

Taking the first derivative of L above with respect to n and equating to zero gives:

$$w(n) + n\frac{dw}{dn} = P f_n$$

$$\Rightarrow w \left[1 + \frac{n}{w}\frac{dw}{dn} \right] = P f_n$$

$$\Rightarrow \frac{w}{P} \left[1 + 1/\eta \right] = f_n \qquad \ldots\ldots\ (7)$$

where $\eta = \frac{w}{n}\frac{dn}{dw}$ = wage elasticity of labour, a constant value

Now, integrating (7) : $n_i = n_i\,(w, P, \eta)$

where n_i is the employment of labour by the *i* th firm.

Aggregating over all firms to get industry demand for labour:

$$N = N\,(w, P, \eta)$$

Substituting (5) into above: $N = N\,(w, Q, \eta)$ .... (8)

Hence employment of labour is a function of wage per worker, industry output and a constant. In the above model, a firm has no power in the product market (since price is determined by industry output) where product prices are determined in the market. For a tradeable good, such an effect is minimal given the size and openness of the Singapore economy. The firm, however, has power in the labour market [since n = n(w)]. This is possible, as Singapore has had a tight labour market situation since the early 70s and employers can attract workers by offering higher wages. This is often one of the reasons for job hopping in the Singapore labour market.

4.3 The Manufacturing Sector

There have been a number of different types of empirical studies on labour employment in general, and particularly in manufacturing. Some have looked at the demand for labour from a firm's perspective, others have focussed on labour hoarding determinants and a few have used a simultaneous equation framework of labour demand and supply to study factors responsible for changes in labour employment.[1] Emphasis then turned to the dynamic specification of the labour demand function where similar issues were examined.[2] It incorporated firms' expectations, forward-looking behaviour and used error correction models for analysis.

In this study, the determinants of labour employment in manufacturing and services are analysed (using aggregate level data) following the demand side framework, according to the theoretical model set out earlier. Although desirable, dynamic specification could not be carried out due to unavailibility of quarterly data (and hence a large enough sample size is unavailable) on some factors determining employment. Also, the focus in dynamic specification is different, as it is more a study of adjustment costs to employment rather than employment determinants per se. With annual data, it is pointless to introduce dynamics anyway, because any feedback arising from the use of a one year lag can be expected to be insignificant. Besides, Mangan (1981) claims that using annual data minimises labour hoarding practices and this might allow the investigation of long run determinants of employment.

Literature Survey on Employment Determinants

First, output is considered an important determinant of employment. Freebairn (1977), Flaig and Steiner (1989), and Hartley and Lynk (1983) identified sluggish employment response to changes in output in some manufacturing industries. Madden and Tuckwell (1975) found that the lead and lag relationship varied for different industries, but none of the series identified a significant lag of output extending beyond 6 months in determining employment. They also explain that short run variations in output are often not matched by corresponding variations in employment, and if need be, they are achieved through employing part-timers or getting workers to work over-time. There is also the possibility of labour hoarding, where, when manufacturing output falls, the demand for labour may not change due to high costs of hiring, firing and retraining, especially that of skilled labour. Thus, the relationship between output and employment is not clear.

---

[1] See Freebairn (1977), Mangan (1981), Mangan and Stokes (1984), and Bertola (1991). Bhati (1978) provides a multi-equation model for the agricultural sector and Diewert and Morrison (1986) discuss the framework on simultaneous modelling.

[2] See Jenkinson (1986), Bond (1988), Flaig and Steiner (1989), Price (1994) and Harmesh (1995).

Second, some studies such as Freebairn (1977) and Newell and Symons (1988) found wage rate to be a key determinant of employment. This is especially so for manufacturing industries which have a high labour share cost or high capital-labour substitutability.

Third, relative prices of other factors of production can also determine demand for labour. For instance, if the price of capital relative to wages decreases, then depending on capital-labour substitutability, capital deepening may result in a fall in the demand for labour. While Flaig and Steiner (1989) and Wren-Lewis (1986) found that relative factor prices played a minor role in employment determination, Bond (1988) found otherwise.

Fourth, Mangan and Stokes (1985) show that trade-related variables like effective protection and exchange rates (price of Australian manufactured goods relative to imported manufactured goods) have had a negative effect on the demand for labour in the Australian manufacturing industry in the 70s.

There are also other variables which can affect labour employment but may not be accurately measurable or proxies for them are simply not available. For instance, profit expectations have been identified as highly significant in the literature, as they affect output decisions and hence employment.[3] Institutional variables like minimum wage rate, standard hours of work, overtime payment and government wage and labour policies have also had an effect on employment either indirectly and/or through affecting firms' expectations of future labour market conditions.

Analytical Model of Employment Growth

Based on the theoretical framework set out earlier, some modifications were made in the chosen explanatory variables to make the model more relevant to Singapore.

---

[3] When expectations are persistently overly optimistic, firms would retain more labour than was warranted by the current situation. A suggested proxy in the literature for profit expectations is operating surplus, but such data are only available from 1991 onwards. On the other hand, data on business expectations for various categories (like new orders received, output expectations, stocks of finished goods) are given in percentages and are available quarterly (taking an average would not be a good representation as the variations between some quarters were quite significant) but are not compatible with the annual data being used in this study.

First, in addition to wages, remuneration was also used since producers might be interested in total cost rather than just wages. Labour costs include wages and salaries (including bonuses), training costs, foreign worker levies, pension, CPF contributions[4] and other benefits like food, lodging and medical care.

Second, a dummy variable was used to assess the foreign worker policy which was generally designed to discourage the excessive use of imported unskilled labour. A levy scheme first introduced in 1980 for the construction sector was extended to cover the manufacturing sector since 1982. The policy was later modified to include a certain ceiling for firms, beyond which foreign blue-collar workers were not allowed to be employed.

To summarise, the model is as follows:

The dependent variable is employment of persons in thousands, (MEMP).

The independent variables are :

1) Nominal Manufacturing GDP output measured in thousands of S$, (MANU).

2) Annual Remuneration per worker (REM) in the manufacturing sector.

3) Dummy variable D, takes the value of 1 after 1981.

The Simultaneous Equation System

The above model assumes that the explanatory variables affect employment. But reverse causality cannot be ruled out, where an increase in labour employment in the manufacturing sector can increase manufactured output, and also affect wages and remuneration. Hence, the specification suffers from possible endogeneity problems and would give rise to spurious results if it is estimated as a single ordinary least square (OLS) equation.

This is one of the problems in the employment studies of Pang (1993), and Disney and Ho (1990) where a single OLS equation was used to examine factors affecting labour demand in the aggregate economy as well as some individual sectors of the economy.

[4] CPF is the central provident fund to which an employer contributes an amount equivalent to a certain percentage of the employee's salary.

Disney and Ho's model specification is based on a partial adjustment mechanism combining output and employment functions but there are a few problems with their model. Two problems arise when output is taken to be a function of the capital stock, wage costs, interest rate and some other factors. First, capital itself depends on interest rate and thus interest rate should not be used as a separate variable in the output function. Second, since wage costs depend on number of workers employed, output is then a function of capital and labour. This leads to a problem in their employment of labour function which depends on output, as output in turn depends on labour. Such specification problems need to be carefully addressed and perhaps these have caused the many problems that the authors had to face in obtaining a cointegrating relationship of a single order in the labour employment function.

Pang (1993) also used a single OLS estimation and the endogeneity problem between labour and output could have led to the other problem, where the output elasticity on employment was found to be less than one percent. Sims (1974), Hazledine (1974) and many others have found it paradoxical that fluctuations in output should tend to induce less than proportionate fluctuations in labour inputs. This is so as it implies that there are increasing returns to labour and the Cobb-Douglas production function, from which the model was theoretically based, cannot hold true. However, some authors have provided explanations for those results, none of which have been substantiated, let alone attempted to be discussed in Pang's study.

The exercise undertaken in this study avoids the problems of the above studies. First, the theoretical framework underlying the model here is general and does not impose any restrictions as in the Cobb-Douglas function. Thus, obtaining an output elasticity of less than one is acceptable. Also, any possible endogeneity is taken into account by adopting the two-stage-least-squares (2SLS) approach to offer more reliable estimates for interpretation.[5]

[5] To detect endogeneity, both the Hausman and Lagrange Multiplier tests were used. The test results failed to reject the exogeneity of the variables. But this is possibly due to the small sample size which lowers the power of the tests and often accepts the null hypothesis of exogeneity of the variables. Based on this reason and the high possibility of endogenity on theoretical grounds, the 2SLS approach was preferred over OLS.

The 2SLS performs OLS in two stages. In the first stage, each of the suspected endogenous variables are regressed on relevant factors and the exogenous variables in the system using OLS. In the second stage, the predicted values of these endogenous variables are then used as regressors in the OLS estimation of the labour employment equation. The computer software, Shazam, is used for the analysis. The system is given as:

Labour Demand Equation:

MEMP = f (MANU, REM, D)

Endogenous Variables: MANU , REM

The Rest of the System:

MANU = f (PRINR, FORI)

REM = f (CPF, WAGE)

where PRINR is the principal exchange rate which is a weighted average exchange rate using the shares of trade with various countries as weights.

FORI is foreign investment commitments in manufacturing.

WAGE is wage per worker.

Since most of the manufacturing output is exported, the exchange rate is an important determinant of MANU. Also, the manufacturing sector is dominated by MNCs and is heavily dependent on foreign investment, thus making FORI an appropriate determinant. Since wages and CPF contributions are components of the remuneration paid, they have been used as determinants of REM.

Data

Annual data from 1973 to 1994 was used, since quarterly data on variables like MEMP, REM and WAGE are not published. Data on MEMP, REM and WAGE were obtained from the annual publication of the *Census of Industrial Production.* Data on PRINR are from the IMF's *International Financial Statistics,* and data on the rest of the variables were obtained from the *Singapore Yearbook of Statistics.*

Empirical Results

The diagnostic tests on specification are obtained from the single OLS equation of the labour demand function (see Appendix 4.1 for details). The logarithmic functional form was satisfactory, as given by the Ramsey Reset test statistic of 0.56, and there were no problems with heteroscedasticity. The full estimation details are given in Appendix 4.2 The main equation, which is the labour demand function given by Equation (8) in logarithms is reported below:

$$\text{Lg MEMP} = \underset{(11.38)}{9.45^{*}} + \underset{(2.19)}{0.36^{*}}\ \text{Lg MANU} - \underset{(-0.19)}{0.06}\ \text{Lg REM} - \underset{(-0.96)}{0.09}\ \text{D}$$

The values in parentheses are t-ratios and * indicates that the coefficient estimates are significant at 5% level. All the variables were found to have the expected sign.

The results show that manufacturing output is the only significant factor. A 1% increase in output is seen to increase jobs by 0.36%. The small magnitude of elasticity reflects the capital intensive or labour-saving technology in the manufacturing sector.

The coefficient of average labour cost per worker (REM) is negative but insignificant. The reason for this could be that wages, which are a large component of REM, are not freely determined in the market. Wages may be prevented from rising due to the ready availability of foreign workers. Lim (et al., 1988) notes that an attempt to encourage female labour force participation could also have restrained wage growth. Chowdhury and Islam (1993:164) view wage determination in Singapore as an 'unclear competitive model'. The authors claim that government intervention in the form of wage recommendations through the National Wages Council, especially during 1973-79 and in 1985 were successful.[6] These wage distortions influence the WAGE and REM variables such that they do not have the expected significant effect on employment. Finally, other factors like strong external demand, political and economic stability of the economy as well as the strike-free environment may be more important in determining employment rather than labour costs.[7]

---

[6] Success refers to the adoption of the wage recommendations not just by the public sector but also by the private sector.

[7] For instance, Chng's (et al., 1986) survey data revealed that foreign investors were heavily influenced by the predicability of the overall economic environment.

The negative but insignificant dummy coefficient shows that the foreign worker policy has little or no effect on the employment of foreign workers as was desired. However, it is inaccurate to say that the policy has not been as successful as hoped, for the following reasons. The employment variable includes foreign and local workers, both skilled and unskilled, and thus, the effectiveness of the foreign policy cannot be investigated accurately. Also, the government has in some years (1983, 1986, 1988 and most recently in 1997) relented or rather eased its foreign worker policy to cope with the tight labour situation or increasing labour costs. Hence, the insignificant effect of the REM variable on labour employment.

But there is some evidence to suggest that the foreign worker policy has not been effective. In 1973, the 100 000 unskilled foreign workers comprised 12.5% of total employment and in 1995, this number had risen three times to constitute 17.6% of total employment.[8] Various goals set have also not been met. For instance, in 1981, it was announced that workers from non-traditional sources such as Indonesia, Thailand, Sri Lanka, Bangladesh and Philippines would be phased out by 1986 and those from traditional sources like Malaysia, by 1991.[9] In 1987, the official view was that the foreign labour force should be no more than 25 % of the total labour force and by 1992, there was to be a wholly Singaporean work force. These have yet to materialise.

To test the existence of a structural break, a dummy variable was included to take on a value of one since 1985 (recession) but it was found to be insignificant and was dropped from the regression. Thus, the parameter estimates are stable over time.

4.4 Summary

With manufacturing employment generally being stable or increasing gradually (except for the recession years 1985/86), it would be difficult to expect factors (if they can be proxied), in an econometric study such as this, to have a significant effect on employment. Nevertheless, this exercise shows that unlike labour and wage costs, manufacturing output is a significant determinant of manufacturing employment in

---

[8] See Hui (1992:174) and Business Times (Singapore) 5 Jan 96.
[9] See Hui (1992:177).

Singapore. Disney and Ho (1990), on the other hand, found wages to be significant but the problems of specification in their model puts doubts on their results.

With the foreign worker policy, more data need to be made available to look at how effective and more appropriate measures can be implemented to stem the flow of unskilled foreign labour. The regionalisation drive of the 90s can be expected to reduce the dependency on unskilled foreign workers as labour intensive manufacturing operations are relocated to the neighbouring second-tier NIEs. With greater emphasis on R&D since the early 90s, and the move to high-tech manufacturing activities, the demand for skilled workers in Singapore is likely to increase.

For comparative purposes, a similar study on the growth of the services sector employment is undertaken below for a comparison.

4.5 The Services Sector

Literature Survey on Employment Determinants

Supply Factors

The Fisher-Clark three-sector theory suggests that technological progress also occurs in the services sector, which helps reduce the relative cost of producing services. The introduction of computers and automation have not only enabled an increase in production of services but have also allowed for the expansion of standardised services and created employment. An opposing view that technology replaces service jobs also exists.

Second, changes in relative factor prices combined with sectoral differences in factor ratios, sectoral differences in elasticities of substitution between labour and capital and the price elasticity of substitution between sectors also account for growth in services sector employment. For example, if the goods industries found it easier to substitute capital for labour and skilled labour for unskilled labour, then the goods sector share of employment would tend to decline and that of services increase. Even if such elasticities were the same in the goods and services industries, there is an a *priori case* for believing that changes in relative factor prices would alter employment shares because the initial distribution of factors may not be the same in the two sectors. The factor prices need not change at the same rate in these sectors either.

Demand Factors

First, the secular view[10] appeals to the manifestation of society's attempt to allocate available resources in response to changing tastes and income. In this view, as income increases, both secondary and tertiary sectors grow relative to the primary sector. As incomes rise even higher, the tertiary sector (demand for services such as leisure, tourism, legal services, education, private health care and insurance) grows relative to the secondary sector.

Second, the accelerating demand for producer services provides another explanation for the rapid increase in services caused by the industrialisation phase. Nicolaides (1990:285) claims that services are found in any manufacturing process such as R&D, commercialisation of technological innovations and marketing of sophisticated products. The growing significance of after-sales maintenance and servicing of products, and the trend towards externalisation of previously in-house services would increase the demand for and employment of labour in such services.

Third, the Bacon-Eltis view[11] sees structural change as an outcome of rapid expansion in the public sector. Since government expenditure tends to be more in favour of services, resources shift away from the goods sector. Peacock (1981) explains that the complementary expansion, which is a consequence of the growing complexity of government associated with the government multiplier effect, could affect services employment in other sectors.[12]

On the trade front, Singapore enjoys a comparative advantage in shipping, tourism via travel services, as well as engineering and business services. Coupled with Singapore's

[10] See Chenery (1961), Fels, Schatz and Wolter (1971), Sabolo (1975) and Kasper and Parry (1978).
[11] See Bacon and Eltis (1978).
[12] For example, with rising or increasing complexity of tax burdens and selective aid and industrial policies, private firms and individuals have a greater incentive to invest in tax avoidance with the aid of tax lawyers, accountants and other administrative staff. Another example is the expansion of social services which is likely to increase the demand for counsellors.

export-led growth strategy, the growing external demand[13] as well as the extent of tradability of services (this depends on trade and non-trade barriers in services) are important factors for services employment. Furthermore, the use of information technology, telecommunications and video conferencing would also boost employment, as it does away with the need to be physically present in the importing country.

The following is a survey of some of the earlier studies on the growth of the services sector employment in various countries.

First, income has been found to be an important determinant of services sector employment. Quibria (1990) gives evidence of Bangladesh and India, where slower per capita income growth has led to a stagnant demand for services. A 1993 report of the Commission of the European Communities attributes most of the increase in the share of employment in services to the growing propensity of people to spend on services as income increases. But Wieczorek (1995:218) cautions that care needs to be exercised when interpreting this, since even when measured in constant prices, the GDP statistics overvalue the real share of services in total spending when compared to purchasing power values.[14] Also, employment shares tend to overrate the actual share of services in total employment, because the proportion of part-timers is higher in services than in other sectors.

Second, on the subject of producer services, an OECD (1985) study found that across countries, the decision to produce internally or to purchase outside varied significantly. In France, the second option was widely preferred while in Germany most enterprises decided in favour of the first. For US, using 1966-81 data, Stanback (et al., 1981) argued that the shift to producers services explains the large contribution of the exogenous demand in services.

---

[13] Between 1970 and 1994, net service earnings increased to about 20% of the economy's GDP and in some years it reached a peak of 30%. In 1993, Singapore was already the 11th largest exporter of services in the world. Its exports of services rose from 1.3% of that of total world exports of services in 1987 to 2.4% in 1995.

[14] Wieczorek (1995:215) reports that, using the International Comparison Project data set (based on purchasing power parity values), the real share of services in US GDP was essentially the same as that of India at 38%.

Third, the Bacon-Eltis view on public sector expansion was supported not only in developing countries like India and Pakistan (Ansari 1995) but in OECD countries as well. Sabolo (1975:35), on the other hand, provides evidence of no such direct link in developing countries and only a weak link exists for a group of developed countries.

Before the case for Singapore is examined, an attempt is made to calculate the price and income elasticities of services in Singapore. Of interest, is the latter in determining the demand for services, and hence the employment in the services sector.

Measure of Price and Income Elasticities of Services

These elasticities can be calculated by regressing:

The log of Real Private Service Expenditure (S) on the log of Real Income (Y) and the log of Real Price of Final Services (P) as seen in the equation below.

Equation 9

$$\log S = \text{constant} + a \log P + b \log Y$$

where

a = price elasticity

b = income elasticity

Variables and Data Used

Real private service expenditure is given by private consumption expenditure on services measured in 1985 market prices. This refers to expenditure on medical services, transport and communications, recreation and education, personal care, expenditure in restaurants, cafes and hotels, and a component of 'other goods and services' which is not categorised further in the available data. Thus, the results should be interpreted with caution.

Real Income is measured by real GDP (that is, GDP in 1985 market prices) and since there are no data on price of final services, the norm of using the relative price of services as a proxy is adopted. This is given by the ratio of implicit price index of services to manufacturing. The implicit price index of services (manufacturing) was measured as the ratio of service (manufacturing) GDP in current prices to the corresponding service (manufacturing) GDP in 1985 market prices where 1985 is the base year.[15] One caveat regarding this proxy is that the price deflators which were constructed from GDP at current and constant prices measure only the movement in the mark-up component. If these movements do not reflect price changes in final goods and services, then the estimated elasticity will be biased.

Annual data are used for all the above variables and these are obtained from the *Singapore Yearbook of Statistics* for 1965-1994.[16] However, 1985 and 86 were omitted as these were recession years.

The following is the equation to be estimated.

Equation 10

Log of Real Private Service Expenditure	= constant	+ a	Log of Relative Price of Services	+ b Log of Real GDP

Testing Stationarity of Series

As in any time-series regression analysis, in order to avoid spurious regressions and biased and inefficient coefficient estimates, the stationarity properties of the variables need to be examined (see Appendix 4.3 for details of this procedure).

The stationarity tests suggest that the first differences of the variables are stationary. The first difference of the relative price of service ratios gives negative values for some years and as logs of negative values would not make sense, Equation (10) is estimated in the hybrid logarithmic form (see details of the estimation in Appendix 4.4).

Equation 11

Log of Real Private Service Expenditure =	- 2.11	- 0.33 Relative Price of Services	+	1.08^{*} Log of Real GDP
	(-1.34)	(-0.21)		(5.34)

The values in parentheses are t-ratios and * indicates that the coefficient estimates are significant at 5% level. The estimated equation is not found to suffer from any serious

[15] This is the method adopted by the Department of Statistics (Singapore).

[16] Although quarterly data is available, annual data was considered more appropriate, as the former may not pick up changes in expenditure due to changes in income as any income change may not be considered permanent enough for the change in expenditure to take effect.

diagnostic deficiencies. The DW statistic of 2.2 indicates no serious autocorrelation and the functional form chosen was satisfactory as Ramsey's Reset test statistic was 0.19 and statistically insignificant. Heteroscedsaticity was not present (based on the regression of squared residuals on squared fitted values) as the test statistic was 0.66 and all the coefficient estimates have the expected signs.

Price Elasticity

Although negative, the value of 0.33 does not directly indicate price elasticity, as the functional form is hybrid logarithmic. It is possible however to calculate the price elasticity for the functional form above, but as the value was insignificant, such an exercise was not carried out.

Income Elasticity

In general, there is no clear evidence about the magnitude of income elasticity in other studies, although recent studies such as Falvey and Gemmel (1991, 1996) and Bergstrand (1991) report statistically significant income elasticities numerically close to one. Early studies such as Fuch (1969), indicate that services in aggregate have a unitary income elasticity of demand and evidence from Houthakker and Taylor (1966), Inman (1985), Summers (1985) and Giersch (ed. 1989:15) support this result. On the other hand, Kravis, Heston and Summers'(1983:201) work on the UK for the period 1968-78 and US for 1950-77, showed that the income elasticity of services was not only below one but was also lower than that for commodities, which registered an income elasticity value greater than one. The same study also showed that it was the reverse for France during 1959-78. Thus, it appears that the magnitude of income elasticity of services is an empirical issue.

Demand for services in this exercise is income elastic and statistically significant at 1.08 and this is close to Seow's (1979) estimate for expenditure on education, health, recreation and other services for four of his 8 categories of income and household size. His other 4 categories had income elasticities ranging from 1.2 to 1.4. For transport and communication however, seven of his 8 categories registered high elasticity values of 1.6 to 1.8.

Seow (1979), using data from The Report on Household Survey (Singapore) for 1972/73, considered an increase in income for which information on expenditure was obtained from higher income levels of groups within the same survey. One advantage of this method was that the quality of services was kept constant. Further, it was assumed that income elasticities differed among various groups of income levels and household size. However, there are some restrictions in this methodology. For example, considering an increase in levels of one group to another imposes the latter group's tastes and preferences in services on the former group. Also, Seow's method can only be applied to those years for which such data on disaggregated household income are available which is a rather static approach.[17]

The method adopted in this exercise is that of an econometric estimation and avoids the above mentioned problems in Seow's methodology. But before attempting to explain the elasticity value obtained in this exercise, two econometric issues need to be discussed. One is to ensure that the estimated equation is a demand equation and the other is the test for stability of the elasticity estimate over time.

Is the Estimated Equation a Demand Equation?

Equation (10) with service expenditure as a regressand can also be taken to be a supply function since expenditure on services represents output or the supply of services, given that services are non-storable. If so, the coefficients of the regressors may not accurately reflect price and income elasticities. Thus, Maddala (1992: 358) proposed that a supply function on price and wages be written, and together with the demand function, unbiased and consistent estimates for the coefficients on price and income can be obtained by solving for the reduced form equations in a simultaneous way.

The reason for not adopting the reduced form solution here is three-fold. First, wage data for services are only available from 1972 onwards and with a smaller sample size, the estimates obtained may not be accurate anyway. Second, Maddala (1992:357) explains that, when the relationship between price and quantity is studied, demand and supply functions need to be considered together. In our case, the objective is to study income elasticity and thus, demand and supply need not be considered simultaneously.

[17] The data can be obtained from The Report on Household Survey (Singapore) which is published every five years and is available for 1972/73, 1977/78, 1982/83, 1987/88 and 1992/93.

Third, and more important, is Leamer's (1981) theoretical proof where he shows that, "it does make sense to regress quantity on price and then to take the estimated function to be a supply curve or a demand curve depending on the sign of the estimated elasticity." Hence, the value of b in Equation (11) can be reasonably interpreted as income elasticity.

Is the Estimated Income Elasticity Stable Over Time?

The sample is first split into two separate samples. The sequential Chow test is then used to test if the income elasticity estimates obtained from performing the same regression for the two samples are equal. The null hypothesis H_o is that the income elasticity estimates of both samples do not differ significantly from one another; thereby indicating stability and the use of a single regression over the entire sample range will then be justified.

The Chow test is performed by the computer package, Shazam, which splits the sample into n_1 (starting with the smallest possible sample size feasible for estimation) and n_2 (total sample size minus n_1) and tests for the equality of estimates from these sample sizes. The test also sequentially increases n_1 by one (hence reducing n_2 by one) and repeats the test for parameter stability (see Appendix 4.5 for full estimation details).

It was found that the Chow test statistic values for the various possible two sample sizes were all less than the corresponding critical values (for the various combinations of degrees of freedom) at 5% level of significance. Thus there is no need for any structural break and the estimation of income elasticity is valid for the entire sample of 1965-1994 (excluding 1985 and 86) and is stable over time.

Explaining the Income Elasticity Value

It seems surprising that income elasticity of services is quite low at 1.08 and more surprising that, it is stable over the time period of 1965-1994. This warrants some explanation.

In the absence of an agricultural sector, both manufacturing and services sectors have played a significant role in the Singapore economy. Since 1970, the manufacturing sector's GDP share has been in the range of 25-30% while that of the services has been within 60-70% between 1965-94. Thus, the GDP shares of both sectors have not experienced drastic changes over time. As such, the stability of the income elasticity for services is understandable, given the aggregation bias in the method. But income elasticity can be expected to be different for different components of consumer service expenditure as Seow (1979) and Falvey and Gemmel (1996) have shown. The change in the composition of expenditure on services is affected by the following changes in habits and preferences of consumers in Singapore: the employment of foreign maids, the growing interest in travel abroad and the tendency to store wealth in local and foreign property. In fact, the Department of Statistics (1997) reports that consumer expenditure on financial services, like brokerage fees for share transactions and life insurance, is fast growing and that buoyant economic growth in the last 10 years saw an increase in the demand for cars; thereby reflecting an increase in the share of personal transport equipment. Since increases in income are siphoned off by these many varied activities over time, total consumer expenditure on services has not changed significantly in response to changes in income.

A related econometric issue is that the stability of the estimated income elasticity could stem from the possibility of omitting relevant variables in the regression equation. For instance, demographic variables like population size, age composition and income inequality may affect the estimated value and contribute to its instability over time. However, Falvey and Gemmel (1996) found that by reestimating the equation using such variables, income elasticity for services as an aggregate, was consistently found to be close to unity across different specifications of equations. This evidence further supports the robustness of the estimated income elasticity of services above.

Analytical Model of Employment Growth

This section provides an empirical analysis of the employment determinants of the services sector.

The dependent variable is employment of persons in thousands, (SEMP).

The independent variables are :

1) Government Expenditure on services (GOVT)[18], is used to assess the strength of government sector as an employer and is measured in S$million in 1985 market prices.

2) Real Private Consumption Expenditure on Services (RPTES), is a proxy for demand for services and has been defined earlier when it was used to calculate the income elasticity of services.

RPTES and GOVT taken together partially represent service output. Although export of services[19] and producer services[20] were included in the estimation, they were found to be insignificant and were dropped from the regression.

3) Annual Remuneration per worker (REM) as defined for the manufacturing sector.

4) A dummy variable (D), which is included to see if using annual data after 1984 as opposed to using biannual data before that (this constraint is imposed by the years that census data were collected), and if the recession of 1985/86 had any effect on SEMP. Unlike the manufacturing sector, the foreign worker policy for the service sector was only implemented in 1990 and was relatively less restrictive. For instance, it started with restricting a firm's workforce composition from Malaysia to be no more than 10%. The policy has been continuously relaxed, and effective from Oct 1 1997, the dependency ceiling (not in relation to any country in particular) was raised from 25% to 30%. It is not only too early to study the effects of the policy on service employment but there is little evidence to show that service firms have regarded the policy as a constraint.

Although many other factors were discussed earlier, not all were found to be suitable for empirical testing as some could not be quantified and appropriate proxies were not

---

[18]GOVT refers to expenditure on security, education, health, environment, public housing and other social and community services, economic services related to national development, communications, trade and industry and labour.

[19] Data on export of services were taken from the balance of payments as well as estimated from the Input-Output tables by obtaining predicted values from a fitted regression of only 4 available observations against a time trend. The insignificance of this variable in the service employment regression only goes to show how difficult and inaccurate it is to measure the export of services. Given that Singapore is a large exporter of services, one would expect this variable to be significant.

[20] There was no proper data on producer services. An attempt was made to measure this in the same way that export of services was estimated from the Input-Output tables. Alternatively, it was measured by removing export of services, PTES and GOVT from service GDP output, but that too did not provide significant results.

available. The small sample size of 16 also restricted the use of the number of determinants for estimation.

The Simultaneous Equation System

As in the case of the manufacturing sector, there are potential endogenity problems due to reverse causality in the model. When service employment increases, service output would increase and remuneration would be affected as wages change according to changes in employment. Thus, as before, a 2SLS estimation is adopted and a system of equations are fed into SHAZAM for analysis. The following is the system:

Labour Demand Equation:

SEMP = f (RPTES, GOVT, REM, D)

Endogenous Variables: RPTES , REM

The Rest of the System:

RPTES = f (RGDP, RELP, GOVT)

REM = f (CPF, WAGE , GOVT)

where RGDP is real GDP in 1985 market prices.

RELP is the relative price of services to the manufacturing sector given by the price deflators of the sectors.

WAGE is wage per worker.

Since expenditure on services is dependent on income and the relative price of services, RGDP and RELP were used as determinants of RPTES. As explained before, CPF and wage are components of REM. GOVT being an exogenous variable to the system, was included as a determinant for both the endogenous variables.

Data

All data were obtained from the *Singapore Yearbook of Statistics* except for WAGE, SEMP, and REM. While WAGE was unpublished data obtained from the Department of Statistics, the latter two were obtained from the *Report on the Survey of Services* for various years, *The Service Sector* 1990-93 and *Census of Services 1994*. The sample size was only 16 because data on SEMP, REM and WAGE were available from 1974 biennially to 1984 and then annually to 1994.

Empirical Results

The logarithmic functional form was satisfactory, as given by the Ramsey Reset test statistic of 3.95 which is insignificant at the 10% level of significance. There were also no problems with heteroskedasticity (see Appendix 4.6 for the single OLS estimation on the labour demand function for services). The estimation details are given in Appendix 4.7. The main equation, which is the labour demand function given by Equation (8) in logarithms is reported below:

$$\underset{}{\text{Lg SEMP}} = \underset{(12.82)}{9.96^{*}} + \underset{(5.85)}{0.29^{*}}\ \text{Lg RPTES} + \underset{(0.35)}{0.03}\ \text{Lg GOVT} + \underset{(3.25)}{0.28^{*}}\ \text{Lg REM} - \underset{(-6.02)}{0.13^{*}}\ \text{D}$$

The values in parentheses are t-ratios and * indicates that the coefficient estimates are significant at 5% level of significance.

The results show that the government sector in Singapore is not a significant employer of services, thus refuting the Bacon-Eltis view. The extensive use of computers in the civil service (the civil service computerisation programme was launched in 1981) may have reduced the demand for labour. Also, Sio and Yeo (1996) report that the civil service has been less active in recruitment during 1980-95. The privatisation of many government schools and hospitals in the late 80s is another likely reason.

Consumer demand for services, RPTES, is a significant determinant, where a 1% rise in RPTES increases labour employment by about 0.3%. Although this elasticity value is low, the significance of RPTES shows support for the secular view in explaining services sector employment which is reinforced by an equally proportionate increase in RPTES that results from a proportionate 1% increase in real income as the income elasticity of services was found to be 1.08 earlier.

The REM coefficient is positive and significant, indicating that labour costs do not deter employment of labour. This could be because remuneration in some services reflect high skills and employers are willing to pay more to employ them. A 1% increase in remuneration per worker leads to a 0.3% increase in workers employed. But it should be acknowledged that the interpretation of the positive labour elasticity is a problem, given that the estimated equation is that of labour demand. In fact, Disney and Ho (1990) also find a similar result for the non-traded sector and they offer three explanations for this. One is that, it is simply a 'perverse' labour demand elasticity and the other is that it is due to some aggregation bias in services. Third, and most plausibly, the specification is unable to separate shifts in the labour demand function from movements along the labour demand function as the wage changes. This could arise when wage increases lead to higher consumption of services and that translates to shifts in the labour demand function rather than a movement, which is what the estimated equation is meant to pick up.

The dummy variable is significant which means that, after 1985, the effects on employment are different from before and the use of biannual and annual data can also give different results. But the sample size is too small and does not allow for separate estimation for two time periods. Thus, careful interpretation of the results is necessary based on the significance of this variable as well as the REM variable.

4.6 Summary

The above analysis highlights (but also cautions the interpretation of) the importance of domestic demand and remuneration in determining labour employment in the services sector. Contrary to Wong's (1997:54) postulation that Singapore, like many developed nations, will see a faster growth in consumer services than producer services; here, it is suspected that producer services and export of services would play a vital role in the future. Unfortunately the availability of poor data and proxies did not allow a study of these effects on employment. There is reason to believe that there would be increasing demand for services from neighbouring countries who are currently keen on attracting FDI in manufacturing (which will fuel the demand for services) but have yet to develop their services sector. The move towards liberalisation in service trade is also expected to boost demand given Singapore's comparative advantage in services. The Department of Statistics (Singapore, 1995a) study states that employment in the services sector is likely to dominate the labour market in the long run.

4.7 Conclusions

In general, with no negative shocks to the economy, there is certainty of jobs in both the services and manufacturing sectors due to expected strong external demand. But shortage of labour has been a problem ever since the early 80s, when the government implemented the foreign worker policy. The supply restrictions on labour are thus being relaxed to cope with the situation as seen in the recent attempt of Singapore to attract skilled foreign labour; the lowering of the foreign worker levy on skilled workers (those earning less than US$1350); the call to Singaporeans abroad to return home; the move to attract skilled workers from abroad by promoting Singapore through Contact Singapore;[21] the lift on the restriction of skilled women's foreign spouses for work opportunities and permanent residency. The success of these measures, as well as the ability and willingness of workers to upgrade their skills, is important for the sustenance of employment in these sectors and hence the growth of the economy.

[21] This was mooted in early 1997 and several centres have already been established in Sydney, Perth, Vancouver, Los Angeles, and Boston to inform those interested to work in Singapore regarding job opportunities, the lifestyle in Singapore and how they can be helped to settle in when working in Singapore.

Appendix 4.1 : OLS Estimation of Labour Demand Function in the Manufacturing Sector

Ordinary Least Squares Estimation

```
*******************************************************************************
Dependent variable is LGMEMP
22 observations used for estimation from 1973 to 1994
*******************************************************************************
Regressor        Coefficient     Standard Error      T-Ratio[Prob]
CONST               9.0096          .25990          34.6658[.000]
LGMANU              .44177          .042547         10.3832[.000]
LGREM              -.19384          .072275         -2.6820[.016]
D                  -.058625         .043400         -1.3508[.194]
*******************************************************************************
R-Squared                  .95980  F-statistic F( 3,  18) 135.2867[.000]
R-Bar-Squared              .95270  S.E. of Regression           .043949
Residual Sum of Squares   .032836  Mean of Dependent Variable   12.5072
S.D. of Dependent Variable .20208  Maximum of Log-likelihood    38.0402
DW-statistic               1.5331
*******************************************************************************
                  Diagnostic Tests
*  Test Statistics *     LM Version      *       F Version       *
*******************************************************************************
* A:Serial Correlation*CHI-SQ( 1)= 1.0503[.305]*F( 1, 17)= .84235[.372]*
* B:Functional Form   *CHI-SQ( 1)= .55578[.456]*F( 1, 17)= .43496[.519]*
* C:Normality         *CHI-SQ( 2)= .83360[.659]*      Not applicable   *
* D:Heteroscedasticity*CHI-SQ( 1)= .33777[.561]*F( 1, 20)= .31060[.584]*
*******************************************************************************
 A:Lagrange multiplier test of residual serial correlation
 B:Ramsey's RESET test using the square of the fitted values
 C:Based on a test of skewness and kurtosis of residuals
 D:Based on the regression of squared residuals on squared fitted values
```

Note: The DW of 1.53 is larger than the critical value of Cointegrating Regression Durbin Watson (CRDW) of 0.386, thus rejecting the null hypothesis of non-cointegration which means that the relationship represented by the equation is stationary (Engle and Granger 1987). Besides, the functional form also does not show any problems in using the levels of the variables in estimating the equation.

Appendix 4.2 : 2SLS Estimation of Labour Demand Function in the Manufacturing Sector

|_2sls lgmemp lgmanu lgrem d (d lgprinr lgfori lgcpf lgwage) / DN rstat
TWO STAGE LEAST SQUARES - DEPENDENT VARIABLE = LGMEMP
5 EXOGENOUS VARIABLES
3 POSSIBLE ENDOGENOUS VARIABLES

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO	P-VALUE
LGMANU	0.35932	0.1637	2.194	0.028
LGREM	-0.57935E-01	0.2973	-0.1949	0.846
D	-0.90547E-01	0.9482E-01	-0.9549	0.340
CONSTANT	9.4483	0.8301	11.38	0.000

R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.9540

|_2sls lgmanu lgprinr lgfori (d lgprinr lgfori lgcpf lgwage) / DN rstat
TWO STAGE LEAST SQUARES - DEPENDENT VARIABLE = LGMANU
5 EXOGENOUS VARIABLES
1 POSSIBLE ENDOGENOUS VARIABLES

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO	P-VALUE
LGPRINR	4.7868	0.5383	8.893	0.000
LGFORI	0.10667E-01	0.6271E-01	0.1701	0.865
CONSTANT	-12.389	2.131	-5.814	0.000

R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.8660

|_2sls lgrem lgcpf lgwage (d lgprinr lgfori lgcpf lgwage)/ DN rstat
TWO STAGE LEAST SQUARES - DEPENDENT VARIABLE = LGREM
5 EXOGENOUS VARIABLES
1 POSSIBLE ENDOGENOUS VARIABLES

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO	P-VALUE
LGCPF	0.45209E-01	0.1024	0.4416	0.659
LGWAGE	0.98955	0.4895E-01	20.22	0.000
CONSTANT	0.15546E-01	0.3042	0.5110E-01	0.959

R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.9494

Appendix 4.3 : Stationarity Tests

For stationarity tests, unit root tests of Dickey and Fuller (1981) are used. Consider the following "augmented Dickey-Fuller (ADF)" regression:

$$\Delta x(t) = \gamma + \delta t + \zeta x(t-1) + \sum_{i=1}^{k} \beta_i \Delta x(t-i) + \varepsilon(t)$$

The test statistics Φ_1, Φ_2 and Φ_3 are designed to test the following:
a) $H_0 : \zeta = 0$
b) $H_0 : \gamma = \delta = \zeta = 0$ (presence of drift)
c) $H_0 : \delta = \zeta = 0$ (presence of deterministic trend)
with the alternative hypothesis in each case being the stationarity of the series.

Testing Levels of the Variables

Test	Real Private Service GDP	Relative Price of Services	Real GDP	Critical Values (5% level)	(10% level)
Φ_1	-0.046	-1.01	-0.78	-3.6	-3.13
Φ_2	5.93*	5.95*	4.91**	5.68	4.03
Φ_3	6.9**	2.97	3.98	7.24	5.34

Note: Critical values for the tests are taken from Fuller (1976:373) and Dickey and Fuller (1981:1063). * and ** give evidence of stationarity at 5% and 10% level of significance respectively.

For the variables, real private service expenditure and relative price of services, the null hypothesis of non-stationarity for tests Φ_2 was rejected as the test values were above the critical values. The former variable also shows stationarity under test Φ_3 at 10% level of significance. Real GDP, on the other hand, is stationary at 10% level for test Φ_2. Since the tests above are not conclusive of stationarity for the levels of the variables, the first differences of the variables need to be checked for stationarity.

Testing First Differences of the Variables

To improve the results, the appropriate lag structure (to mop up any serial correlation in the estimation) was selected based on minimising Akaike Information Criterion (AIC), and maximising the log likelihood function. The unit root tests were then performed by regressing the second difference of the variable on the first difference of the first lag of the variable, and the second difference of the optimal lags of the variable and a constant. This requires the estimation of the following ADF regression:

$$\Delta^2 x(t) = \gamma_1 + \zeta_1 \Delta x(t-1) + \sum_{i=1}^{k} \beta_i' \Delta^2 x(t-i) + \varepsilon_1(t)$$

The null hypothesis tests whether $\zeta_1 = 0$ and the alternative hypothesis is stationarity of the series. The test statistics obtained are summarised below.

Real Private Service Expenditure	Relative Price of Services	Real GDP	Critical Values (5% level significance)
-1.395	-3.485*	-1.854	-3.0

Note: Critical value is taken from Maddala (1992).
* gives evidence of stationarity at 5% level of significance.

Only the first difference of the relative price of services is I (1) as its test statistic (the absolute value) is greater than the critical value, implying that the null hypothesis of non-stationarity is rejected. Although, many empirical studies have shown that the other two variables are integrated of order not more than one,[22] the results obtained above are possible due to the small sample size used, which in turn lowers the power of the unit root tests (that is, the chances of rejecting the null hypothesis of the unit root is low, although they may be no unit root present). Given these, for the existence of a relationship between these variables suspected of I(1), the residuals of the estimated relationship using the first differences of the variables, must exhibit stationarity.[23] In order to test that, an estimation of the equation (10) by OLS using the first differences is done and the results are reported in Appendix 4.4

An ADF regression was then performed on the levels of the residuals, $\hat{u}$, obtained from equation (11). As shown below, the ADF regression is then done without a constant or time trend. The null hypothesis that the residuals were non-stationary was then tested. The following was the estimated equation:

$$\Delta \hat{u}_t = \underset{(0.28)^*}{-1.06\, \hat{u}_{t-1}} + \underset{(0.20)}{0.10\, \Delta \hat{u}_{t-1}}$$

The t-ratio on $\hat{u}_{t-1}$ was -3.84 which is clearly greater than the critical value of -3.12 (obtained from Phillips and Ouliaris's (1990) tables on residual-based critical values), implying that $\hat{u}$ is stationary.[24] Thus, since the residuals of the estimated equation (11) are stationary, it can be concluded that there is a cointegrating relationship between the variables as the data is sufficiently informative on the long run characteristics of the series. But note that the long run relationship of concern, equation (11) is static as no lags of the variables were included.[25]

[22] While Cheung and Lai (1992) show evidence of unit root for real GDP for US and UK, Nelson and Plosser (1982), and Walton (1988) show that unit root exists for GNP in the US and UK respectively. See also, Cochrane (1988) and Diebold and Rudebusch (1989).

[23] See Engle and Granger (1991).

[24] The DW statistics was 1.97 indicating no serious problems with serial correlation and this reinforces the existence of a cointegrating relationship.

[25] Similar static relationships have been estimated in Giersch (ed., 1989:15) and Adams and Hickman (ed.1983: 201).

Appendix 4.4 : Estimation of Price and Income Elasticities of Services Using First Differences

Note: RPTES - Real Private Service Expenditure
RELP - Relative Price of Services
RGDP - Real GDP

Ordinary Least Squares Estimation

Dependent variable is LGRPTES
27 observations used for estimation from 1 to 27

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CONST	-2.1130	1.5725	-1.3437[.192]
RELP	-.33141	1.5791	-.20988[.836]
LGRGDP	1.0844	.20316	5.3376[.000]

R-Squared	.54675	F-statistic F(2, 24)	14.4754[.000]
R-Bar-Squared	.50898	S.E. of Regression	.64921
Residual Sum of Squares	10.1153	Mean of Dependent Variable	6.2393
S.D. of Dependent Variable	.92647	Maximum of Log-likelihood	-25.0572
DW-statistic	2.2026		

Diagnostic Tests

Test Statistics	LM Version	F Version
A:Serial Correlation	CHI-SQ(1)= .31282[.576]	F(1, 23)= .26960[.609]
B:Functional Form	CHI-SQ(1)= .19291[.661]	F(1, 23)= .16552[.688]
C:Normality	CHI-SQ(2)= 28.9969[.000]	Not applicable
D:Heteroscedasticity	CHI-SQ(1)= .66045[.416]	F(1, 25)= .62686[.436]

A:Lagrange multiplier test of residual serial correlation
B:Ramsey's RESET test using the square of the fitted values
C:Based on a test of skewness and kurtosis of residuals
D:Based on the regression of squared residuals on squared fitted values

Appendix 4.5 : Test for Stability of Income Elasticity Estimate

```
|_Sample 1 27
|_ols lgrptes relp  lgrgdp /rstat

REQUIRED MEMORY IS PAR=   4 CURRENT PAR=  700
 OLS ESTIMATION
    27 OBSERVATIONS     DEPENDENT VARIABLE = LGRPTES
...NOTE..SAMPLE RANGE SET TO:    1,   27
```

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO 24 DF	P-VALUE
RELP	-0.33141	1.579	-0.2099	0.836
LGRGDP	1.0844	0.2032	5.338	0.000
CONSTANT	-2.1130	1.573	-1.344	0.192

```
|_Diagnos/Chowtest
```

SEQUENTIAL CHOW AND GOLDFELD-QUANDT TESTS

N1	N2	SSE1	SSE2	CHOW	G-Q	DF1	DF2
4	23	0.40503E-01	10.015	0.41757E-01	0.80887E-01	1	20
5	22	0.82039E-01	9.8763	0.11035	0.78913E-01	2	19
6	21	0.10431	9.8517	0.11202	0.63530E-01	3	18
7	20	0.10810	9.8387	0.11857	0.46694E-01	4	17
8	19	0.11964	9.6811	0.22466	0.39546E-01	5	16
9	18	0.38140	8.9698	0.57201	0.10630	6	15
10	17	1.2263	8.2689	0.45716	0.29661	7	14
11	16	1.2640	8.2660	0.42996	0.24849	8	13
12	15	1.2861	8.0619	0.57460	0.21270	9	12
13	14	1.2946	7.5695	0.98807	0.18813	10	11
14	13	1.3133	7.0983	1.4178	0.16819	11	10
15	12	1.5085	6.8927	1.4282	0.16414	12	9
16	11	1.7439	6.7952	1.2921	0.15793	13	8
17	10	2.0299	6.5797	1.2242	0.15426	14	7
18	9	2.1445	6.1653	1.5208	0.13913	15	6
19	8	4.7800	5.0471	0.20533	0.29596	16	5
20	7	5.0850	4.6555	0.26936	0.25700	17	4
21	6	5.1749	3.6070	1.0628	0.23911	18	3
22	5	5.3415	3.5889	0.92877	0.15667	19	2
23	4	5.4364	2.5562	1.8591	0.10634	20	1

CHOW TEST - F DISTRIBUTION WITH DF1= 3 AND DF2= 21

Appendix 4.6 : OLS Estimation of Labour Demand Function in the Services Sector

Ordinary Least Squares Estimation

****

Dependent variable is LGSEMP
16 observations used for estimation from 1 to 16

****

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CONST	10.0402	.74439	13.4879[.000]
LGRPTES	.29024	.049967	5.8086[.000]
LGGOVT	-.046380	.095500	-.48566[.637]
LGREM	.28752	.080330	3.5793[.004]
D	-.12650	.025165	-5.0267[.000]

****

R-Squared	.99242	F-statistic F(4, 11)	360.2723[.000]
R-Bar-Squared	.98967	S.E. of Regression	.021235
Residual Sum of Squares	.0049600	Mean of Dependent Variable	13.0617
S.D. of Dependent Variable	.20893	Maximum of Log-likelihood	41.9285
DW-statistic	1.8309		

****

Diagnostic Tests

Test Statistics	LM Version	F Version
A:Serial Correlation	CHI-SQ(1)= .18577[.666]	F(1, 10)= .11747[.739]
B:Functional Form	CHI-SQ(1)= 3.9518[.047]	F(1, 10)= 3.2800[.100]
C:Normality	CHI-SQ(2)= .34184[.843]	Not applicable
D:Heteroscedasticity	CHI-SQ(1)= .5785E-3[.981]	F(1, 14)= .5062E-3[.982]

****

A:Lagrange multiplier test of residual serial correlation
B:Ramsey's RESET test using the square of the fitted values
C:Based on a test of skewness and kurtosis of residuals
D:Based on the regression of squared residuals on squared fitted values

Appendix 4.7 : 2SLS Estimation of Labour Demand Function in the Services Sector

l_2sls_lgsemp lgrptes lggovt lgrem d (d lgrelp lggovt lgrgdp lgcpf lgwage) / DN rstat
TWO STAGE LEAST SQUARES - DEPENDENT VARIABLE = LGSEMP
6 EXOGENOUS VARIABLES
3 POSSIBLE ENDOGENOUS VARIABLES

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO	P-VALUE
LGRPTES	0.28832	0.4926E-01	5.853	0.000
LGGOVT	0.32450E-01	0.9172E-01	0.3538	0.724
LGREM	0.27943	0.8608E-01	3.246	0.001
D	-0.12806	0.2128E-01	-6.018	0.000
CONSTANT	9.9629	0.7772	12.82	0.000

R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.9924

l_2sls lgrptes lggovt lgrelp lgrgdp (d lgrelp lggovt lgrgdp lgcpf lgwage) / DN rstat
TWO STAGE LEAST SQUARES - DEPENDENT VARIABLE = LGRPTES
6 EXOGENOUS VARIABLES
1 POSSIBLE ENDOGENOUS VARIABLES

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO	P-VALUE
LGGOVT	-0.54057	0.1459	-3.705	0.000
LGRELP	-0.18680	0.2274	-0.8213	0.411
LGRGDP	1.4733	0.1164	12.65	0.000
CONSTANT	-1.7307	0.3642	-4.753	0.000

R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.9917

l_2sls lgrem lgcpf lgwage lggovt (d lgrelp lggovt lgrgdp lgcpf lgwage) / DN rstat
TWO STAGE LEAST SQUARES - DEPENDENT VARIABLE = LGREM
6 EXOGENOUS VARIABLES
1 POSSIBLE ENDOGENOUS VARIABLES

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO	P-VALUE
LGCPF	0.21006	0.4866E-01	4.317	0.000
LGWAGE	1.1127	0.3197	3.481	0.001
LGGOVT	0.56620	0.2002	2.829	0.005
CONSTANT	-6.6232	0.6284	-10.54	0.000

R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.9886

Chapter 5

Productivity Performance : Total Factor Productivity Measure

5.1 Introduction

Total factor productivity (TFP) serves as an important measure of the productive performance of a firm because it considers the contribution of more than one input to output.

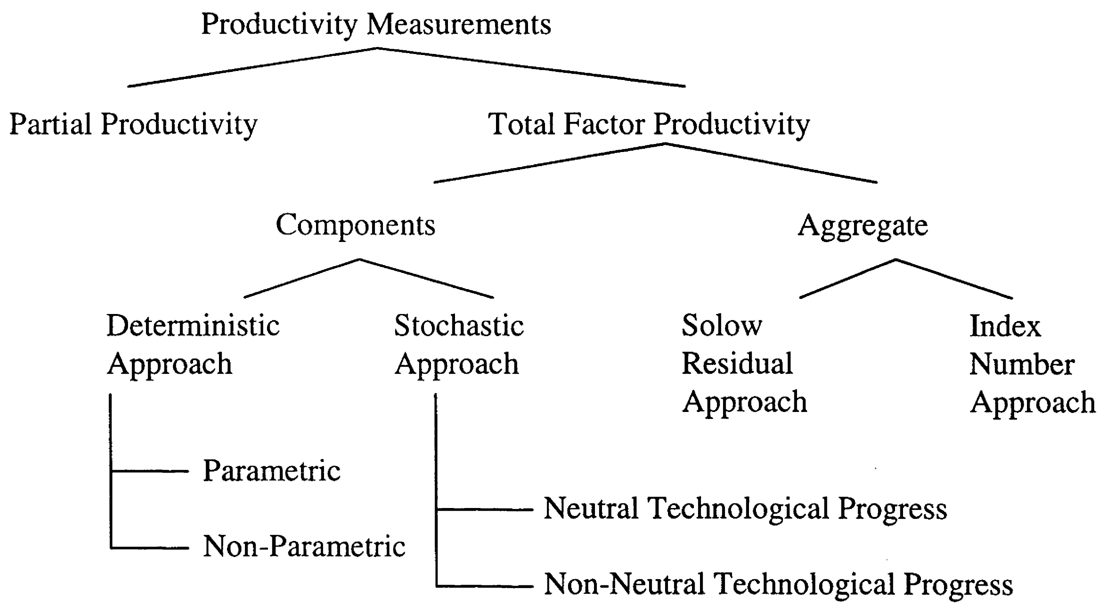
The concept of TFP is important to the growth process in the long run, as there are constraints imposed by population growth, together with diminishing returns that set in as capital intensity is increased. One way to secure economic growth beyond these limits is to secure ongoing increases in TFP. This is a very relevant issue for Singapore, which the OECD has upgraded to the status of an 'advanced newly developing country'. Some of the sources of TFP growth are changes in manpower characteristics, particularly the level of education and training, industrial restructuring as measured by shifts in employment from one industry to another, changes in the composition of capital used, and technical progress reflecting innovation and other qualitative advancements that improve the comprehension of technology over time.

This chapter is organised as follows. First, some theories and methodologies underlying TFP studies are discussed to highlight the advantages and disadvantages of various approaches. Second, the choice of the model for the study is explained, followed by the decompositional framework of the model. Then the theoretical underpinning of the model is described and lastly, the data sources and construction of variables for the empirical exercise are detailed.

5.2 Some Theories and Methodologies Underlying TFP Studies

The measurement of TFP growth has received considerable attention from theoretical and applied economists over the past four decades. The flowchart below is used to explain some of the many ways to calculate TFP.

Approaches to TFP Measurements



Productivity can be measured either as a partial measure or as a total factor productivity measure. The former, being output per worker, only considers labour input and ignores all other inputs, thereby causing misleading analyses. For instance, improvements in this measure could be due to capital substitution, changes in scale economies, quality improvements in labour, better discipline, new work rules and a host of other reasons unrelated to simply the more efficient use of labour. Thus, Coelli (1995a:220) claims that the use of this measure in the formulation of management and policy advice is likely to result in excessive use of other inputs which are not included in the efficiency measure. On the other hand, TFP measures avoid some of these problems like that of factor substitution, and in addition, can deal with scale economies and technological bias.

The two broad categories of TFP measures are the Aggregate and the TFP Components approaches. The aggregate approach can be further subdivided into the index number approach and the Solow residual approach. The former does not require any specification of a production function explicitly and this can be done using the Quantity Index number or the Tornqvist and Malmquist Index numbers. The quantity indexes are calculated using the Paasche or the more popular Laspeyres index. The Laspeyres index assumes that the production function is linear, which implies perfect substitutability of factors of production. The Tornqvist index number's underlying functional form is a translog production function at two points, *t* and *t-1*, and it can be measured in terms of price and quantity data at each point in time. When this index is corrected by a scale factor, it is equal to the mean of two Malmquist indexes. The Malmquist index is calculated using a nonparametric approach and is defined as production structures with arbitrary returns to scale, elasticity of substitution, and technical change biases.[1]

The Solow residual approach on the other hand, requires the specification of the production function and the production function parameters are calculated as factor shares using price and quantity data. It allows prices, and thereby marginal productivities, to vary unlike the Laspeyres and Paasche indexes. It assumes an aggregate production function of the form,

$$Y = A(t)\, f(x)$$

where x and y are inputs and output respectively. The technology function given by A, is assumed to be Hicks-neutral and thus equally capital and labour-augmenting. It is also exogenous and varies only with time. Hence the rate of technical change is disembodied in the sense that it is not associated with any particular input. Solow also assumes that f (•) is homogenous of degree one and that inputs are paid the value of their marginal product. This assumption indicates that producers maximise profit, implying that there can be no technical or allocative inefficiency. TFP growth is the residual of output growth after accounting for input growth. Thus, it is equivalent to technical change and is represented as a vertical shift of the production function.

Solow made the assumption that the time derivatives of A could be approximated by discrete changes but the resulting index is time invariant only under a very restrictive assumption of approximation of time. Using continuous time formulation, a Divisia index of productivity growth can also be obtained and evaluated directly from the data, without econometric estimation and this method is less restrictive than other indexes.

---

[1] See Caves, Christensen, and Diewert (1982).

Limitations of the Aggregate Approaches

The index number approach discussed above is not based on statistical theory, so statistical methods cannot be applied to evaluate their reliability. The quantity index approach is argued to be merely a useful concept but is not convenient for actual measurement of productivity growth. Moreover, Yotopoulos and Nugent (1976) explain that marginal productivities remain constant for a linear function, regardless of how fast one input grows in relation to the other, and thus TFP estimates are likely to be biased. With the Tornqvist index number, it has been shown that if the output prices do not approximate marginal costs, this index yields flawed TFP estimates. The Malmquist index's main drawback, on the other hand, is that it is deterministic.

The other aggregate measure, given by the Solow's residual approach, has been widely used in empirical studies and is based on some very strong assumptions, such as constant returns to scale, a competitive market and Hicks-neutral technology. Also, in this methodology, domestic price indexes and deflators are often used to deflate capital. Chen (1997) explains that the quality of improvement in the imported capital goods may not be accurately reflected by these deflators, and the under-deflation of capital input may result in underestimation of TFP.

Being a residual measure, Solow's approach to the TFP estimate would include all that is not accounted for, such as qualitative improvements in labour and capital input, economies of scale, X-inefficiency etc. Thus, Abramovitz (1956) refers to the TFP index as a "measure of ignorance" and Nadiri (1970) claims that, if indeed the inputs are measured properly and the function governing their interactions is correctly specified, residual TFP growth should be zero.

Where computations are concerned in this method, it is not easy to estimate accurately the required returns to capital and often the price of capital is used as a proxy. With the Divisia index, it is computationally difficult when there are more than two inputs and since this index is a line integral, its value is said to depend on the path of integration, leading to the problem of cycling (Hulten 1973).

Finally, the technology which is represented by A, is taken to be disembodied and exogenous and is either allowed to vary with time or with respect to some input. There is no separate adjustment for technological improvement embodied (change in efficiency) in labour or the capital stock where the new inputs are more efficient than the old inputs. However, more recent studies have tried to control for embodied improvements in the capital stock by use of vintage models or otherwise and that for labour by making qualitative adjustments in the age-sex-education composition of the labour force. But there is yet to be a consensus on the most suitable way of capturing this embodied technology component, such that the TFP residual will only capture the effects of disembodied technological change. In fact, Chen (1997) concludes that Singapore's small TFP should be interpreted as an indication that embodied technological change is more important than disembodied technological change.

The concept of embodied technology forms the very essence of Romer's (1986) endogenous growth models which argue for sustainable growth in the long-run. Hulten's (1992) findings indicate that 20 per cent or more of the residual TFP could be attributed to embodied technological change. Endogenous technological change can be due to the accumulation of knowledge in the learning-by-doing process, improvement in the instructions for mixing together raw materials, diffusion of new technology, improved managerial practice, R&D undertaken by government or profit-maximising agents, or can be affected by the overall market structure of industry because it affects the methods used for acquiring, developing or modifying technology.

Thus, more often than not, the concept of TFP change is used synonymously with technological change in the productivity literature. The conventional growth accounting measure does not distinguish between pure technological change (disembodied technological change or what has now been increasingly termed as technological progress) and changes in efficiency with which a known technology is applied to production, that is, embodied technological change (or technical efficiency, TE).[2] It is crucial to know how substantial productivity gains due to such 'technological mastery' are and if they outweigh gains from technological progress (TP).

Another theory underlying the importance of embodied technological change is

[2]Chen (1997) echoes the same view when he claimed that, "TFP, strictly speaking, should be used only for disembodied technological change." In light of this, he disagrees with Tsao (1982), Krugman (1994) and Young (1994) as they equated Singapore's low TFP to slow technological change, and argues that this is only one aspect of technological change.

Vernon's (1966) product cycle theory which Krugman (1979,1990) and Dollar (1986) had drawn upon to explain trade that takes place between North and South countries. There are two kinds of goods, new and old, and these are determined over time by two processes of technological change. New goods are recently developed products through the process of innovation and this superior ability to exploit new technology can be found in the developed countries in the North. In the early stages of a product's life, production needs to be located close to the market and thus these products are first produced and exported by the North. Once the production of a good becomes standardised, it is possible to produce it far from the main market. Thus, due to lower costs of production in the South, production in the form of foreign direct investment takes place in the South or the South could also 'borrow' this technology (often embodied in capital) in the form of patents and start producing these goods. The product cycle arises because what is a new good in one period eventually becomes an old good. The technology lag which takes the form of technical change, allows the South to produce and export old products. The 'flying geese' pattern is a development along this concept.[3] With technology transfer to the South, new products are transformed into old products, often resulting in an increase in the variety of products or product quality as they are modified or imitated by the South. The greater the variety of goods or high quality production of the South, the higher the rate of TE and hence TFP in the South. Therefore, the South necessarily invests in capital and accumulation of knowledge (human capital). Human capital is required for performing the necessary modifications or imitations and this is captured by TE.

The existence of TE is thus not just a theoretical concept and there is a need to address and quantify this measure to add more depth to the concept of TFP. The concepts of technological change and embodied technological progress are analytically different and thus have different policy implications. Nishimizu and Page (1982) explain that high rates of TP can coexist with deteriorating TE, perhaps due to failures in achieving technological mastery or due to short-run cost-minimising behaviour in the face of quasi-fixed vintage of capital and thus with low or often observed negative overall rates of TFP change. On the other hand, relatively low rates of TP can co-exist with rapidly improving TE. Policy actions intended to improve the rate of TFP growth can be badly

[3] Chen (1997) uses the 'flying geese' phenomenon (that has led to increased intra-industry trade within the Asia-Pacific region) to support his case that Singapore together with the other East Asian economies, can sustain growth; although they have been proven to be input-driven economies.

misdirected if focussed on accelerating the rate of innovation, for example, in circumstances where the cause of lagging TFP change is a low rate of mastery of diffusion of best practice technology.

This shortcoming has motivated the use of 'frontier' production studies where the change in TFP is decomposed into technological progress and changes in technical efficiency.[4] It is important to know how far off a firm is from the technological frontier at any one time, and how quickly it can reach the frontier. An illustration of these concepts is presented later, using the stochastic production frontier approach.

The TFP components approach is in accord with the theoretical definition of a production frontier. The word, 'frontier', emphasises the idea of maximality which it embodies and represents the 'best practice' technology. It estimates a frontier relationship that provides a benchmark - a most efficient industry or firm, and allows the calculation of relative efficiencies. Also, unlike the growth accounting approach which provides a picture of the shape of the technology of an average firm, the estimation of a frontier function will be most heavily influenced by the best performing firms and hence reflect the technology they are using. The frontier approach can be further subdivided into the deterministic and stochastic frontier approaches. The deterministic approach can be adopted using parametric and non-parametric approaches while the stochastic approach uses statistical techniques. In addition, the stochastic frontier approach[5] can be subdivided into neutral (fixed coefficients model) and non-neutral technological progress approaches (varying coefficients model), based on different assumptions on technological progress across time and observations.

Frontier Production Function

Farrel (1957) initiated this concept by describing an industry 'envelope' isoquant and this was followed by estimation of econometric frontiers by others. In general, there are three approaches found in the literature. These may be characterised as deterministic, probabilistic and stochastic estimation techniques.

a) The deterministic frontier model is defined by

---

[4] For a survey of the literature on the frontier production function, see Kalirajan and Shand (1994).
[5] For a comprehensive survey of stochastic frontier production functions, see Bauer (1990a) and Battese (1992).

$Y_i = f(X_i ; \beta) \exp(-U_i)$ $\qquad$ i = 1, 2, ..., N (no. of firms)

where Y_i represents the possible production level for the *i* th sample industry, $f(X_i ; \beta)$ is a suitable function of the vector of inputs X_i for the *i* th industry and a vector β of unknown parameters. U_i is a non-negative random variable associated with industry-specific factors which contribute to the *i* th industry not attaining maximum efficiency of production. Technical efficiency is measured by the ratio of actual output to potential output. The presence of U_i in the model is associated with technical efficiency of the industry and this implies that exp $(-U_i)$ has random values between zero and one. Thus it follows that the possible production Y_i, is bounded above by the non-stochastic (that is, deterministic) quantity $f(X_i ; \beta)$, and corresponds closely to the theoretical concept of the frontier as a boundary since all observations lie below the frontier.

The deterministic frontier model can be estimated through parametric and non-parametric approaches. The latter involves linear programming techniques and is supported by a subset of the data and this technique is often called the Data Envelopment (DEA) Analysis. The advantage of this procedure is that it is not based on any explicit model of the frontier. That is, there is no functional form imposed but being deterministic, it takes no account of the possible influence of measurement error and other noise in the data. However, Coelli (1995a) recommends that DEA be used when production involves more than one product, and the construction of an aggregate measure of output is difficult. Also, if price data are difficult to come by, this method becomes more attractive than estimating a multi-product cost or profit frontier.

The parametric approach has the ability to characterise frontier technology in a simple mathematical form and accommodates non-constant returns to scale but the functional form imposed needs to be appropriate. Work on the estimation using parametric frontier production functions are characterised by Aigner and Chu (1968), Afriat (1972) and Richmond (1974).

The development of a probabilistic frontier approach by Timmer (1971) was an attempt to allow some observations to lie above the frontier. He accomplishes this by allowing a pre-specified percentage of the most efficient observations to lie above the frontier.

Limitations of the Deterministic Frontier Models

The main criticism of the deterministic frontier is that no account is taken of the possible influence of measurement errors and other noise upon the shape and positioning of the estimated frontier, since all observed deviations from the estimates frontier are assumed to be the result of technical inefficiency. The non-parametric approach, in particular, is susceptible to measurement errors and extreme observations or outliers. On the other hand, the parametric approach of the probabilistic frontier's selection of the percentage of observations allowed to lie above the frontier is essentially very arbitrary, lacking explicit economic or statistical justification. Although Richmond (1974) using the probabilistic frontier tried an alternative method of estimation, the corrected OLS technique,[6] some of the residuals were still found to have the 'wrong sign' and ended up above the estimated production frontier. Another problem with this technique was that the correction to the constant term is not independent of the distribution assumed for U_i.

Greene (1980) states that the more serious shortcoming of these deterministic frontier estimators is their lack of identifiable statistical properties which do not allow for inference (or test the fit of the data by the production function) to be made as no standard errors can be derived for them. An attempt by Schmidt (1976) to specify the distribution assumptions for the disturbance terms such that the model can be estimated by maximum-likelihood techniques has been proven to violate the regularity condition. In particular, since $Y_i \leq f(X_i; \beta)$, the range of random variable Y depends on the parameters to be estimated. Therefore, the usual Cramer rule cannot be invoked to determine the asymptotic distributions of parameter estimates and it is not clear how else to obtain the standard errors of these estimators. Richmond (1974) suggested that the residuals follow a gamma distribution and although Greene (1980) agreed to the attractive statistical properties of this distribution, he laments that there is no theory to link the distribution to any specific economic process accounting for technical inefficiency.

The notion of this type of frontier shared by all firms ignores the real possibility that a firm's performance may be affected by factors entirely outside its control and to lump

[6] This involved using the moments of the error distribution, estimated by the OLS residuals, to adjust the intercept term of the model.

the effects of exogenous factors together with the effects of measurement error and inefficiency is somewhat questionable. The arguments discussed above then led to the formulation of the stochastic frontier model of Aigner (et al. 1977) and Meeusen and Van den Broeck (1977).

The deterministic production frontier assumes that all data points lie below the frontier, while the stochastic frontier allows some units to be more efficient than the estimated frontier. The deterministic frontier should therefore deliver higher estimates of inefficiency than stochastic ones. The stochastic frontier model also relieves the deterministic production frontier of excessive sensitivity to outliers and is recommended when data on inputs are not suitable measured (especially in services) and there is a need to allow for measurement errors.

b) The stochastic frontier production function is defined by

$$Y_i = f(X_i ; \beta) \exp(V_i - U_i) \qquad i = 1, 2, \ldots\ldots, N \text{ (no. of firms)} \qquad (1)$$

where the error term is composed of two parts, V_i and U_i . The random error V_i is assumed to be independently and identically distributed as $N(0, \sigma_v^2)$ and is associated with measurement errors, other statistical 'noise', and random factors (weather, industrial action etc.) not under the control of the firm. Sheenan (1997:61) explains that unlike the one-sided error structure (where $V_i = 0$) of the deterministic frontier, the two components of the error term in this model allow the statistical noise to be distinguished from inefficiency. The white noise term V_i helps overcome the data accuracy requirements imposed by linear programming techniques and deterministic production functions techniques, and therefore facilitates the estimation of real world data.

The main criticism of the stochastic frontier is that there is no *a priori* justification for the selection of any particular distributional form for the U_i. As in the deterministic model, U_i captures technical inefficiency and is a one-sided error component associated with firm-specific factors. It has been assumed by various authors to follow either non-negative truncations of the $N(\mu, \sigma_u^2)$ distribution or half-normal distributions, that is, N (0, σ_u^2), exponential or a gamma distribution. The negative value of U_i will vary among industries, depending on their technical efficiency or how close to the maximum possible output the *i* th industry can be by using the inputs X_i in a technically efficient way.

With panel data, this model can be written as :

$$Y_{it} = \beta_0 + X'_{it}\beta + V_{it} - U_{it} \quad (2)$$

where $i = 1,2, ..., N$ (no. of firms)

$t = 1,2, ..., T$ (no. of time periods)

By pooling the data, attempts were made to estimate time-varying and time-invariant TE by assuming different density functions for U_{it}.[7] Battese and Coelli (1995) explain that the main limitations of this approach are the imposition of the non-negativity constraint on U_{it} and the simple and restrictive assumption that U_{it} and V_{it} are independently distributed for all t =1, 2.,..., T and i = 1, 2,....., N. More has to be done to account for the possible correlated structures of the technical inefficiency effects and the random errors in the frontier.

In general, there are two methods of using panel data for estimation. In the first, the estimation of the parameters of the production frontier is conditional on fixed values of industry-specific but time invariant U_i's. This is the fixed effects model of the 'within' estimator of the β coefficients. In the second, the estimation is based on industry and time specific U_{it}'s and this is the random effects model.

Fixed Effects Model

In this model, the β_i's are considered as unknown fixed parameters. The parameter, β_0 is not identified in the mean. This implies that different values of β_0, β's and U_i's may lead to the same conditional mean $E(y_i/x_i)$. This happens due to the singularity of the matrix of the regressors. The model is specified as :

[7] See Battese and Coelli (1988), Battese, Coelli and Colby (1989), Kalirajan and Shand (1989), Kalirajan (1990) and Battese and Coelli (1992).

$$Y_{it} = \beta_{0i} + X'_{it}\beta + V_{it} \qquad (3)$$

where $\beta_{0i} = \beta_0 - U_{it}$

$i = 1,2, ..., N$ (no. of firms)

$t = 1,2, ..., T$ (no. of time periods)

Thus each firm has its own production level, sharing only the slope with the others. Technical efficiency is given by TE = exp ($\hat{u}_i$) where the most efficient firm will have a TE measure of one. The 'within' estimator of β's can be obtained by ordinary least square estimation of

$$Y_{it} - \bar{Y}_i = \beta' (X'_{it} - \bar{X}_i) + u_{it} \qquad (4)$$

The model has the advantage of allowing correlation between the inefficiency term and the dependent variables, and can be obtained without distributional assumptions on efficiency.

Limitations of the Fixed Effects Model

The estimation of β_0, and hence the efficiencies, may be viewed as somewhat arbitrary as firm-specific effects could include the influence of variables that may vary across firms but are invariant over time. Simar (1992) explains that the inefficiency measures will be typically sensitive to scale factors and the estimation of the production frontier will solely be based on the temporal variation of the production factors. The main disadvantage is that coefficients of time-invariant regressors cannot be estimated in this approach as these regressors are eliminated in the 'within' transformation of (4) above. Simar (1992) has also shown that this model appears to provide a poor estimation of the intercepts and the slope coefficients of frontier production functions, and consequently unreasonable TE estimates.

The Random Effects Model

Here, the stochastic nature of the efficiency effects is taken into account and the model can be written as:

$$Y_{it} = \beta_0 + \sum \beta_j X'_{jt} + V_{it} - U_{it}$$

The parameters can be estimated by generalised least square estimation (GLS), or maximum likelihood estimation. With the use of GLS, time-invariant regressors can be included and the model provides for consistent unbiased estimates if the regressors X'_{jt} are not correlated with the technical efficiency effects U_{it}. However, if they are correlated, then an instrumental variable approach can be used for estimation. But it may not be easy to choose the appropriate instrument.

Limitations of the Random Effects Model

One limitation with the above approach is the strong assumption that there would be no correlation between the regressors X_{it} and U_{it}. If a firm is aware of technical inefficiency (U_{it}), it is only rational to expect that the firm's input decision X_i is affected by this knowledge. The model is also highly parametrised and is rigid in the sense that TE must either increase or decrease at a decreasing rate, decrease at an increasing rate or remain constant. The choice of the density function of U_{it} is also crucial to the estimates obtained.

Cornwell, Schmidt and Sickles (1990) were able to be improve on the rigidity in the approach by assuming that the firm effects at different time periods were a quadratic function of time with the coefficients varying over firms according to a multivariate distribution. Thus there was no need to specify any special density function of U_{it} and firm-specific TE can now be calculated as:

$$TE = \hat{u}_{it} = \hat{\beta}_{ot} - \hat{\beta}_{oit}$$

where $\hat{\beta}_{ot} = \max \{ \hat{\beta}_{oi} \}$

However, Cornwell, Schmidt and Sickles only discussed the above formulation theoretically and restricted their empirical analysis to estimating TE as a 'lumpsum' with cross-sectional heterogeneity only in the intercepts.

5.3 The Stochastic Production Frontier Approach

The main limitation of the stochastic frontier approach discussed above is that for a given period of time, the production frontier is neutrally shifted from the 'average' and the realised production function. Over time, the production frontiers themselves shift neutrally, implying that technical change is also of a neutral type and the rate of technical change over time is constant among industries.

However, this approach is a major improvement over the conventional growth accounting approach as it facilitates the decomposition of output growth into not just input growth and TFP growth, but further decomposes TFP growth into TP and changes in TE. The conventional measure equates TFP growth with TP and ignores technical inefficiency. This means that firms are assumed to operate on the frontier as they are all technically efficient.

Another special feature of the stochastic frontier approach is that it treats total input growth as the residual unlike the growth accounting method. The main advantage of this is that problems which are usually encountered in productivity analyses, such as the adjustment for input quality changes, can then be avoided. The common argument that TFP as a residue causes misinterpretations does not hold in this methodology and thus TFP is likely to be a good performance measure in this model.

This approach has also been shown to be superior to the deterministic approach as it allows the error component to be separated into firm-specific factors and random factors. Given these advantages, the chosen model for this exercise is based on the stochastic frontier approach incorporating a neutral shift to enable a similar basis for comparison with the growth accounting which also assumes a neutral shift of the production function), but an improvement over existing models is incorporated by discarding the rigid assumption that the rate of technical change over time is constant among industries.

The other class of stochastic frontier models incorporate a non-neutral shift of the frontier whereby no assumptions of the distribution of technical efficiency are required and there is additional information of input-specific efficiency.

Production and Cost Frontier Estimations

TFP can be measured either from the production, profit or the cost frontier approach. Estimation of the production (profit/cost) functions using ordinary least square (OLS) technique provides unbiased estimates from a statistical perspective, but any such estimates must be biased downwards (upwards) in terms of the underlying economic theory that motivated them. Such biases exist when the concave production function or the convex cost function are estimated by a linear function using the OLS method.

Often the choice of the function is related to the nature of the inputs and output. If inputs are exogenous, a production frontier is used for estimation, and if output is exogenous, a cost frontier by duality is estimated. But Mundlak (1996) shows that estimates based on duality, unlike direct estimators of the production frontier, do not utilise all the available information and therefore are statistically inefficient and the loss in efficiency may be sizeable.

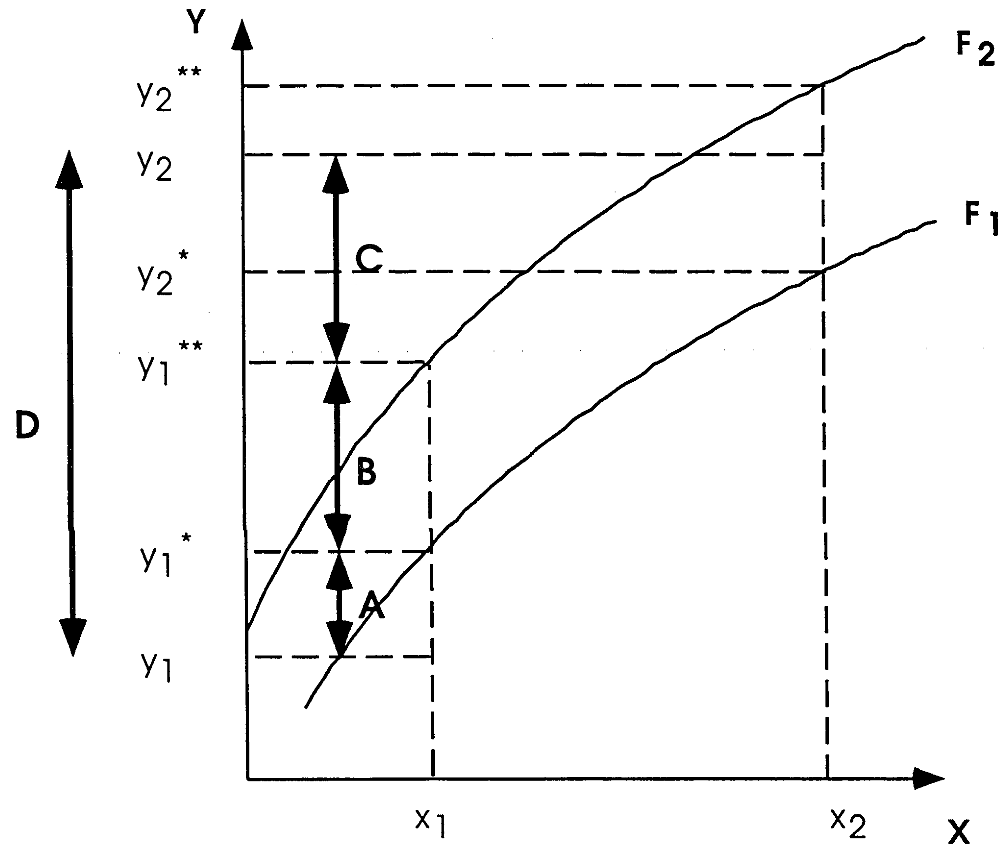
There are basically four other potential limitations to the cost function method. First, cost functions presume continuous adjustments of the factor mix to minimise cost (Tybout and Westbrook 1995). For various reasons, such as poor management or X-inefficiency, and labour shortage, the adjustment mix may be delayed. So, using cost functions to estimate technical efficiency may not give accurate results. Second, cost functions require output and factor price data which are not easy to obtain and often proxies have to be used for such data. The simultaneity between output and the error term is also said to be a problem with cost functions. Third, measuring industry costs is susceptible to measurement error, let alone the lack in accuracy of obtaining industry output and input data. Although the latter form of measurement error enters the estimation of the production function, at least it does not have to include the added inaccuracy of output and factor price data.

Fourth, maximum output is defined as the output corresponding to the minimum point on the average cost curve, and empirical determination is difficult, especially in the context of multi-product industries. Klein and Preston (1967) also point out that determination of the 'sharply defined minimum point' of the cost curve is impossible. Moreover, if most cost curves are L-shaped, as Johnston (1960) found in a number of cases, the determination of potential output become ambiguous. Hence, more reliable estimates of TE, TP and TFP can be obtained from the estimation of a production frontier.

The Decompositional Framework of Output Growth

The relationship of TFP growth to output growth in the stochastic frontier approach has been demonstrated by Kalirajan, Obwona and Zhao (1996) in Figure 5.1.

Figure 5.1: Sources of Output Growth



Assume that the industry faces production frontiers F_1 and F_2 (they are parallel to each other) in period 1 and period 2 respectively. Technology is assumed to be Hicks-neutral. If the industry is technically efficient, output would be on the frontier, that is, industry would be able to produce output y_1* in period 1, using x_1 input level and output y_2** in period 2, using x_2 input level. However, in periods 1 and 2, industry may be producing output y_1 and y_2 respectively, due to technical inefficiency in production. Hence by Farrell's (1957) definition, technical efficiency

$$TE = \frac{y}{y^*} \qquad \text{where} \qquad 0 < TE \leq 1$$

Alternatively, technical inefficiency in terms of output forgone can then be represented by the distance between the frontier output and actual output of a given industry in the figure. Or, the industry in period 1 is said to experience TE1 in period 1 if it is able to increase production from y_1 to y_1* and TE2 in period 2 if it is able to increase production from y_2 to y_2**. Thus, change in technical efficiency over time is the difference between TE1 and TE2 and technological progress is measured by the distance between frontier 2 and frontier 1 given by, $y_1** - y_1*$ evaluated at x_1 input level. The input growth between the two periods denoted by Δy_x causes the output growth of $y_2** - y_1**$. This output growth can be decomposed into three components, that is, input growth, TP, and change in TE.

The decomposition can be mathematically expressed as follows:

$$
\begin{aligned}
D &= y_2 - y_1 \\
&= A + B + C \\
&= [y_1* - y_1] + [y_1** - y_1*] + [y_2 - y_1**] \\
&= [y_1* - y_1] + [y_1** - y_1*] + [y_2 - y_1**] + [y_2** - y_2**] \\
&= [y_1* - y_1] + [y_1** - y_1*] - [y_2** - y_2] + [y_2** - y_1**] \\
&= \{(y_1* - y_1) - (y_2** - y_2)\} + (y_1** - y_1*) + (y_2** - y_1**) \qquad (5) \\
&= \dot{TE} + \dot{TP} + \dot{y}_x*
\end{aligned}
$$

where $y_2 - y_1$ = production output growth between two periods

$\dot{TE}$ = change in technical efficiency

$\dot{TP}$ = technological progress (shifts in the production frontier over time)

$\dot{y}_x*$ = change in output production due to input growth (shifts along the production frontier)

Total factor productivity growth measures output growth after taking into account input growth, and consists of changes in technical efficiency over time and shifts in technology over time. It can be expressed as follows:

$$\dot{TFP} = \dot{TE} + \dot{TP}$$

Description of Model

In applying the stochastic production frontier to panel data (as will be the case in this exercise), it is necessary to look into the assumption of technical efficiency and the specification of the model on a time-series dimension. The following cases for u_{it} (of Equation 2) are worth considering:

1) u_{it}'s remain constant over time or are time-invariant. This is to say that the TE of industries follows a particular distribution during a particular period of time and this distribution remains unchanged over time, and thus TE of each industry remains constant over time. Any deviation from the production function results from random shock rather than inefficiency.

2) u_{it}'s are correlated over time for a particular industry and Cov $(u_{it}, u_{it'}) = \sigma_{tt}$ for all i and Cov $(u_{it}, u_{jt'}) = 0$ for all $i \neq j$. Here, any variation from technical efficiency follows a traceable pattern.

3) u_{it}'s are uncorrelated with other units across industries at any point in time as well as over time for any particular industry. Here, technical efficiency is determined by the specific production of the i th industry at the t th time.

In case 1), u_{it} can be expressed as u_i and this is Pitt and Lee's (1981) model for the estimation of the average technical efficiency. Battese, Coelli and Colby (1989), using panel data, relaxed the assumption for the distribution of u_{it}, which was still normally distributed but not necessarily truncated at zero.

Case 2) is a general case of case 1), as the latter is not economically rational and is unable to deal with changing technical efficiency. Economists argue that it is possible for industries to be aware of inefficiency if the period of investigation is sufficiently long, and if inefficiency is detected, then it is economically rational and realistic to expect a profit-maximising industry to deal with it. To deal with this, a time-variant model for u_{it} is necessary.

So far, three time invariant models have been proposed. In the simplest and most straightforward specification, proposed by Battese and Coelli (1992), u_{it} is assumed to be an exponential function of time, where,

$$u_{it} = \eta_{it} u_i = \{ \exp [-\eta (t - T)] \} u_i$$

where T is the length of time and *t* refers to the *t* th period. Both Cao (1995) and Wong and Tok (1994) used this specification for Singapore's manufacturing industries. But in this specification, it is implicitly assumed that variation of all firm effects (technical efficiency) is monotone throughout time periods and that one rate of change applies to all industries in the sample. Technical efficiency either increases, remains constant or decreases depending on whether $\eta > 0$, $\eta = 0$ or $\eta < 0$. This is, as the authors have pointed out, 'a rigid parametrisation'.

In a relatively flexible model, proposed by Cornwell, Schmidt and Sickles (1990), u_{it} is assumed to be a quadratic function of time where the frontier production function is defined as:

$$Y_{it} = \alpha_i + X'_{it}\beta + v_{it} \qquad \text{and} \qquad \alpha_{it} = \theta_{i1} + \theta_{i2} t + \theta_{i3} t^2$$

where *t* is time trend. Similarly, Kumbhakar (1990) proposed the following time-variant model for u_{it} but no empirical application has yet been attempted :

$$u_{it} = \gamma(t) \tau_i \qquad \text{and} \qquad \gamma(t) = [1 + \exp (bt + ct^2)]^{-1}$$

The latter two models are superior to the first one since, in addition to the direction of the time trend, the concavity or convexity behaviour of technical efficiency over time can also be determined by the parameter θ_{i3} and *c* above. In both cases, u_{it} is a monotonic function of time.

For the following reason, not all of these models are relevant for the services and manufacturing sectors in Singapore. Between the late 70s to the 90s, the Singapore government's ongoing policy has been geared towards encouraging manufacturing industries to progress from labour intensive production processes to capital intensive and higher value added activities. The increasing use of capital and information technology intensive operations has also changed the provision of services in the economy. Furthermore, the impact of technology, government policy and incentives are also expected to vary among the industries. Thus, it is unrealistic to assume that TE of different industries (within the broad sectors of manufacturing and services), given their differences in products and market behaviour, would vary with the same magnitude over time. The possibility of different responses need to be taken into account.

To capture these variations, the distribution of TE is assumed to follow case 3), according to the specifications of a multivariate distribution. Thus, u_{it} in the most general sense is assumed to follow a truncated normal distribution, allowing the modal efficiency to be strictly positive and identifying it in the estimation. The related assumptions are as follows:

$u_{it} \sim N(\mu, \sigma_u^2)$

$v_{it} \sim N(0, \sigma_v^2)$

$E(u_{it}\ u_{i't'}) = 0$ for all $i \neq i'$ and $t \neq t'$

$E(u_{it}\ u_{i't'}) = \sigma_u^2$ for $i = i'$ and $t = t'$

$E(v_{it}\ v_{i't'}) = 0$ for all $i \neq i'$ and $t \neq t'$

$E(v_{it}\ v_{i't'}) = \sigma_v^2$ for $i = i'$ and $t = t'$

$E(u_{it}\ v_{i't'}) = 0$ for all i and t

where $t = 1, 2, \ldots T$ (no. of years) and $i = 1, 2, \ldots N$ (no. of industries in a sector)

μ = mean of the truncated normal distribution of u_{it}

σ_u^2, σ_v^2 = variances of distributions u_{it} and v_{it} respectively.

Unlike the specifications of Pitt and Lee (1981), Schmidt and Sickles (1984), Battese, Coelli and Colby (1989), Kumbhakar (1990) and Cornwell, Schmidt and Sickles (1990), the above specification does not impose a uniform pattern of change over time in technical efficiency for all industries in the sample. Maximum likelihood methods of estimation can be used to estimate the frontier coefficients as shown in Drysdale, Kalirajan and Zhao (1995).

For both the manufacturing and services samples, it was found that when u_{it} followed a half-normal distribution, the frontier model has significant explanatory power.[8] Cao (1995) also found this to be true for manufacturing industries in Singapore. Wong and Tok (1994), however, used the more general truncated normal distribution but failed to provide statistical evidence for their choice. The half-normal distribution has also been widely used by Aigner (et al. 1977), Jondrow et al. (1982), Kalirajan and Flinn (1983), Schmidt and Sickles (1984) and Battese, Coelli and Colby (1989), but they are mainly defined on cross-section rather than on panel data.

In addition, a parameter, γ , varying between 0 and 1, and which is the ratio of the variance of the distribution u_{it} to the variance of the residual term in Equation (1) is estimated . If γ is found to be zero or close to zero, this means that the residual terms are dominated by the true random noise v_{it} . This suggests that the random variable u_{it}, and thus the stochastic frontier model, has little explanatory power. Conversely, if γ is found to be close to 1, then the residuals are dominated by u_{it} and the model has high explanatory power.

5.4 Data Sources and Variables Construction

Data Sources

For the manufacturing sector, value added, capital expenditure, net value of fixed assets, remuneration paid to workers, and the numbers employed in each industry can be obtained from the annual publication, *Report on the Census of Industrial Production.*

For the services sector, all of the above information can be obtained from the *Report on Survey of Services* for various years, *The Service Sector 1990-93, Census of Services 1994*, as well as separate *Economics Survey Series* published on Wholesale and Retail, Transport and Communication, Financial and Business Services. Data on workers

[8] Evidence for this is provided in Chapter 7 and 8 for the manufacturing and services sectors respectively.

employed by occupational groups and average weekly hours worked by these occupational categories were obtained from the annual issues of the *Singapore Yearbook of Labour Statistics* and the *Report on the Labour Force Survey of Singapore.*

The GDP deflators by sectors and the gross domestic fixed capital formation price deflators for the various categories of capital assets as well as the property price indices are obtained from the *Singapore Yearbook of Statistics.*

Use of Panel Data

The services sector consists of 17 service industries, some at two and some at 3-digit industry level. The manufacturing sector has 28, 3-digit manufacturing industries. A point to note is that data on services were available biennially from 1974 to 1984 and annually since then. For the missing years, the values were taken to be averages of the preceding and the consecutive year. The period of study for both sectors is from 1975 to 1994. The details of the breakdown of the 17 service industries and 28 manufacturing industries are given in Appendix 5.1.

For the estimation of the above equation, pooled data (where all observations are characterised by the same regression equation at all points in time) are used for the following reasons. First, observing industries over a number of years permits a test for structural change in the production function. Second, it is not possible to estimate the TFP of individual industries from a single cross-section. Third, by observing the industry more than once, TFP can be estimated more precisely. Fourth, Sheenan (1997:66) claims that the use of panel data reduces the sensitivity of the results to the measure of capital stock, often fraught with inaccuracies and arbitrariness.

Finally, the use of pooled data permits the comparison of our results with earlier studies that have used aggregate data, or pooled data of the various 3-digit industries separately for the manufacturing sector. For the services sector, Virabhak (1996) has calculated TFP for each service industry separately, and Rao and Lee (1995) have calculated TFP for the services sector as a residual, where the manufacturing sector is netted out from the total economy. Both of these studies have used the growth accounting approach. This is the first study which attempts to use pooled information for the manufacturing and services sectors.

Construction of Variables

The value added measure is obtained from published data[9] and is a contrast to the netting out of inputs from the gross output measure. The latter is the commonly used method in many of the TFP studies on Singapore. Since the possibility of the use of industry-specific inputs exist, obtaining value added by netting out expenditure on labour, capital, energy and materials input from gross output, instead of using published data on value added, can be inaccurate. Thus, Bernolak (1980) claims that this measure has the advantage that it can be matched with the resources used in production.

However, Norsworthy and Jang (1993) and Oulton and O'Mahony (1994) argue that using value added distorts technology in estimating TFP growth because all raw and semifinished materials, subassemblies, energy and purchase services, are omitted from measured inputs. Moreover, price variation across industries could be a source of value added variation.

The published valued added data is single-deflated in that it is deflated only once using the GDP deflator (with 1985 as the base year) after the value added was calculated. Unfortunately, the GDP deflators from the national accounts are not industry-specific.[10]

For manufacturing, capital assets are basically composed of land, buildings and structures, machinery equipment, office equipment and transport equipment. But due to varying categorisation of capital assets over time,[11] capital expenditure was taken as an aggregate value. This was at gross value as data on capital assets sold was not available since 1993. The gross capital expenditure was then deflated by the average of the gross domestic capital formation price deflators of non-residential building, transport equipment, machinery and equipment, taken from the national accounts.

To depreciate gross capital expenditure, Jorgenson's (1990) depreciation rates were used as independent depreciation rates for Singapore were not available. The estimates

---

[9] The published value added data were collected by subtracting materials, utilities, fuel, transportation costs and work contracted out from gross output.

[10] For example, the broad sector manufacturing GDP deflator had to be used for all of the twenty-eight 3-digit industries in the manufacturing sector. For the services sector, the GDP deflator for commerce was used for 3 of its sub-service components; the GDP deflator for Transport and Communication was used for 6 of its sub-service sectors and that for Financial and Business services was used for 8 of its sub-services categories.

[11] From 1974 to 1990, capital assets was given in 4 categories. In 1991, it was revised to 2 assets groups.

for various capital assets are given as: 0.0361 for non-residential building, 0.1048 for machinery and equipment, 0.02935 for transport equipment, 0.2729 for office equipment. As aggregate capital expenditure was considered, a simple average of 0.1768 of the above rates was used.

For the services sector, capital assets were considered separately according to the following categories: a) land and building b) transport equipment c) machinery and equipment. Gross capital expenditure of each of these capital assets were then calculated as for the manufacturing sector and were deflated appropriately by separate price indices. For land and building, the property price index of various types were considered.[12] For transport equipment and machinery and equipment, the appropriate gross domestic fixed capital formation price deflators were used. This was the same for all service industries. A point to note is that since no industry-specific asset price deflators were available, the implicit assumption here is that all industries experienced the same rates of price increase for their capital assets.

Finally, the capital stock series was calculated using the perpetual inventory method with 1974 as the benchmark year for both the service and manufacturing sectors. The net value of fixed assets[13] for 1974 was used as the initial capital stock for both sectors. By assuming depreciation rates for each asset type, the relationship between investment and capital stock at the beginning of any year is given by

$$K_{it} = (1-d_i)\ K_{i,t-1} + I_{t-1}$$

where

K_{it} = capital stock of asset category i at time t

d_i = depreciation rate by asset category i

I_{t-1} = gross investment at time t-1

Thus, a time series of the value of capital stock can be constructed from cumulated past capital expenditures after they have been adjusted for depreciation. Strictly speaking, there should be some adjustment for capacity because it is actually employed capital that

[12] See Appendix 5.2 for details.

[13] Fixed assets refers to all physical assets owned by the establishment.

contributes to output, not unemployed capital. To the extent that capacity-utilisation is over-stated, the measure of the productive capital stock will be over-stated and hence TFP understated. Unfortunately, no such information is available to obtain more accurate results.

Labour

The main measure used was the number of workers employed in each sector. For services, however, another measure was also used, where the number of workers employed was adjusted according to 3 occupational groups and their average weekly hours worked using 1974 as a base index. They are: i) professional, administration, management, and related workers, ii) production, transport, and other related workers, iii) clerical, sales, service and related workers. Data on these occupational categories were given for the single digit service industries, 6, 7 and 8. Thus, the ratio of each of these workers in these categories was assumed to be the same for all the 2 and 3 digit service industries within that single digit service sector. Data on average weekly hours worked by occupation for each single digit service sector were available from 1974-87. However, the data format was changed subsequently, to provide only overall average hours worked across all occupations for each single digit service industry. Thus, from 1987 onwards, weights were used to assign hours worked to each occupational group (see Appendix 5.3 for details).

Appendix 5.1 : List of Industries in the Manufacturing and Services Sectors

The Service Sector

61	Wholesale Trade
62	Retail Trade
63	Hotels and Catering
711	Land Transport
712	Water Transport
713	Air Transport
714	Services Allied to Transport
715	Storage and Warehousing
72	Communications
81	Finance Services
82	Insurance Services
831	Real estate
832	Legal Services
833	Accounting, Auditing & Book-keeping Services
834	Information Technology Services
835	Engineering, Architectural & Technical Services
836/9	Other Business Services

The Manufacturing Sector

311/2	Food
313	Beverage
314	Tobacco Products
321	Textiles
322	Wearing Apparel
323	Leather & Leather Products
324	Footwear
331	Timber Products (except Furniture)
332	Furniture & Fixtures
341	Paper & Paper Products
342	Printing & Publishing
351	Industrial Chemicals and Gases
352	Paints, Pharmaceutical & Other Chemical Products
353/4	Petroleum Products
355/6	Rubber Products & Jelutong Processing
357	Plastic Products
361/2	Pottery and Glass Products
363	Structural Clay Products
364	Cement
365	Concrete Products
369	Nonmetallic Mineral Products
371	Iron & Steel
372	Non-ferrous Metal
381	Fabricated Metal Products
382	Industrial Machinery
383	Electrical Machinery
384	Electronic Products
385	Transport Equipment

Appendix 5.2 : Use of property price index to deflate land and buildings.

The following are various types of land and building:
i) offices ii) shops iii) industrial.
The list below shows how the various service industries were classified.

Industrial	:715
Offices/Industrial	:711-714
Offices	:81-836
Shops	:61,62
Offices/Shops	:63,72

Thus the property price indices were used according to the above list and where some services do not fit exclusively into any particular category, a simple average was applied.

Appendix 5.3 : Assigning weights to occupational groups to calculate the hours worked by occupational groups.

Select the occupational group which has the largest number employed within the chosen industry. Assign weights to the other occupational groups according to the formula below. If category (iii) has the highest number, then

Weight for (i) = Number employed in (i)/ Number employed in (iii)
Weight for (ii) = Number employed in (ii)/ Number employed in (iii)

The weights obtained using 1987 values are assumed to remain the same for all the years from 1988-94.

Thus for any given year, number of weekly hours worked by those in (iii) can be found from the equation below:

Number of weekly hours for industry (overall weekly hours is available)
= [share (iii) + weight for (i) * share (i) + weight for (ii) * share(ii)] * Number of weekly hours by those in (iii)

where share (j) = ratio of number employed in the j th occupation to total employment for the service sector in the given year.
* represents the multiplication operator.

Using the above information, weekly hours for those in (i) and (ii) can then be calculated using appropriate weights and shares.

Chapter 6

Total Factor Productivity Studies in Singapore

6.1 Introduction

Since the early 90s, discussions on total factor productivity have become increasingly important for Singapore. Young (1992) first argued that, although Singapore and Hong Kong were two similar cities, Singapore was nowhere near its twin city in terms of TFP. This was then emphasised by Krugman (1994) who found that Singapore was one of the NIEs which experienced no TFP growth.

Lim (1986:5) once commented that, "if a country can raise its standard of living so spectacularly with a very low TFP growth, does it then matter whether TFP growth is low?"[1] Peebles and Wilson (1996: 205), as a reply to Lim, argued that an important point is missed in this comment which only looks at the benefits resulting from high growth and ignores the cost of achieving such growth. This means that TFP analysis in Singapore is not to be taken lightly.

The Singapore Productivity and Standards Board was set up in April 1996 with one of its goals being that of raising the economy's TFP growth. It was noted that most developed countries at the same development stage as Singapore were having TFP growth rates between 2% and 4% while Singapore registered an insignificant 0.4% between 1980 and 1992. The target is now set to reach at least 2% in order to sustain a (labour) productivity growth of 4% and a GDP growth of 7%.[2] The importance of TFP in Singapore is further reflected in the numerous studies undertaken to examine the issue.

6.2 Review of TFP Studies on Singapore

There has been substantial amount of empirical work done on TFP studies using both

[1] Peebles and Wilson (1996:204) report that Singapore's chosen role model, Switzerland, in Young's (1994) study, registered zero TFP growth and being the richest country in the world, this resurrects Lim's question.

[2] See The Straits Times (Singapore) 2 Nov 1995, and Department of Statistics (Singapore, 1997).

cross-country and inter-temporal analysis for Singapore, some of which are summarised in Table 6.1.

Table 6.1 : TFP Growth Estimates for Singapore (Percent)

Source	Time Period	Overall Economy	Time Period	Manu	Serv
Bosworth, Collins & Chen (1995)	1960-92	0.60			
Chen (1977)	1955-70	3.62	1960-70	3.34	
Collins and Bosworth (1996)	1960-73	0.90			
	1973-84	1.0			
	1984-94	3.10			
Drysdale and Huang (1996)	1960-90	0.80			
Kawai (1994)	1970-80	0.70			
	1980-90	1.60			
Kim & Lau (1994)	1964-90	1.90			
Leung (1997)			1983-93	2-3	
Nehru & Dhareshwar (1994)	1960-87	-0.80			
	1960-73	4.70			
	1973-87	1.50			
Rao and Lee (1995)	1966-73	1.30			
	1976-84	0.60	1976-84	-0.40	0.90
	1987-94	2.60	1987-94	3.20	2.20
Sarel (1995)	1975-90	0.02			
Sarel (1997)	1978-96	2.23			
	1991-96	2.46			
Takenake (1995)	1970-92	-2.40			
Tsao (1982)	1966-72	0.60	1966-72	0.06	
	1972-80	-0.90	1972-80	2.16	
Tsao (1985)			1970-79	0.08	
Van Eklan (1995)	1961-91	1.80			
Virabhak (1996) [a]			1976-84		-0.14 to 0.13
			1986-92/93		-0.09 to 0.20
World Bank (1993) [b]	1960-90	1.19			
		-3.01			
Wong and Gan (1994)			1981-85	-0.80	
			1986-90	4.01	
Young (1992)	1966-85	-0.50			
Young (1994)	1970-85	0.10			
Young (1995)	1966-90	0.20	1970-90	-1.00	

Note: [a] Except for real estate which registered a TFP growth of 1.6 % for 1976-84, and storage and warehousing which had a TFP growth of 0.57 % for 1986-92/93, all other industries were within the stated range.

[b] The lower value was obtained sing a sample of high and low-income countries while the higher value was obtained using a sample that of high-income countries only.

Source: Compiled from various studies.

Most of the studies quoted above show that TFP growth in Singapore has been insignificant, particularly in comparison with the NIEs and other countries. After the pioneering work of Tsao (1982) on Singapore, studies like Wong and Gan (1994), Toh and Low (1994), and Rao and Lee (1995) have reexamined this issue and concluded that TFP growth has increased in the latter half of the 80s. While Sarel (1997) shows improvements in TFP growth estimate in the early 90s, Leung's (1997) results are inconclusive. It is obvious that the summary shows results which vary quite significantly from one another and this is due to different methodologies and data used and different time periods of study. Nevertheless, a brief critical analysis of some of these studies are necessary to understand the problems that still exist in the analysis of TFP growth.

First, a review of often-cited cross-country analyses in which Singapore is included is done. This is followed by some of the studies which have concentrated only on Singapore.

Review of Cross-Country TFP Studies

Most of these studies focus on the aggregate economy's TFP growth and extra caution on interpretation is necessary on aggregate economy studies due to aggregation bias. Since the economy's overall measure of TFP growth is effectively a weighted sum of the three sectors: agriculture, manufacturing and services. Any shift in labour from a less productive to a more productive sector would result in an increase in overall TFP growth without there having been any real change in TFP growth rates of either sector. Singapore is unlikely to have experienced any such inter-sectoral labour shifts (due to the virtual absence of agriculture and the importance of both services and manufacturing since the early 70s) and thereby is not strictly comparable to other economies which might register higher TFP growth due to differences in the structure of their economy.

Goh and Low (1996:5) point out the following problems in Singapore's data on capital that might lead to inaccurate TFP growth estimates where international comparisons are concerned. First, capital stock data are not officially published and estimating them by various methods is bound to lead to inaccuracy. Second, some capital input data tend to be over-reported as entrepreneurs bring forward depreciation to avoid taxes, as government policy encourages them to do so under accelerated depreciation allowance to promote new technology.

The studies reviewed below are centred on the aggregate economy or the manufacturing sector. This is followed by a review of TFP studies on services.

Pack and Page (1992) in their World Bank (1993) report used two approaches in their TFP study. The first approach was the estimation of a Cobb-Douglas production function method based on Nishimizu and Page (1982). Here, it is assumed that every country has access to the same production function which is taken to represent the best practice and they share the same elasticities of output with respect to inputs and are subject to the same unitary elasticity of substitution between factors. The other strong assumption is that the rate of technological progress is constant and is given by the average TFP growth rate of high-income countries. This is clearly a subjective benchmark. This approach resulted in Singapore being classified as investment-driven.

The sensitivity of the results of this study to changes in the composition of the sample was made apparent by Lall, Tan and Chew (1996) where they showed that, in a growth accounting exercise, a higher share of capital will hurt countries like Singapore which have high rates of capital accumulation. Also, as noted by the World Bank (1993:77) and Harberger (1996:367), a substantial amount of capital was spent in providing housing in Singapore. The latter study explains that the marginal product of housing capital is much lower than corporate capital and this results in lower output growth and hence, possibly, lower TFP growth for Singapore. The hypothesis that TFP ought to only reflect industrial investment was supported by De Long and Summers (1991) who argue that it is investment in equipment (comprising electrical and non-electrical machinery) more so than other forms of investment that contribute to output growth. Peebles and Wilson (1996:205) explain that instead of using the cruder ratio of total investment to GDP, if tests were done using only investment in machinery, then the conclusion that capital-driven Singapore is inefficient in its capital usage may not been true.

The second approach corresponds to the transitional dynamics of an enhanced neoclassical growth model with human capital, attributed to Mankiw, Romer and Weil (1992). Here, the average rate of real per capita income growth is regressed on a shift variable (which measures the relative per capita income gap between the subject country and the US in 1960), primary school enrolment rate in 1960, growth rate of the economically active population, and average share of investment in GDP over 1960-85, using a database of more than 100 countries. The deviations from this average experience of the regression result is then taken to represent changes in TE and hence changes in TFP growth since technological progress is assumed to be constant. With this approach, Singapore was reclassified as productivity-driven together with Japan, Korea, Taiwan and Hong Kong.

But a few points need to be noted with the second approach which classifies Singapore as productivity-driven. First, the deviations do not necessarily measure changes in TE.[3] Second, Singh (1995:43) explains that one of the criteria for late industrialises to 'catch up' (this is often associated with the concept of TE) with the advanced countries is to invest in tertiary education. Furthermore, Knowles' (1997) provides empirical evidence across 77 countries whereby tertiary education provides the largest increases in the marginal product of labour for both high and low-income countries. Thus, comparing primary school enrolment does not seem appropriate. Third, using the share of investment in GDP in Singapore's case would reflect more on the import of technology for use (that is, TP) and there may be minimal learning-by-doing spillover effects and thus, little change in TE is said to take place. Lastly, using cross-country data masks the Singaporean case where there is overwhelming evidence that Singapore's change in TE has been low or even negative for the manufacturing and services sectors.[4]

Solow (1994:51) echoes the views of many by stating that these international cross-section regressions "seem altogether too vulnerable to bias from omitted variables, to reverse causation, and above all to the recurrent suspicion that the experiences of very different national economies are not to be explained as they represented different 'points' on some well-defined surface." These regressions are sensitive to the choice of explanatory variables and often exchange rates are a poor proxy for relative purchasing power. But using the Penn World Tables, which follow purchasing power parity,

[3]Eggleston (1997:20) claims that the estimate is a 'double residual' since estimates of TE change are the residual after subtracting the average TFP growth rate for high-income economies from the individual country TFP growth estimates, which are themselves Solow residuals of growth.

[4] See Chapters 7 and 8 for evidence, and Wong and Tok (1994).

Bosworth, Collins and Chen (1995), Sarel (1995), and Drysdale and Huang (1996)[5] provide empirical results that support Young (1992) and Krugman (1994) in their claim that Singapore's output growth is input driven and is less significant than the other NIEs.

Young (1992, 1994, 1995)

Young adopted the conventional growth accounting approach and used data on the aggregate economy to show that Singapore's TFP growth was low and insignificant compared to that of Hong Kong. Unfortunately, the conventional approach places great importance on how inputs are adjusted as the TFP growth estimate is calculated as a residual. There is great debate and little consensus on the measurement of capital and quality-adjusted labour,[6] which have led to very different capital share estimates and hence different TFP results from Young.[7]

In the conventional growth accounting framework, TFP growth is a measure of disembodied TP. Young's low TFP growth estimate is scrutinised for Singapore in Chapters 7 and 8 in this study using a stochastic frontier model. Thus, Young's inference that Singapore's targeting polices are flawed is tested here. As it was industrial targeting that brought in huge amounts of FDI and hence disembodied TP in the form of advanced machinery and equipment, our hypothesis is that Singapore's TP cannot be as low as Young concludes. Furthermore, as Krugman (1992) pointed out, Young's postulation that Singapore has consistently pushed itself into technologies too far ahead of itself to benefit from learning by doing, may be correct, and is tested in this study.

In his 1992 study, Young admits that Singapore's low and negative TFP growth rates can be partly attributed to business cycle fluctuations but his later attempts did not address this issue. In fact, in his 1994 study, output growth was measured from 1970 to 1985 but 1985 is a recession year for many countries and it may have affected some countries more than others, thereby leading to biases in his cross-country TFP

[5] They also used the more reliable investment data rather than capital stock. Dowrick (1995) points out that Young's (1992) findings depended on the notoriously unreliable capital stock estimates and suggests the use of investment flow data.

[6] See Hulten (1990) and Chen (1997) for a discussion on the debate on input adjustments.

[7] See Nehru and Dhareshwar (1994), Rao and Lee (1995) and in particular, Sarel (1995, 1997).

comparisons. Young (1994) also admits that his TFP estimate is a very crude measure using a cross-sectional regression analysis on 66 countries, and on close examination, one is inclined to think that it is so crude that some of his conclusions may well be biased. Eggleston (1997:20) too notes that inconsistencies between the individual country results and other studies regarding output and export growth achievements, underscore the importance of differences in data and methodology in Young's (1994) study.

Lastly, Young 's (1995) belief that neoclassical growth theory is able to explain most of the differences between the TFP performance of the NICs and that of postwar economies is challenged by Sarel (1995) who, amongst others, has raised the possibility that initial conditions have an important role to play. The stochastic frontier approach discussed by Nishimizu and Page (1982) is also a departure from the neoclassical growth theory and the TFP estimates obtained from the models adopting such an approach can be expected to offer an alternative explanation to cross-country TFP performances.

Krugman (1994, 1997)

Krugman's (1994) provocative article had two main objectives. One was to reassure the Western world of the success of their economic system based on a free market system and the other was to allay fears of threat (that the West was losing their technological advantage, and of the success of government intervention in the market) arising from the rapid growth of the East Asian economies. He drew on Young (1992,1994) and Kim and Lau (1994) to emphasise the fact that the East Asian economies had low TFP growth despite having high output growth because most of the growth was input-driven and such growth was not sustainable.

Krugman's analogy of Singapore to the Soviet Union needs little more to be said as it has met with much criticism from many authors.[8] Although Krugman's caution that TFP growth being mainly input-driven is difficult to sustain in the long run, can be accepted in the broad sense (in fact, the simple truth is that no economy can sustain rapid growth rates in the long run), his explanations and future predictions are still debatable. For

[8]Among them are a review in the Foreign Affairs (1994), Hughes (1995), Goh and Low (1996), Lall (et al., 1996), Eggleston (1997) and Chen (1997).

instance, he explains Singapore's growth by saying that "Singapore's economy has always been relatively efficient; it just used to be starved of capital and educated workers." First, it is unclear as to what this 'efficiency' is and what it is relative to. Is it a reference to the initial conditions of Singapore or the general governance of the economy? Second, one can also argue that some of this efficiency must be related to the use of inputs.

Krugman also attributes Singapore's growth to 'perspiration rather than inspiration.' This is not necessarily untrue but the strategy of 'perspiration first and inspiration later' is clearly not bad or is yet to be proven wrong.[9] Which path is right or better is a debatable issue as there is no satisfactory way of studying the economy under these scenarios.[10] Clearly, the conditions governing the choice of perspiration or inspiration or more realistically speaking, the mix of both these elements, have been overlooked in Krugman's analysis. Given the constraints facing the economy then, Singapore tried to maximise growth by opting for such a strategy in the past. As the economy matures, Singapore has realised the need for a change in its strategy and finding the optimum mix of perspiration and inspiration has become crucial. Thus, for predictions on growth, the willingness and ability of Singapore to take on the necessary mix is what ought to be evaluated. Making straightforward projections of trends leads to misleading conclusions.

In fact, Krugman's predictions have yet to come true. First, although Krugman predicted that Japan would turn around soon, it has yet to recover from its 1991 recession given its high TFP growth in the past. Second, the doomed scenario of Singapore is nowhere to be seen. Third, although the 1997 currency crisis which has hit some of the Asian economies seems to speak well of Kurgman's predictions, it has little to do with the fact that these economies growth have been input-driven. But as Krugman (1997) rightly pointed out, it clearly has something to do with governments.

In general, many have yet to accept Krugman's analysis. While Eggleston (1997) questions if Krugman is 'mything the point', Hughes (1995) claims that Krugman's

[9]Singapore's emphasis on skilled labour and its efforts to raise R&D expenditure significantly since the early 90s is some indication of such a strategy.
[10]Although possible, a simulation exercise may not be able to adequately capture the underlying dynamics of these scnerios.

arguments have not explained the steady increase in complexity, skills and productivity that have pushed Singapore into increasingly capital and technology intensive industries. Chen (1997) also strongly disagrees with Krugman and Young and goes on to explain how in the context of the new growth theory, input-driven economic growth is sustainable. This argument, arising from endogenous growth theories, is partly taken up in the stochastic frontier model adopted in later chapters in this study.

Kawai (1994)

A non-parametric technique, which does not assume any specific functional form for the production function, was chosen to estimate TFP levels using the growth accounting approach. But the data used to estimate TFP was not explained, leaving much doubt on the results which showed that Singapore and the other three NIEs had rapidly raised their TFP level to 60 percent of the US level by 1990. Furthermore, the analysis on Singapore is unbelievable, as it revealed that import substitution (which was the strategy only from 1961-66 and since then has been replaced by outward looking export-orientation strategy) had a positive and significant effect on TFP growth. The international comparative analysis on TFP growth also suffers from simultaneity bias.

Kim and Lau (1994)

The authors used both parametric (where a meta-production function was estimated allowing for non-constant scale economies and the production elasticities to vary with changes in factor intensities) and non-parametric (index approach) methods to conclude that TFP growth, although higher than the conventional growth accounting estimates, was in line with Young's (1992) results. They provide the following reasons for the insignificant TFP growth: the use of gross capital instead of net capital overstates true capital stock and thus understates capital-augmentation rate; the employment of mature technologies amortises the possibility of any gains; capital goods are on-the-shelf variety and thus indigenous improvements are limited; any existing technological progress is embodied only in high-tech industries; improvements in capital and labour are just not fully reflected. They also found that they had to reject conventional assumptions like constant returns to scale, neutrality of technological progress, and profit maximisation.

Rao and Lee (1995) criticised this study on three grounds. First, the robustness of the results was questioned if another country was used as a numeraire instead of the US. Second, the hypothesis of the existence of the meta-production function may not be accepted for a different set of countries. Third, the meta-production function imposes equality on the augmentation factor across countries.

McCleery (1996), on the other hand, notes that the results are not necessarily convincing, given doubts about the power of the statistical tests and correctness of the specification of the functional form.

Harberger (1996), too, criticised this study on various grounds. He argues that removing scale economies and calculating the TFP residual is incorrect as economies of scale should be included in the TFP residual along with other real cost reductions. He further questions the implicit possibility of never-ending scale economies in Kim and Lau's (1994) method. He is also sceptical of the use of regression technique for the following reasons. First, there is no reason to expect a neutral shift of the production function, such that it is so 'nicely regular'. Second, there is bound to be multicollinearity, with growth in labour, capital, human capital and output, and the inclusion of a time trend variable, will then explain 'almost everything'. Even without a time trend, capital and labour are said to 'fight each other for explanatory power over output movements', thus leading to incorrect coefficients. The multicollinearity problem is in some sense unavoidable as the unexplained residual explains too much if only capital and labour are considered. The omitted variable situation is difficult to resolve but remains an important issue since the more one knows about the model, the smaller will be the size of the unknown residual.

Third, Harberger explains that using first differences does not provide more information about the growth path itself (since labour force growth does not differ much from year to year and capital stock growth is cyclical). Rather, it is only concerned with deviations from the mainline growth path, thus providing little help. Harberger estimated time-series regressions for a group of countries with the levels and first differences using capital and labour derived by the two-deflator approach[11] and found the results absurd. This, he suggested, could be the reason for the use of panel data by Kim and Lau, who

[11]This approach is characterised by the use of a single numeraire-cum-deflator, the CPI index, and the use of a 'standard worker' as the basic unit in which labour is measured, and the measurement of any worker's labour quantum by the ratio of his total earnings to that of his real wage.

then assume simply that several countries can be used to fit a single production function with the difference merely represented by a constant term.

Nehru and Dhareshwar (1994)

They used 'new' estimates of physical and human capital stock[12] in their estimation of a Cobb-Douglas production function based on growth accounting, where they applied an error-correction model to measure the short-run responses of output to change in inputs and to study the long-run relationship between the level of output and inputs. However, many of the results are suspect as the imposition of the constant returns to scale was found to be statistically binding in their model. Also, Singapore was singled out for anomalies in TFP growth rates when they were estimated for different time periods. This is to be expected with the use of panel data which is a combination of cross-country and inter-temporal variation. However, the evidence, seems to suggest a fall in TFP growth from 1960-73 to 1973-87 but the authors caution interpretation of these results for the above reasons.

Sarel (1995)

In this cross-country study on the four tigers, using Penn World Tables, Sarel found Singapore's TFP growth to be lowest among the NIEs but highlights the sensitivity of the results by raising questions on good data for capital stock estimation and the need for different depreciation rates for the different types of capital across countries and across industries. In particular, he shows how different depreciation rates and time periods can lead to very different results as in Young's (1992) study.

Sarel's concept of 'extensive growth' (where output is raised by increasing inputs) spells doom for Singapore, but it is yet to be conclusively proven that Singapore has passed or is nearing that critical stage where diminishing returns to capital is about to set in. Collins and Bosworth (1996:190) show that in 1994, Singapore's capital-output ratio of 2.9 was comparable to that of 3.2 for the US, suggesting that significant limits on future capital accumulation may be faced. But their estimate of a fairly high ratio of 2.8 for Indonesia is difficult to accept, thus weakening their estimates and the implications for Singapore.

---

[12]See Nehru, Swanson and Dubey (1993) and Nehru and Dhareshwar (1993) for the derivation of data on these 'new' estimates.

Kim and Lau (1994), on the other hand, noted that the imbalance in factor growth has caused capital deepening and resulted in decreasing returns to scale for Singapore and the other NIEs. They provide possible explanations as to why decreasing returns to scale were observed and why this may not necessarily be the actual situation as some factors, like land and research and development were omitted, and the natural resource base may actually be declining in some countries. Solow (1991:12) agrees that the existence of diminishing returns to scale in at least one factor of production is difficult to test empirically, that the data seems to be compatible with both theories on the aspect of returns, and therefore it is important to remind ourselves of 'genuine, open-minded scepticism' which is the right attitude. But even if there were decreasing returns to scale, this would lead to a bidding down of returns to capital and perhaps, investment in research and development will become more attractive. Thus, this transitory stage can uplift Singapore into its next phase and not necessarily spell doom. Chen (1997) also takes a dynamic view that being an economy that has been input-driven over the past two decades does not preclude the possibility that this will change when the economy becomes more mature.

Sarel (1997)

Using Penn World Tables on five ASEAN countries, and applying growth accounting methodology, Sarel uses an alternative method to estimate factor shares which he terms as technological factor shares. Unlike factor shares often calculated from national accounts data, these shares are not affected by the industrial structure of the economy and its level of development. The capital shares obtained for Singapore were much lower than those of Young's (1995) and the difference in capital shares was able to account for more than 70% of the difference in TFP growth estimates of this study and that of Young's.[13] Not only was TFP growth for Singapore shown to be significantly higher in the early 90s, but TFP growth's contribution to output growth increased from 44% for 1978-96 to 50% for 1991-96.

Sarel also shows that the marginal product of capital for Singapore, which is a key determinant of the rate of return to investment and hence capital, falls from 0.48 in 1978

[13]Toh and Low (1996) have also pointed out that if capital shares which are closer to industrialised countries are used for Singapore, then TFP growth would not be as dismal as the previous studies claim. Using higher capital shares, especially where capital growth rates are high, would result in lower TFP growth.

to 0.38 in the mid 80s (possibly due to the large amounts of capital using used in housing at that time) and then picks up slightly after which it is stable until 1996. This is contrary to Young's (1992) evidence on diminishing returns to capital which was calculated from the dubious capital price equation, well known to be fraught with inaccuracies. Furthermore, Park (1996:363) suggests that if the rate of return in the region is higher than that in advanced countries, and as long as that differential remains, the volume of capital stock will continue to grow and in a neoclassical framework, the rate of growth will be higher.

A few arguments about Sarel's exercise need to be noted. First, his assumption that technologies are not fundamentally different across countries and over time is highly questionable; more so, when any such differences are assumed to be fully captured by controlling for the average stock of capital per person across countries and over time. Stiglitz (1992:46) explains that 'effective' technologies in countries are different due to differential knowledge in terms of usage and differences in economies of scale when used by small and large economies.

Second, obtaining technological factor shares based on the sample to be used would be more appropriate than using those obtained from a random sample of 16 countries.[14] The robustness of his results should be tested against alternative samples of countries, but unfortunately, data may not be available to do this.

Third, the adjustment by age-related productivity differences across labour is not without its limitations, as it depends on whether age is expected to increase or decrease productivity and this varies across industries and occupations. But his 'effective labour supply per person' adjusted for other demographic differences can be expected to compensate for this ambiguity on age-related productivity adjustment.

Fourth, while Sarel's attempt to take foreign workers into consideration in his TFP growth analysis is well-intentioned, he does not provide any reasons or justifications for his assumptions on the adjustment factor which appear to be ad hoc. Thus, they carry little weight in his conclusion that foreign workers significantly lowered TFP growth in

[14]But Sarel justifies this to some extent in his assumption stated earlier that the level of development and different structures of production in the economy do not affect these technological shares.

Singapore in the early 90s.

Review of Inter-Temporal TFP Studies

Tsao(1982)

Tsao undertook the first comprehensive study on TFP for Singapore using data for 28 manufacturing industries from 1970-79. Using the conventional growth accounting method and a translog functional form, she found TFP growth to be input-driven and negligible. Since the agricultural sector in Singapore was very small, the source of TFP growth from the shift to manufacturing sector was virtually nil and nor is the shift from the industrial sector to the services sector in the early 70s an important source of productivity growth. Inputs were an important source as much of the unemployed domestic labour was absorbed by significant amounts of foreign capital brought in by FDI into Singapore at that time.

The study also found no support for Verdoon's law which states that as output increases, economies of scale, both static and dynamic, enable productivity to increase so that higher output growth leads to higher productivity growth. This further reinforces the observation that output growth was input driven, leaving a small and insignificant TFP growth as the residual.

Wong (1994)

Wong is the first to focus on determinants of TFP growth in the manufacturing sector with data on 28 manufacturing industries for the decade of the 80s. Using manufacturing industry's TFP growth as the dependent variable, Wong regressed it only against two independent variables at a time to avoid causality effects. But it was found that many of the estimated coefficients would become insignificant at 5% level of significance for a two-tailed test and there was no reason provided to justify the one-tailed test. Thus, due to omission of relevant variables, the two chosen regressors used in the estimation may then show up as significantly affecting TFP growth, thereby providing misleading results. One solution to this problem would be the use of a simultaneous equation system.

The other major problem with this study is that TFP growth has been shown to be composed of TP and changes in TE. Thus, factors may affect TP and improvements in

TE in opposing directions and not considering their separate effects to study the overall effect on total factor productivity growth may lead to distorted policy implications.

Nevertheless, he reports that average establishment size and average export growth could be possible determinants.[15] He also finds that TFP growth is negatively correlated with capital deepening (measured by capital-labour ratio) and that there were significant positive relationships between TFP growth and the two measures of human capital he used. Finally, TFP growth was positively correlated with machinery investment (measured by ratio of investment to industrial output) possibly because the equipment investment embodies new technology, boosting productivity growth. Some evidence was also provided to show that structural change during the 80s had not adversely affected the TFP performance of Singapore's manufacturing industries.

Wong and Gan (1994)

Wong and Gan used the growth accounting method with data on 27 manufacturing industries for the decade of the 80s and found a substantial improvement in TFP growth in the later part of the 80s. They also found support for Verdoon's law as there were large positive correlations between TFP growth and output growth in most of the industries.

Evidence was also found to suggest that fluctuations in TFP growth in the manufacturing sector were caused by supply-side rather than demand-side shocks. Supply-side shocks are such that real output growth raises real wages which raises the marginal productivity of workers and thus TFP growth increases. Demand-side shocks are seen to work through increase in real prices, which are due to real output growth, and thus TFP growth increases.

The total reallocation effect (which reflects the productivity consequences of change in the composition of industrial output among industries with different rates of TFP growth) rather than within or intra-industry effect was found to be a more important source of TFP growth. However, the concept of total reallocation effect is dependent on perfect competition in factor markets. But imperfections in factor markets are likely to

[15]Jeanne-Lim (1995:56), on the other hand, reports that there is no strong positive correlation between TFP growth and export orientation across industries.

exist so that factor returns do not necessarily reflect marginal factor productivities. For instance, in Singapore, the ready pool of foreign labour, the imposition of a foreign worker levy, government intervention to reduce income equality and the control over land prices, clearly distort the factor market and thus the calculated reallocation effect may be a gross overestimate. More evidence is clearly needed to allay fears of the existence of some of these imperfections, before their results can be accepted.

Wong and Tok (1994)

Using the Divisia-Translog index approach and the recently improved stochastic frontier production function method with the above data, Wong and Tok found that the two TFP estimates were highly correlated and that the change in TE (only five of the 26 manufacturing industries recorded improvements in TE while the rest experienced deterioration in TE) was a more important source of TFP growth than TP for most individual industries. The surprising result for which the authors did not provide any explanation was that, fifteen of the 26 industries experienced zero TP from 1981 to 1990. However, some TFP growth was found for twelve of the 26 industries. There are also a few limitations in the stochastic frontier model that they used.

One is the strong assumption that variation of all industry effects (that is, TE) is monotone throughout time and that the rate of technical change was constant for industries over time. Second, it is highly likely that inter-temporal variation is masked by inter-industry variations in shaping the trend and the estimated coefficients of the production function with their use of only ten years of observations with 28 manufacturing industries. Third, the use of a time trend in their model is a rigid proxy for TP as it does not allow for inter-industry differences within the sector. Fourth, there was no attempt to test for the appropriateness of the Cobb-Douglas production function and the use of a truncated normal distribution for industry-specific effects. Such assumptions if not justified clearly produce misleading results.

Van Eklan (1995)

Van Eklan's study applies the growth accounting method to a translogarthmic production function with a large data set of 1961-91 and includes land as a separate factor of production in the aggregate economy. The TFP growth results were very similar to Tsao (1982) and Rao and Lee (1995). As Sarel (1997:38) explains, including land would understate the share of capital and overstate the TFP growth, which partly explains the higher TFP growth values obtained in this study. Another reason for the higher TFP growth estimates could be that changes in input quality have not been accounted for.

Also, the underlying assumptions that the rate of return to capital and land are equal and that Singapore's ratio of value of capital stock to value of land is the same as that of the US are rather unconvincing. The first assumption on the rate of returns cannot hold; as land is scarce in Singapore and capital is relatively more abundant as Singapore has always been open to foreign direct investment and placed no restrictions on the import of capital. The basis for the second assumption seems to hinge merely on the convenience of using available information on land rents in the US due to unavailability of such data in Singapore. But this totally disregards the different levels of development in Singapore and the US which would have a direct effect on the ratios in these economies. Furthermore, indirect subsidies given to residential structures in Singapore would upwardly bias land rents in the economy.

Elaine-Seow and Lall (1996)

The authors calculate TFP growth using data for 30 manufacturing industries in the decade of the 80s by adopting the conventional Divisia index to estimate a translog cost function without imposing the constant returns to scale condition. Their results are very optimistic in that TFP growth of 6.19% in 1981-90 accounted for more than 76% of output growth. Their TFP growth results are a big contrast to that of Wong and Gan (1994). Industries for which Wong and Gan found negative (positive) productivity growth had positive (even larger) growth rates in this study.

However, Bauer (1990a:44) warns that translog cost functions contain the 'Greene Problem' which makes modelling the relationship between the two-sided disturbances on the input share equations (which are composed in part of allocative inefficiency) and the nonnegative allocative inefficiency disturbance in the cost equation problematic. Furthermore, the cost function is price dependent and obtaining accurate input prices has always been a major problem in itself. Perhaps this partly explains why some of the industries in the sample violated local theoretical consistency requirements. In particular, of 360 observations, monotonicity was violated for 13 observations, output cost elasticity was found to be negative for 9 observations and the Hessian was negative semi-definite for only 80 observations. Also, increasing returns to scale were unusually large for some years for various industries. These are likely to have resulted in inflated TFP estimates.

Leung (1997)

Using the growth accounting method with data on 30 manufacturing industries from 1983-93, Leung finds that the manufacturing sector's TFP growth is still low and could not conclude that Singapore did particularly well in improving its manufacturing productivity in the early 90s. His results also suggest that Singapore has not gained much from learning-by-doing. Although we do not dispute either of these claims, there are many problems in Leung's study that need to be addressed.

First, the study directly used reported capital stock estimates (it is not clear if fixed assets or capital expenditure was used) which totally disregards the cumulated past capital expenditure, and since depreciation cannot be 100% within a year, resulting in the underestimation of capital use. Second, the weighting system used (based on earnings data) to capture the effects of a better educated work force over time is not clearly set out. It may be inaccurate to measure labour quality changes in this way, given the tight labour market situation in Singapore since the late 70s; whereby an increase in earnings may not necessarily reflect an increase in skills. Earnings include not only bonuses which are paid out based on economic growth and profits, but also foreign worker levies, thus reflecting government policy. Hence, more evidence needs to be provided to substantiate the use of earnings to adjust for numbers employed in order to reflect improvements in education.

Another problem lies in Leung's attempt to identify factors that influence TFP growth by the ordinary least square regression technique. Similar to Wong (1994), this arises from the failure to realise that TFP growth is made up of two components, TP and changes in TE as underlined in the stochastic production frontier. Thus, the regressors used may have different effects on these two components and thereby its overall effect on TFP growth will be determined by the interaction of these effects. Nishimizu and Page (1982) explain that high rates of TP can coexist with deteriorating TE and vice versa and policy actions intended to improve the rate of TFP growth can be badly misdirected, for example, if focussed on accelerating the rate of innovation in circumstances where the cause of lagging TFP change is a low rate of mastery or diffusion of best practice technology.

There are also other problems with the regressors that were used in the estimated equation to understand the determinants of TFP growth. First, there is a high possibility of multicollinearity between foreign ownership and export orientation being used as two separate regressors. Since Singapore's domestic market is small, most foreign owned firms are export oriented. Thus, both the variables may be explaining the same cause rather than two different causes of TFP growth. Second, the use of cumulative output as a proxy for learning-by-doing does not realistically consider the diminishing returns that it entails. Thus, the inclusion of the square term of the cumulative output in the regression might have been appropriate.

However, the use of cumulative output to capture the learning-by-doing process has serious limitations. Learning-by-doing leads to efficient use of resources where the maximum possible output is obtained from a given set of inputs and technology, regardless of levels of inputs. Besides, it is extremely difficult to isolate the increase in output resulting from learning-by-doing since an increase in demand or lower production costs resulting from a fall in the input prices can also affect output. Generally, alternative estimates like R&D expenditure or capital intensity (Findlay, 1995) can be used. In fact, Leung uses the capital-labour ratio (often a measure of capital intensity) and claims that, "technology is not properly absorbed (learned)" by this variable. Thus, Leung acknowledges that this variable is also a proxy for learning-by-doing.

Finally, the impact of learning-by-doing on output may operate through improvements in the method of application of inputs regardless of the level of inputs. Thus, in order to understand the influence of learning-by-doing on TFP growth, differences in the method of application of inputs should be measured.

Review of TFP Studies on Services

Only two studies, Rao and Lee (1995) and Virabhak (1996) have attempted to estimate TFP growth in the more difficult and thus commonly neglected services sector.

Rao and Lee (1995)

Adopting the conventional growth accounting method, but adjusting for changes in the educational composition as well as weekly hours worked by the labour force, Rao and Lee obtained higher TFP growth estimates for both services and manufacturing for 1987-94 compared to 1976-84. Although the attempt to consider quality changes in labour is appreciated, first, the question of the robustness of their results remains. Second, as Sarel (1997:39) explains, such an adjustment might understate the true rate of TFP growth by attributing a large part of the increase in output to better (more educated) labour, because the treatment of education as a pure investment good overvalues the returns on investment in education with respect to economic growth. Thus, education can be a consumption good where consumers, having more to spend, would be willing to get themselves educated to increase their utility; or education could be undertaken as it has a strong signalling motive where more education enables better access to the labour market.

Sarel (1997) further argues that the concept of TFP implicitly assumes a certain absolute level of knowledge, proficiency, skill and efficiency, and measuring TFP growth gives more information on the rate of improvement of these factors. Thus, using education levels to define quality-adjusted labour would give information on the rate of improvement of these factors, conditional on the level of education. This conditional concept puts doubt on the interpretation of the TFP growth results obtained.

Rao and Lee also used average exponential growth rates to estimate labour input for 1967-72 and the proportion of GDP growth due to capital, labour and TFP growth. No justification was provided for the use of such growth rates. Their claim that using other types of growth rates would give similar results if the economy operates on a smooth exponential growth path economy covering a long period, cannot hold if no evidence is provided to show Singapore's growth path. Perhaps a sensitivity test could have been done using alternative growth rates to strengthen the case for their estimates.

More importantly, services was taken as a residual where employment and capital stock of the service sector was obtained by conveniently subtracting the employment and capital stock in the manufacturing sector from that of the total economy, thereby including utilities and construction as services.[16] An alternative to this residual concept of services is certainly long overdue in respect to the literature on services and given the importance of services in Singapore.

Virabhak (1996)

Using a similar method to the above, Virabhak undertook the first sectoral TFP growth analysis of the services sector with some adjustments to account for the average weekly hours worked by three occupational groups in the labour force. Unfortunately, her paper does not go beyond presenting some of these useful TFP growth estimates.

The main findings were that TFP growth in the services sector (based on the majority of the service groups and not on any service sector aggregate) hovers about zero and in general, follows a cyclical pattern. However, the TFP growth contribution to output growth was seen to increase in the late 80s.

Two points regarding the data used should be noted. One, the value added measure was calculated in factor prices but the GDP deflator used with these value added measures was incompatible as it was in market prices. Second, labour remuneration was calculated based on basic wages although data (unfortunately) on remuneration components such as the central provident fund, average wage supplement and other bonuses were only available in terms of gross wages.[17] Thus, labour shares could be overestimated, leading to inaccurate TFP growth results.

6.3 Conclusion

Many studies such as Pack and Page (1992), Wong and Tok (1994), Sarel (1995, 1997), Rao and Lee (1995) and Virabhak (1996) have assumed a Cobb-Douglas production function, without validating it with any statistical testing. The nature of returns to scale has an important bearing on input shares and hence the magnitude of TFP estimates. In particular, except for the first two studies mentioned here, the rest of the studies used

[16]One reason for this could be to get around data constraints on capital stock for services as these data were only published from 1974 biennially to 1985 and annually since then.

[17]Basic wages refers to payments made on piece rate or an hourly, daily or monthly basis, before deduction of the employees' CPF contribution and personal income tax. Gross wages include basic wages and overtime payments, commissions, employer's CPF contribution and other payments in kind but excludes bonuses.

two inputs, capital and labour, with the implicit assumption that the elasticity of substitution between capital and labour is unity. Rodrik (1996: 192) explains that if the true elasticity is below one, then capital deepening would cause the factor share of capital to fall over time and the true TFP growth would increase correspondingly.[18] Thus it is important not to impose the constant returns to scale assumption to obtain more accurate TFP growth estimates.

In addition, except for Wong and Tok (1994), all other studies reviewed here used the conventional growth accounting approach to estimate TFP growth rates. In general, input growth was found to be the main source of output growth in the aggregate economy, manufacturing and services sectors. TFP growth, although significantly lower than the other countries, improved in the late 80s. While the Department of Statistics (Singapore, 1997) cautions against the declining trend in TFP growth in the economy since 1986, Sarel (1997) provides evidence of improvement for the early 90s but Leung (1997) is unable to reach similar conclusions for the manufacturing sector. It is thus interesting to explore the services sector's contribution in the light of these results, especially in the early 90s. The following chapters focus on TFP growth analysis for the manufacturing and services sectors using both the conventional growth accounting approach and an improved version of the model used by Wong and Tok (1994) for the stochastic frontier approach, without imposing the constant returns to scale condition.

[18] See Rodrik (1996:193) for an example.

Chapter 7

Total Factor Productivity in the Manufacturing Sector

7.1 Introduction

The manufacturing sector has played a key role in the Singapore economy since the early 70s and the government is committed to retaining a manufacturing base of at least a quarter of GDP to ensure an annual growth rate of 7% for the manufacturing sector until the year 2000.[1] Given this prominence, it is crucial that TFP gains from this sector be evaluated to shed light on policies governing the long-term growth of this sector.

While most cross-country TFP studies have focused on the aggregate economy, there have been some inter-temporal studies on the manufacturing sector. For 1960-70, Chen (1977) showed that the manufacturing sector's TFP growth was 3.34% and for 1970-79, Tsao (1985) showed an insignificant 0.08% TFP growth. Although, Young (1995) estimated an average annual TFP growth of −1% for 1970-90, Wong and Gan (1994) provide evidence of an improvement of annual TFP growth of 4.81% from 1981-85 to 1986-90 while Rao and Lee (1995) show further improvements of TFP growth from 1976-84 to 1987-94. Leung (1997), on the other hand, was unable to conclude on TFP growth improvements for the early 90s. These mixed results clearly warrant further investigation.

This chapter is organised into two broad sections. The first section briefly explains the conventional growth accounting approach. A Cobb-Douglas production function is then estimated for the manufacturing sector using new data (panel data for 28 manufacturing industries from 1975 to 94) by first pooling and then by the use of the fixed effects model in a panel data framework. This is followed by a test on the functional form, the appropriateness of the pooling methodology and robustness of the estimation. Then TFP levels and TFP growth rates estimates are distinguished for analysis. The second section uses the improved and more recently developed stochastic frontier approach for

---

[1] This was declared by the Minister of State for Trade and Industry and reported in The Straits Times (Singapore) 2 Nov 1995.

comparison with the TFP estimates obtained in the first section. The frontier approach then decomposes output growth into input growth, TP and changes in TE. In addition, Verdoon's law is tested and the relationship between technical progress and changes in technical efficiency is examined.

7.2 Growth Accounting Approach

Measuring TFP Growth

The Cobb-Douglas functional form with capital and labour is chosen to estimate the production frontier for the manufacturing sector. Energy and materials inputs are not considered as such information is not available for the service sector and intermediate inputs are relatively minor for services. To make a consistent comparison, these were not considered for the manufacturing sector either. Furthermore, Caves and Barton (1990:167) claim that material inputs can normally be adjusted to realised changes in output within the course of a year. Hence, the only factors considered are capital and labour, with the implicit assumption that intermediate inputs are at least weakly separable from other inputs.

The reason for use of this functional form is that, with technologies more complex than the Cobb-Douglas, the explicit form of dual relationship will usually be more complicated, and Kopp and Smith (1980) found that an overly flexible functional form would result in more generalised estimates with a loss in statistical efficiency. Some economists raise theoretical objections to the translog function (which is more general than the Cobb-Douglas) because it need not be well behaved for every possible combination of inputs; output need not increase monotonically with all inputs and isoquants need not be everywhere convex.[2] Also, as secondary data are used, the Cobb-Douglas production function is a good approximation to a situation of heterogeneous technology as discussed by Mundlak (1988). Caves and Barton (1990:22) also provide evidence of studies on a wide variety of industrial studies for which Cobb-Douglas has fitted the data well.

The growth accounting approach calculates TFP growth rates as the residual growth in

[2] See Caves and Barton (1990:22), Berndt and Christensen (1973).

real output after accounting for capital and labour input growth. In the equation below, technical change is given by A, an exogenous factor, and is assumed to be Hicks-neutral as it is equally capital and labour-augmenting. In other words, the marginal rate of technical substitution between capital and labour remains the same over time.

The Cobb-Douglas production function is given as:

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

where Y = value added output
K = capital
L = labour
α and β are the capital and labour shares respectively

The underlying assumption is that there are constant returns to scale, i.e. $\alpha + \beta = 1$

<u>The Pooled Model of the Production Function</u>

$$\underset{}{\text{Log } Y} = \underset{(0.157)}{1.53^{*}} + \underset{(0.021)}{0.64^{*}} \text{ Log } K + \underset{(0.022)}{0.36^{*}} \text{ Log } L + \underset{(0.005)}{0.001} \; T$$

where Y is value added output in the manufacturing sector
K is capital input used
L is number of workers employed
T is the time trend

Standard errors are given in parentheses and * indicates significance of the estimated coefficients at least at 5% level of significance. The Ramsey Reset test statistic of 1.35 is below the critical value of 3.84 at 5% level of significance indicating that the functional form was not misspecified and there were no major problems with heteroscedasticity. The above equation was corrected for autocorrelation using the exact maximum likelihood method[3] and the corrected Durbin Watson (DW) statistic of 1.99 was satisfactory (see Appendix 7.1 for details of estimation). A time trend was included to remove the effect of time-specific factors.

Although constant returns to scale were not imposed, the sum of the capital and labour shares was found to be one in the above estimation, indicating the existence of constant

---

[3] This method of correcting autocorrelation uses stochastic initial values for the disturbances and has the advantage that, if the iterations are convergent, it always converges to a stationary solution. The computations are based on the 'inverse interpolation' method.

returns to scale.

The input shares obtained above are close to those obtained by Rao and Lee (1995) for the period 1976-94, where the capital share was 0.59 and the labour share was 0.41.

Testing for Appropriateness of Estimated Input Shares

It has been shown above that the Ramsey Reset test does not reject the specified functional form and the constant returns to scale condition is not rejected for the estimated equation.

In a Cobb-Douglas model, under conditions of perfect competition (with factors being paid according to their marginal products), α and β are capital and labour income respectively, in income derived from output of that sector. Thus, it suffices to test whether $\hat{\beta}$ is significantly different from the average share of the wage bill in output.[4] The average share of the wage bill in output is given by the ratio of remuneration[5] paid out to workers to the value added output. Since panel data were used, the average is taken over each industry's ratio in each time period.

The null hypothesis below states that the estimated labour share from the production frontier is not significantly different from the share of the wage bill given by actual data.

Test $H_0: \hat{\beta} = 0.39$

The above test provided a Wald test statistic of the chi-square distribution with 1 degree of freedom, $\chi_1^2 = 1.95$. Since the value is not greater than the critical value of

[4] Chen (1977:122) states that the stability of the factor shares in income imply that a Cobb-Douglas production function is a compatible approach. But Van Eklan (1995:8) warns that the assumption that income shares reflect output elasticities is likely to be violated for capital goods especially in the case of foreign direct investment, where monopoly suppliers of capital goods may earn a return in excess of the marginal product of capital. Expanding on this, and drawing on Sarel's (1997) explanation, a point to note is that the income shares can be affected by differences in the structure of production, government taxes, regulations and incentives and the market structure governing the different industries within the broad sectors of manufacturing and services.

[5] Remuneration is composed of 3 components, namely, wages and salaries, employer's contribution to central provident fund/pension funds and other benefits like medical benefits, cost of food, accommodation and benefits in kind. Allowances given to unpaid family workers were also included.

3.84 at 5% level of significance, the null hypothesis stated above cannot be rejected. This along with the earlier evidence of constant returns to scale implies that the Cobb-Douglas functional form is appropriate for the present data for the manufacturing sector.

The Random and Fixed Effects Model

With panel data, questions are often raised on the existence of cross-sectional heterogeneity and autocorrelation in the sample. While autocorrelation can be easily corrected for by autoregression techniques in Ordinary Least Square (OLS) regression, cross-sectional heterogeneity can be a problem. In this case, the cross-sectional heterogeneity refers to the individual industry effects as they produce different output and may even operate differently, although they belong to the same broad sector. There are two common methods of estimation to take into account the individual industry effects using panel data: the fixed effects (FE) and random effects (RE) models

When the individual effects are constant over time *t*, but specific to the individual cross-sectional industry *i*, it constitutes the FE model with constant-slope, variable intercept framework. When the individual effects are allowed to vary over time *t*, besides being specific to the individual cross-sectional industry *i*, it is the RE model. Mundlak (1978) argues that one should always treat the individual effects as random.

Consider the FE model below:

$$Y_{it} = \alpha_{0i} + X'_{it}\alpha + u_{it}$$

and $\alpha_{0i} = \alpha_0 + \varepsilon_i$

$u_{it} = \varepsilon_i + v_{it}$

where $i = 1,.......n$

$t = 1,.......T$

u_{it} is a composed error term that combines the time-invariant individual industry effects ε_i, and the statistical disturbance term v_{it}, which is assumed to be normally distributed and uncorrelated with ε_i and X'_{it} 's in the model.

Unlike the RE model, in the FE model, the time-invariant regressors are eliminated in the 'within' transformation and if dummies are used to represent different industries, it is costly in terms of degrees of freedom lost. And the variability of the data within each industry through time is being utilised; not the variance in the data across industries at any given point in time. Since the magnitude of the variance in a data set is typically between, rather than within industries, this procedure has the disadvantage of greatly reducing the variance of the regressors, creating two problems. First, the reduction in the variance of the regressors tends to exacerbate any multicollinearity problems. Second, it lowers the signal-to-noise ratio for any given set of measurement errors, causing the estimates to bias towards zero.

However, the RE model is not without its limitations. Unlike the FE model, this procedure utilises variations in the data both between industries at a given point in time as well as within each industry through time. Thus, instead of working conditionally on the industry effects ε_i , we take their stochastic nature explicitly into account. The underlying assumption is that the individual effects are uncorrelated with the other regressors (that is, ε_i and X'_{it}'s are not correlated). But this is not necessarily true and if such a correlation exists, it would lead to inconsistent and biased estimates. Hence, the FE model, which includes the industry-specific effects as regressors rather than neglecting them to the error terms, overcomes this problem.[6]

The possibility of such a correlation existing between the regressors and the error terms is due to the following reason. While ε_i is unobservable from the estimation, its permanency would lead us to expect industries to observe ε_i and to take its level into account when choosing the explanatory variables, X'_{it}'s. It is possible, of course, that industries also observe v_{it}, the period-specific shocks. It is customary in the literature to assume that the X'_{it}'s at time *t* are chosen before v_{it} is observed by the industry (or that the industry never observes v_{it}), making the X'_{it}'s at time *t* independent of this component of the error term. If this assumption is violated, then the FE estimators will join the RE estimators in being inconsistent.

It becomes necessary, therefore, to choose the method that best fits the sample and the purpose of the analysis. One way to proceed is to rely on the statistical properties of the sample, in which case we would apply the RE model for random samples and the FE model otherwise. There also exists the Hausman's chi-square test to test the RE model

[6] See Evans et al. (1993:434).

against the FE model. Mundlak (1978:70), however, argues that the decision to use either model is both arbitrary and misleading, and it is up to the user to decide on the type of inference required. Also, the possibility of correlation between the industry effects and the regressors in the model cannot be ruled out. When there is no such correlation and the model is properly specified, both approximation methods yield consistent estimates of the parameters. Given the above arguments, the FE model was chosen over the RE model.

The Fixed Effects Model

A common formulation of the model assumes that differences across industries can be captured in the differences in the constant term. The λ_i's, which are unknown fixed parameters, are estimated using dummies representing each industry. However, α and β, the 'within' estimators, are assumed to be constant across industries. For the purpose of analysis, the model can be written as:

$$\text{Log } Y_{it} = \sum_{j=1}^{s} \lambda_j + \beta \text{ Log } L_{it} + \alpha \text{ Log } K_{it} + \delta T + u_{it}$$

where i = 1,......N (no. of industries)
t = 1,.....20 (no. of years)
j = 1,..... s (no. of dummies representing industry codes)

Y = value added output
L = number of workers
K = capital used
T = time trend
λ = industry dummy

The above model is usually referred to as the least squares dummy variable model and the advantage of this model is that standard errors for all parameter estimators can be obtained, which allows for statistical testing.

Eight dummies were used to group industries according to their 2-digit industry codes to better capture the industry-specific effects.[7] The model was then estimated over the period of 1975-94. Since no constant was included in the estimations, the number of dummies used is equal to the number of grouped industries. As in the earlier estimation,

[7] Using separate dummies for each 3-digit industry in the manufacturing sector did not provide statistically significant capital shares and the constant returns to scale condition was violated.

the constant returns to scale condition was not imposed in the estimation. The estimated results (without specifying the dummy coefficients) are provided below.

The fixed effects model estimation is given by :

$$\text{Log } Y_{it} = \sum_{j=1}^{8} \lambda_j^{*} + \underset{(0.037)}{0.59^{*}} \text{ Log } K_{it} + \underset{(0.028)}{0.33^{*}} \text{ Log } L_{it} + \underset{(0.004)}{0.09^{*}}\ T$$

where i = 1 to 17 , j = 1 to 8, t = 1 to 20

The full estimation with the dummy coefficients is given in Appendix 7.2. Standard errors are given in parenthesis and * means that the coefficient estimate is significant at the 5% level of significance.

The above equation was satisfactorily corrected for autocorrelation by the Cochrane-Orcutt iterative estimation[8], providing a DW statistic of 1.96. The capital and labour shares are positive and significant. The test of the appropriateness of the functional form is given by the Ramsey Reset test (based on the squared of fitted values). The statistic of 3.56 is below the critical value of 3.84, so we cannot reject the null hypothesis that the functional form is not misspecified. The heteroscedasticity test statistic of 2.15 (based on the regression of squared residuals on squared fitted values) is below the critical value of χ_1^2 = 5.02, posing no major problems. The constant returns to scale condition given by the Wald chi-square test statistic of 5.71, is below the critical value of 6.63 at 1% level of significance, indicating the use of the Cobb-Douglas functional form as appropriate.

The capital and labour shares are positive and significant. All the dummy coefficients are positive and significant, thus reinforcing the existence of heterogeneity among the manufacturing industries.

Since the Cobb-Douglas functional form has been accepted, it is sufficient to check on

---

[8] This method of correcting autocorrelation assumes that the initial values for the disturbances are fixed and the estimation is iterated until a convergence criterion is satisfied. The computations are based on 'successive substitution'.

either the labour or capital share. The labour share estimate is then checked against the share of the wage bill share from actual data.

$$H_o: \hat{\beta} = 0.39$$

The t statistic of 5.45 obtained was above the critical value of 1.96. This result seems to suggest that the estimate of the labour share coefficient is not representative of the labour share from the actual data. However, given the advantages of the FE model using industry-specific dummies, incorporating panel data, one is inclined to think that the estimate obtained using this model would be valid.

Comparing the above FE model with the pooled model, the capital share of the FE model is much lower and its labour share is higher than the pooled model. The industry-specific effects (λ_j's) are much larger than the assumed single technology factor (the constant) in the pooled model. Thus, factoring out each grouped industry's technology factor has left less output accruing to capital input.

TFP Levels and TFP Growth Rates

Lucas (1988) first drew attention to the differences underlying the interpretation of levels and growth rates. These concepts are however related - an increase in TFP level does not mean that the TFP growth rate has increased but an increase in the TFP growth rate implies that the level of production, and hence TFP level, is raised. Wu (1997) explains that TFP growth rate is often related to technological progress which allows for sustainable growth in the long run; while changes in TFP levels reflect changes in technical efficiency, which in turn are due mainly to the effects of catching up. When TFP levels are high, TFP growth rates are expected to be low.

TFP Levels

Fixed effects estimation with industry-specific dummies is used to estimate TFP levels. The TFP level for each manufacturing industry *i* in each time period *t* is given by:

$$e^{\ln \text{TFP Level}} = \text{Log } Y_{it} - \hat{\beta} \text{ Log } L_{it} - \hat{\alpha} \text{ Log } K_{it} - \lambda_j - \delta T$$

Each of the industry's TFP level for time *t* is then weighted by its share in the total value added output of the sector in time *t*. The manufacturing sector's TFP level is obtained for each time *t* by summing the weighted TFP levels of all manufacturing industries (see Appendix 7.3 for estimated TFP levels of the manufacturing sector over the period 1975-1994).

The manufacturing sector's TFP levels declined from 1982 to 1985, which is the period of recovery from the second oil price shock of 1979/80 and the start of the recession in 1985. The TFP levels then increased during the recovery period from the 1985/86 recession until 1988, after which they declined. The decline in the late 80s was possibly due to the start of a change in the structure of the economy where regionalisation (which is firms from Singapore relocating their operations to lower-cost countries) and the move to high-technology intensive manufacturing operations were being encouraged. This transition period might have required firms to adjust their operations, thereby affecting their TFP levels.

<u>TFP Growth Rates</u>

These can be obtained for each industry *i* at each time *t* and are given as:

$$\text{TFP Growth Rate} = \hat{Y} - \alpha \hat{K} - \beta \hat{L}$$

where ^ refers to growth rates.

This is the residual approach adopted by most TFP studies. The above method was first used to calculate TFP growth rates of each industry in the manufacturing sector. The rates obtained varied very widely over time within each industry, as well as across industries, and merely taking the weighted average to arrive at TFP growth rates did not seem appropriate. Thus, an alternative method using the fitted annual TFP growth rates was used to check on the robustness of the results from the residual method. To do this, logs of the aggregated weighted industry TFP levels over the period of 1975-94 are regressed on a time trend and constant. The coefficient of the time trend gives the annual TFP growth rate for the period concerned. The estimated equation, satisfactorily corrected for autocorrelation, is given below.

$$\text{Log TFP Level} = \underset{(0.162)}{-0.022} - \underset{(0.012)}{0.0147}\ T$$

Standard errors are given in parenthesis. See Appendix 7.4 for full estimation details.

It was found that the average annual TFP growth rate of -1.47% over 1975-94 was not statistically significant. According to Nehru and Dhareshwar (1994:18), this negative value could be due to the fact that the central observations around the recession years of 1984-1986, rather than observations at the end, have had a larger influence on the fitted regression line and thus is not representative of the entire period. They further explain that several structural breaks like the oil shocks of 1973/74 and 1979/80 and the recession of 1985/86 tend to lead to a low estimated output growth for the entire period of 1975-94 when compared to sub periods within. The residual method on the other hand, gave an average annual TFP growth of 0.79% for 1975-94.

Comparison of TFP Estimates with Other Studies

Studies such as Rao and Lee (1995), and Wong and Gan (1994) calculated TFP growth for two sub periods to make a comparison. Using the above mentioned methods, the following results are summarised in Table 7.1 for comparison.

Table 7.1 : TFP Growth Rates for the Manufacturing Sector

Period	Rao and Lee (1995)	Fitted Method	Residual Method
1976-84	-0.40	4.01	3.24
1987-94	3.20	-5.40	-3.44
	Wong and Gan (1994)	Fitted Method	Residual Method
1981-85	-0.80	____	-7.80
1986-90	4.01	____	1.06
1990-94	Not Applicable	____	- 4.70

Note: The fitted method was not used for the other sub periods as there were insufficient degrees of freedom for accurate estimation.

The result obtained in this study, contrary to the Rao and Lee result, shows that TFP growth has decreased from 1976-84 to 1987-94. Comparing with the Wong and Gan study, ignoring the TFP magnitudes, the trend is the same since TFP growth has improved in the latter part of the 80s. In 1990-94, the TFP growth was negative. The magnitudes of TFP growth rates obtained in this exercise are rather different from the above studies (which also used the growth accounting methodology). In all of these studies, there are some differences that should be noted. For instance, Rao and Lee (1995) used exponential growth rates to estimate labour input for 1967-72, and the proportion of output growth due to capital, labour and TFP growth. They tried to adjust for labour input by considering changes in educational composition, and used an average (over the period of 1961-63) incremental-ratio of 1.5 to multiply the GDP for 1960 in 1985 prices to obtain the benchmark capital stock for 1960. Lastly, data for the manufacturing sector was at the aggregate level. Wong and Gan (1994), on the other hand, considered 4 asset types, seven occupational categories and three energy types and used 1980 capital expenditure as the benchmark. They used the price of capital services calculated based on Jorgenson, Gollop and Fraumeni (1987) but used data on manufacturing at a disaggregated level. Unlike these studies, this exercise used the fixed effects model, thus making better use of the information in the panel data structure.

Also, Domar (1961) has shown that the value added measure of TFP growth (as was used in this exercise), exceeds the gross measure of output. On the input side, Star (1974) explains that aggregation bias in the way inputs are measured may have resulted in an upward bias in TFP growth. For instance, in this exercise the capital component in the manufacturing sector was not decomposed into its various components and for both sectors, energy and material inputs were not considered. Lastly, as this method calculates TFP as a residual, it inevitably includes not just technological progress but also random errors and all that is not accounted for by inputs growth.[9]

7.3 Stochastic Production Frontier Approach

The following Cobb-Douglas model is used in the estimation of the stochastic production frontier:

$$\text{Log } Y_{it} = \phi + \beta \text{ Log } L_{it} + \alpha \text{ Log } K_{it} + \sum_{t=1}^{19} \delta_t + \sum_{j=1}^{s} \lambda_j - u_{it} + v_{it}$$

where i = 1,......N (no. of industries),

[9] These include economies of scale, reallocation effects, embodied technological change, quality improvements in labour, interaction of factor inputs, etc.

$t =$ 1,.....20 (no. of years),
$j =$ 1,.......s (no. of dummies representing industry codes)

Y = value added output
L = number of workers
K = capital used
δ = time dummies representing time periods
λ = grouped industry dummies
u_{it} = industry-specific characteristics that have a bearing on technical efficiency
v_{it} = statistical disturbance term, distributed as $N(0, \sigma_v^2)$

The reliability of the estimates of TFP growth, TP, and changes in TE hinge crucially on the specification of the model. Several functional forms such as the Cobb-Douglas, CES and the translog production functions can be used to model production. Although it is argued that the translog production frontier is a more general type of production function, it may not provide efficient estimates because multicollinearity among the explanatory variables cannot be avoided. The translog model also consumes many degrees of freedom which can cause inefficiency if the sample size is small, and Goldberger (1964) has criticised the model for over parameterisation. The Cobb-Douglas form, on the other hand, has been extensively used in stochastic frontier production analysis and Tybout (1990) explains that it allows maximum flexibility in dealing with data imperfections. The continued use of this functional form in recent surveys of empirical applications of frontier production functions by Battese (1992), Bravo-Ureta and Pinheiro (1993) and Coelli (1995a) further reveals that the Cobb-Douglas technology specifications still continue to dominate. Finally, to enable comparison with the empirically tested and accepted functional form used in the growth accounting methodology, the Cobb-Douglas function was chosen (and tested) for the stochastic frontier approach.

The estimation was done using the same panel data with 8 industry dummies as used in the growth accounting approach. A point to note is that, although Wong and Tok (1994) used the stochastic frontier model, they assumed a Cobb-Douglas production function without validating it with any statistical testing. As the nature of returns to scale has an important bearing on input shares and hence the magnitude of TFP estimates, their assumption of the functional form may lead to biased TFP estimates if, in reality, there were no constant returns to scale. Also, the panel data used in this exercise consist of 20 years of observations compared to their 10 years of observations. Thus, its less likely for inter-industry variations to mask the inter-temporal variation in shaping the trend and estimated coefficients of the production function. In the model adopted here, Wong and Tok's (1994) rigid parameterisation that variation of all industry effects (technical efficiency) is monotone throughout the time periods, and that one rate of change applies to all industries in the sample is relaxed.

Time dummies have also been used in our estimations as a way of allowing TP of the industries to vary across time, besides varying among industries within a particular year (which are captured by the use of industry dummies). Wong and Tok (1994) used a time trend instead, as a proxy for TP, but this is a rigid proxy as it does not allow for inter-industry differences within the sector. If TP differs according to industries, the time trend will bias the residual of the production function and thus TE in the following way. In the case of industries with greater than average TP in applying new technology, TE will then include the residual effect of TP which the time trend failed to reflect. These industries would then appear to be more efficient than they actually are, because the time trend represents an average trend which is uniform to all industries. Conversely, industries with less than average TE would appear less efficient than they actually are, because the time trend has captured more than it should.

Estimation Results

To estimate the model, a Fortran program, Tealec, which adopts the maximum likelihood estimation was used.[10] The key estimated results are provided in Table 7.2 and details of the estimation are provided in Appendix 7.5.

The input shares were found to be statistically significant and the capital share was very close to that of the fixed effects model under the growth accounting methodology. All industry dummies were significant, indicating that the heterogeneity in the industries has to be accounted for to obtain unbiased estimates. The significant time dummies indicate that there was variation in technological progress through time.

[10] It was developed at the Department of Statistics, Australian National University.

Table 7.2 : Maximum Likelihood Estimates of the Stochastic Production Function for the Manufacturing Sector

Variable	Estimates
Constant, ϕ	-1.31* (0.410)
Log (K)	0.60* (0.024)
Log (L)	0.39* (0.026)
Time Dummies (19)	10 were significant
Industry Dummies (8)	All were significant
γ	0.53* (0.173)
LR Test of the One-Sided Error with 1 Restriction	0.27 x 10^4

Note: Figures in parenthesis are the standard errors.
* means that the coefficient is significant at the 1% level of significance.

The validity of the frontier production model can be checked by testing the significance of the γ parameter which is the ratio of the industry-specific variance to total variance. A significant γ suggests that the frontier production function is significantly different from the traditional Cobb-Douglas function which does not involve non-negative industry-specific effects. The γ value of 0.5, although low, was statistically significant at 1% level but it has been argued that the t-test is not appropriate in a situation in which the random variable follows a half-normal distribution. Coelli (1995b) explains that the two-sided likelihood ratio (LR) test is also not appropriate as the alternative hypothesis to γ being zero is that it is positive (since it cannot be less than zero). Hence, the one-sided LR test was proposed and the critical value for a test α is equal to the critical value of the χ_1^2 distribution for a standard test of size 2 α. It can be seen that the LR test statistic exceeds the one-sided critical value of 2.71 at 5% level of significance, indicating that the stochastic frontier model is more suitable than the average (OLS) production function model for the present data set.

Decomposition of Output Growth

Using the parameter estimates of the model, input growth, TP and change in TE can be calculated according to Equation (5) in Chapter 5. Unlike the growth accounting method, TFP growth is not calculated as a residual but is given by the sum of changes in technical efficiency and technological progress. For the broad sector of manufacturing, decomposition of output growth was obtained by using the weighted average of each manufacturing industry's decomposition, where the weights used are given by the average of the share of the industry's value added to the total value added of the sector in the beginning and end of the period concerned. The TFP growth estimations are summarised in Table 7.3 for certain time periods to enable comparison with the growth accounting exercise and the earlier studies (see Appendix 7.6 for details at the disaggregated level (industries) of the manufacturing sector).

Table 7.3 : Decomposition of Output Growth in the Manufacturing Sector

Period	Output Growth	Input Growth	TFP Growth	Change in TE	TP
1976-84	3.92	2.9 (74 %)	1.02 (26 %)	-0.25	1.27
1987-94	1.67	2.12 (126.9 %)	-0.45 (-26.9 %)	-0.68	0.23
1981-85	0.22	0.45	-0.23	0.16	-0.39
1986-90	1.13	0.85 (75.2 %)	0.28 (24.8 %)	-0.13	0.41
1990-94	0.59	0.81 (137.3 %)	-0.22 (-37.3 %)	-0.27	0.05

Note: Output growth = $(Y_2 - Y_1)/Y_1$

Figures in parenthesis are the contribution to output growth.

When annual averages were used for the above time periods, the direction of the trends was the same as above, although the magnitudes differed.

As in other studies, input growth rather than TFP growth contributed to output growth in the manufacturing sector. But this is no cause for alarm, as Lau claims that this is a stage NIEs have to go through and in a state of early economic development, a nation has to stress input growth.[11] He commented that this was also the case for US and Japan in their early periods and that Singapore has hardly reached the limits of tangible capital accumulation as its investment is still well below that of the US and Japan. Similar views are shared by Azariadis and Drazen (1990) and Collins and Bosworth (1996).

While there is truth in Krugman's claim that input growth cannot possibly sustain TFP growth in the long-run, some others offer explanations as to why this may still be

[11] Southeast Asia Business Times (Singapore) 8 May 1997.

possible for some time. Collins and Bosworth (1996:196) argue that Singapore, along with other East Asian countries, have had a skilled work force relative to its capital stock in the early stages of development, and that raised the return to capital and accounted for the faster rates of capital accumulation. Relatedly, Park (1996:196) explains that as long as the positive differential between the rate of return to capital in the East Asian region and that of US remains sufficiently high, the volume of capital stock will continue to grow and, in a neoclassical growth framework, the rate of growth in this region will be higher. The policy implication of this is that Singapore must try and ensure a high enough rate of return to capital. In the past this was done by numerous government incentives and tax allowances in its export-oriented growth strategy and its move to get manufacturing operations to be more capital intensive. These price distortions served to increase the return to capital, thereby attracting foreign investment which brought foreign capital and technology. However, with the neighbouring countries wooing FDI and providing cheap labour, Singapore has to change its strategy to sustain growth.

Table 7.3 shows that, as in the growth accounting exercise, TFP growth for manufacturing has decreased from 1976-84 to 1987-94, unlike the results of Rao and Lee (1995). For the decade of the 80s, the results are similar to those of Wong and Gan (1994), as there was an improvement in TFP growth in the latter part of the 80s which is to be expected given that the early 80s was adversely affected by the recession. In general, there has been a decline in TFP growth of the manufacturing sector (weighted aggregate of the industries) over the periods of 1976-84, 1986-90 and 1990-94. However, for individual industries, over 1976-84, about 54% of the 28 manufacturing industries recorded positive productivity growth and the figure increased to 82% for 1986-90, possibly due to recovery from the 1985 recession. In the early 90s only about 29% of the 28 industries saw positive productivity growth but there was no pattern evident in the industries TFP growth behaviour before the early 90s.

It can also be seen from Table 7.3 that, although TP was positive, it was declining and the deterioration in TE was the main cause for the low and declining TFP growth over time.[12] One possible explanation is the following. In Singapore, managers and

[12] In contrast, Huang (et al., 1998) found that most state-owned manufacturing enterprises in China experienced improvements in TE with little TP. In these enterprises, it was suggested that managers had short-term interests and were less interested in investing in new technology.

employees in major decision making positions often do not job hop and stay with the firm for a fair period of time. As such, they take a strong interest in the firms' performance and development and thus see investment in technological innovation as worthwhile in order to compete with the other firms. They are less interested in firm's short-term performance, which would be to use resources efficiently, and this is directly related to the size of the cake which could be distributed as income. The job hopping tendency among workers is another deterrent for managers to invest in workers training.

The poor productivity performance of the manufacturing industries in the early 90s is of particular concern. As noted earlier, not only was TP low for most industries, but there was deterioration in TE for important industries like transport equipment, chemical processing, and petroleum products, which collectively performed badly. With the industrial chemicals and gases, petroleum products, and paint, pharmaceutical and other chemical products, robust regional demand led to setting up of new projects and an expansion of plant facilities in the early 90s,[13] thus resulting in very high input growth which led to negative TFP growth. The government's gearing of manufacturing operations towards more high tech activities and its encouragement of the regionalisation drive of the 90s (whereby firms relocated their manufacturing operations to countries with cheaper labour) were partly responsible for poor TFP growth performance in labour intensive industries such as textile, wearing apparel, footwear, furniture and fixtures. The dominant electronics sector was exceptional with improvements in TE and positive but low TFP growth. The low TFP growth in the electronics industry could be attributed to a global slowdown in the demand for consumer electronics due to two reasons. First, there is a high correlation between output growth and TFP growth (shown later). Second, weak demand causes excess capacity and there is little incentive to invest in new technology. Also, local investments in manufacturing surged in the 90s[14] and unlike the MNCs, these domestic firms would require more time to adjust and adapt themselves to the technology before being able to generate higher value added output.

Technological Progress

TP has been positive (except for 1981-85) and declining over time. The positive TP can

[13] See Singapore Investment News, various issues.
[14] See Department of Statistics (Singapore, 1995c).

be attributed to the inflow of foreign technology as Singapore has always been open to foreign direct investment and has placed no restrictions on the import of capital. The rising share of capital goods in the retained imports of Singapore is some evidence for that (see Table 7.4 and Appendix 7.7 for details on this decomposition).

Table 7.4 : Composition of Retained Imports in the Manufacturing Sector (%)

Year	Consumption Goods	Intermediate Goods	Capital Goods
1978	16.8	59.3	23.9
1983	15.1	61.8	23.1
1988	18.1	46.1	35.8
1994	19.3	35.3	45.0

Source: Calculated from Singapore Yearbook of Statistics, various issues.

The continuous and rising import of foreign technology, embodying improvements in the quality of the capital has led the way to technological progress which is partly the reason for Singapore's success. Some support for this can be obtained from the following. Wong (1994) provides evidence of a significant and positive relationship between TFP growth and machinery investment. Given the arguments presented later and the evidence of deterioration in TE in Table 7.3, TFP growth is very likely to have come from TP. Coe and Helpman (1995) show that a 1% increase in R&D capital stock in the US leads to an increase of 0.22% in Singapore's TFP growth. These international spillovers again illustrate Singapore's benefits gained from foreign technology through the operation of MNCs.

In 1981-85, there was a decline in output growth from technological progress. This seems difficult to accept, given that although new capital (and hence better technology) is unlikely to be imported during a recession, the old technology of 1985 is still available. But during a recession, the already available best technology may not be used if there is a large decrease in demand. It may now seem worthwhile or optimal for industries to use the 1981 technology instead, to cater to lower demand. Thus, since the best available technology is not used in 1985, the output growth from TP would be negative. Also, over time, the skills to use the 1981 technology more efficiently have already been acquired, resulting in positive changes in TE.

The decline in TP, as seen in Table 7.3, as well as at the disaggregated level of the manufacturing industries (see Appendix 7.6), is to be expected. Since Singapore has started importing technology since the early 70s, and is higher up in the ladder of high tech manufactured products, there are limits to the acquisition and access of better and newer foreign technology. But this could well be a cyclical behaviour and there is no reason to believe that the rate of innovation in high tech manufacturing industries falls over time. However, over-reliance on TP without improvements in TE can be a constraint.

Improvements in Technical Efficiency

Table 7.3 shows that, except for 1981-85, all other periods saw a deterioration in TE. At the disaggregated industrial level (see Appendix 7.6a) for 1976-84, only six of the 28 industries registered improvements in TE. This could be because, with the import of foreign technology, there have been difficulties applying Western technology or more capital intensive technologies. Also, with the high wage policy of 1979/80 to shift from labour intensive manufacturing into capital intensive activities, many manufacturing firms were either forced out or had to automate to take advantage of the government's many incentives in order to face competition in the wake of rising wages. Thus, they were not ready for the effective application of better technology, being ill-equipped with skills needed to cope with the technology. Young (1992) and, Chowdhury and Islam (1993:92) provide evidence of very high rates of structural change in manufacturing employment between 1976-86 and within the manufacturing sector between 1965-80, in comparison to many other countries. This rapid structural change has not allowed Singapore to apply new technology effectively.

During 1981-85, about 61% of the 28 manufacturing industries showed improvements in the use of resources. This can be so if the industries are operating on the rising portion of the short-run cost function, then, a decision to cut output would reduce costs. Also, with the 1985 recession, many workers were retrenched and labour would be used relatively more efficiently and plant capacity may not be underutilised yet, since orders for manufactured products may have been placed well in advance of the recession and production has to be met. Also, there is a shift to a lower production frontier in 1985, thereby enabling improvements in TE to be experienced.

For 1986-90, the change in TE was negative at the weighted aggregate level in Table 7.3 but was found to be positive for fourteen of the 28 manufacturing industries (see Appendix 7.6b). These fourteen did not include key industries like electrical machinery, electronics products and chemical processing industries. Perhaps for these industries, recovery from the 1985 recession was slow since a significant number of trained foreign and local workers who were retrenched may have found new jobs. Thus, new workers had to be recruited and trained for the same job, resulting in some inefficiency. But for the other industries which showed some improvement in TE, perhaps with retraining provided for workers (a Skills Development Fund was set up by the government in the early 80s) and with labour hoarding practices, these industries were better able to use resources and technology efficiently.

In the early 90s an improvement in TE was noted for only seven of the 28 manufacturing industries. This took place as foreign and local companies were starting to shift their operations to regions where cheap labour was available,[15] and hence, there may have been insufficient time for workers to apply their knowledge, accumulated after the 1985/86 recession. The regionalisation drive of the 90s is in line with restructuring the Singapore economy where the government is encouraging the next phase of more capital intensive manufacturing operations, and it is unlikely that TE can be improved even in the late 90s as time is required to apply the more advanced technology after adoption.

Thus, it can be seen that TP from the import of foreign technology did not bring with it improvements in skill and knowledge of the labour force or improvements in management, know-how or organisation practices. Leung's (1997) results also suggest that Singapore has not gained much from learning-by-doing. In the past, foreign MNCs set up operations in Singapore to take advantage of the nation's cheap labour as well as government incentives provided to attract FDI. As explained earlier, these served to raise the return to capital and made Singapore a viable place for MNCs. But the spillover effect from foreign investment is questionable in the absence of convincing evidence, except for a few isolated studies.[16] A recent study by Shimada (1996), for example, shows that after the mid 80s favourable growth induced by TFP was led

[15] The establishment of the Growth Triangle in 1990, as well as the location of firms from Singapore to industrial parks that Singapore had help develop in China, are some examples.
[16] See Fransman (1984).

mainly by foreign companies; while local companies were still suffering from delays in restructuring and new investment. He concluded that favourable spillover effects from foreign firms to local firms were limited to date. Kholdy (1997) further suggests that, in general, foreign firms' techniques of production are complicated and cannot be duplicated easily by domestic firms. However, with the electronics industry in Singapore, Hobday (1994) and Pang (1993) argue that there have been spillover effects with no or little leapfrogging in this industry, and new technology was increasingly applied through a gradual process of learning.

The spillover effect from foreign firms to the local market occurs through four main channels: increased competition in local markets, training of local workers, links to local industries and the acceleration of technology transfer. The first channel may have had some effect but there were only a few large enough domestic firms to compete with the MNCs, so any rippling effect would have been slow to reach the other sectors.[17] Although some evidence exists for links to local industries and training of local workers,[18] the main channel of spillover effects was still the import of foreign technology.

This is not to say that Singapore should not continue attracting foreign investment, but its increasingly difficult to ensure a high rate of return to capital, given the limits to technology and the aggressive strategy of attracting FDI by the neighbouring countries. A competitive edge for Singapore can however be gained by cutting costs. Unit labour costs in Singapore were on an upward trend for five consecutive years from 1988.[19] If labour (including increases in the import of skilled and unskilled labour) and capital can be used efficiently, production costs would be reduced and this would show up as positive changes in TE. Toh and Low (1996) claim that Singapore has a latent resource[20] which is the 'premium' offered to foreign investors despite its rapidly rising

---

[17] Chng et al. (1986) provides evidence of the sprouting of 'sparse and shallow roots in the domestic economy' due to the presence of MNCs. Furthermore, he reports that the low technological capabilities of local suppliers was cited as the major reason for the low level of local subcontracting.

[18] Ibid.

[19] See National Productivity Board (1994:11). But the increase in unit costs can be partly due to the appreciation of the Singapore dollar.

[20] This resource was defined as 'something that needs the synergy, cooperation/teamwork of both labour and capital. It is related to the overall production environment, managerial expertise and governmental committment in economic growth, thus constituting an externality.'

costs. But the question remains as to why this resource has not resulted in some efficiency gains?

For Singapore, the key to sustained economic growth is to obtain improvements in TE by using resources and technology efficiently and cultivating the spirit of innovation which also helps to secure TP. These are possible through human capital development at both management and technical level. Wong (1994) provides evidence of a positive relationship between TFP growth and a human capital measure given by the ratio of administrative and managerial workers to total employment. It is encouraging to note that Singapore's Strategic Economic Plan of 1991 strongly recommends human resource development, and presently, there are many programmes and schemes in place to enhance workforce productivity to meet technological upgrading. Wong (1997:52) warns that workforce flexibility relies on the close link between training systems and labour markets, otherwise, the consequence could be large numbers of 'educated unemployed' as found in India, Egypt and the Philippines. However, it is too early to expect results from the government's efforts and only time will tell how effective these attempts have been.

Wong (ibid) also observes that the Toyotaist approach (which appreciates more individual skills) fits Singapore better than Fordist mass production (which essentially seek to lower costs by minimising product diversity and maximising economies of scale), as Singapore is moving to higher value added activities. But Singapore not only lacks labour quality, it also has an insufficient number of workers.[21] The World Competitiveness Report 1997 shows that the availability and qualifications of human resources in Singapore have slipped to ninth from fifth position in 1995. Thus, the 'perspiration theory' that Krugman (1994) and others have been referring to is not directly applicable to Singapore, although it cannot be disputed that the miraculous growth of Singapore was achieved through technological progress. Wolff (1994:92) and Freeman (1994) also claim that, supported by high capital and investment inputs, the high technology gap of the early stage had enabled Singapore to attain TFP growth arising from the 'catch-up' effect.

---

[21] This is evidenced by the government's call to increase birth rate as well as its more recent attempts to attract foreign talent and urge Singaporeans abroad to return home. The Straits Times (Singapore) 9 Aug 1997 reported that Singapore would need 17 000 graduates a year by the year 2000 and the current output is 10 000 graduates a year.

But the question of why there was no improvement in TE or rather why over some periods there was a deterioration in TE is still not fully answered.

It has been noted earlier that Singapore lacked innovative ability and this is partly due to insufficient R&D. Singapore's technological base is weak and lags behind the efforts of developed countries, let alone other NIEs. This is shown by the low share of R&D expenditure to GDP of Singapore relative to other countries (Table 7.5).

Table 7.5 : Share of R&D Expenditure to GDP

	1981	1985	1990	1995
Singapore	0.26	0.54	0.84	1.35**
Taiwan	0.94	1.01	1.66	1.81
South Korea	0.67	1.48	1.95	2.61
US	2.43	2.08	2.81	2.58*
Japan	2.38	2.48	2.79	2.59

Note : * refers to 1994 value and ** refers to 1996 value.
R&D statistics in Hong Kong are hard to come by.

Source: Economic Survey of Singapore and Taiwan Statistical Databook, various issues.

Thus, Singapore is not in a good position to cultivate the habit of innovation as such an environment is largely missing. Drawing on Dowrick's (1995:94) argument, a free-riding strategy might well be optimal (given the huge sunk costs and the delay in returns to research), but the ability to absorb appropriate knowledge still depends on one's own research capability. Although Singapore has consciously and successfully raised the R&D expenditure to GDP ratio over the years, it still pales in comparison with the others (Table 7.5) and has yet to meet the target of 2% set for 1995.[22] Not only is the nation's R&D manpower ratio of 41 research scientists and engineers per 10 000 workers far below that of Japan's ratio of 81, United States' ratio of 75, Taiwan's ratio of 54 and South Korea's 47, but Singapore is estimated to require 13 000 research scientists and engineers by the year 2000 and is expected to be 40% short of this

[22] It is however encouraging to note that the World Economic Forum's Global Competitivness Report 97 has listed Singapore as head of a pack of 53 countries for technology. This is the most significantly improved factor for Singapore and it measures the intensity of R&D, level of technology and the stock of accumulated knowledge capital. See Southeast Asia Business Times (Singapore) 21 May 1997.

figure.[23] In fact, Maynes (et al., 1997:15) found that government expenditure on education is not a significant factor in determining Singapore's GDP growth. Given Knowles' (1997) empirical evidence across 77 countries that tertiary education provides the largest increases in the marginal product of labour for both high and low-income countries, there is a need to raise the quality of Singapore's labour force.

Relationship Between Technological Progress and Changes in Technical Efficiency

Over time, almost 92% of the 28 manufacturing industries have a negative or a very low positive correlation between TP and changes in TE. In particular, relatively labour intensive manufacturing industries like food, beverage, textile and apparel, have had sufficient time for firms to assimilate the best-practice technology by learning-by-doing and thus have some improvements in TE. However, with limits to better technology in these industries, little improvement in TP was seen. On the other hand, industrial and electrical machinery and transport equipment are likely to be more technically advanced because of the dynamic setting of shifting technological frontiers. Their lower levels of TE could arise from a lag of adjustment by firms in addition to management slack and other sources of inefficiency. The Petroleum and Iron and Steel industries stand out as having a positive correlation of 0.45 and 0.52 respectively, indicating that with TP, improvements in TE have also taken place. The highly capital intensive nature of these industries may be a reason for employing relatively fewer workers and firms may have incentive to provide more training for those who have to master specific skills to operate the machines in these industries.

Verdoon's Law

In the light of the above analysis on the decomposition of output growth, one issue worth investigating is Verdoon's law which postulates a positive relationship between output growth and TFP growth. While Tsao (1982) shows that Verdoon's law does not exist for the manufacturing sector in the decade of the 70s, Wong and Gan (1994) show that the law exists for most of the manufacturing industries in the decade of the 80s. The evidence on the existence of the law is given by obtaining the correlation coefficient between TFP growth and output growth (Table 7.6).

[23]See Business Times (Singapore) 30 Oct 1995 and 18 Nov 1997.

Table 7.6 : Correlation Coefficient Between TFP Growth and Output Growth in the Manufacturing Sector

Time Period	Correlation Coefficient
1976-1980	0.44
1981-1989	0.58
1990-1994	-0.51

In general, there was a positive relationship between output growth and TFP growth in the late 70s and the decade of the 80s. The relationship was stronger in the 80s, because manufacturing operations were more capital intensive and allowed economies of scale to coexist with TFP growth in that decade. However, in the early 90s, a negative relationship was found due to the restructuring phase where huge investments in high value added capital were made and R&D expenditures were increased, thereby lowering TFP growth, although output growth may have been positive. However, at the disaggregated industrial level, the relationship was strong and positive (correlation coefficient of 0.7 and above) for almost 50% of the 28 industries, except for Pottery and Glass industry which showed a strong negative correlation coefficient.

7.5 Summary and Conclusions

It was shown that using new data (panel data for 28 industries over 1975-94), and applying the conventional growth accounting method, TFP growth in Singapore's manufacturing sector declined in the late 80s and was negative in the early 90s. The same result was obtained using the improved stochastic frontier model. As in other studies, input growth was the main source of output growth.

The negative TFP growth of the manufacturing sector in the early 90s was partly attributed to the regionalisation drive of the 90s (whereby firms were relocating their operations to cheaper countries abroad) and the structural change to more high tech manufacturing activities. However, there is no reason to believe that this would continue and being input-driven in the past does not preclude the possibility that this will change when the Singapore economy matures. Significant increases in R&D expenditure since the early 90s could provide returns in the long run. The structural change and regionalisation move would force existing firms to use skilled workers and focus on training. Also, government measures to attract skilled labour, if successful, would lead to more efficient use of resources and technology. The emphasis and incentives provided for MNCs to set up operational headquarters has seen good response since the early 90s, in anticipation of strong regional demand and given the advanced infrastructural support of Singapore. The increase in output growth through this avenue is likely to lead to TFP growth by Verdoon's law.

The evidence of a positive relationship between TFP growth and output growth in the 70s and 80s suggests that economies of scale may be important for TFP growth. But for most of the manufacturing industries TP did not coexist with improvements in TE; which in part can be explained by the capital and technology intensity of the manufacturing industry.

In particular, the decompositional analysis of the stochastic frontier approach showed that, although the manufacturing sector benefited from technological progress, the overwhelming presence of a deterioration in technical efficiency resulted in low and declining TFP growth for the sector. With limits to the acquisition and access to better and newer technology, improvements in technical efficiency, in addition to more technological progress, hold the key to TFP growth.

Appendix 7.1 : Estimation of Pooled Model for the Manufacturing Sector

Ordinary Least Squares Estimation

```
*******************************************************************************
Dependent variable is  YLOG
560 observations used for estimation from    1 to  560
*******************************************************************************
Regressor          Coefficient      Standard Error       T-Ratio[Prob]
CONST                 1.3701            .14738           9.2959[.000]
KLOG                  .67809            .022075          30.7171[.000]
LLOG                  .33261            .022541          14.7556[.000]
T                   -.0034857           .0043409         -.80299[.422]
*******************************************************************************
R-Squared                   .90719  F-statistic F( 3, 556)    1811.5[.000]
R-Bar-Squared                .90669  S.E. of Regression            .46288
Residual Sum of Squares    119.1286  Mean of Dependent Variable    11.9523
S.D. of Dependent Variable   1.5153  Maximum of Log-likelihood   -361.2403
DW-statistic                1.3144
*******************************************************************************
                       Diagnostic Tests
*   Test Statistics  *      LM Version        *        F Version        *
*******************************************************************************
* A:Serial Correlation*CHI-SQ( 1)= 66.3879[.000]*F( 1, 555)= 74.6442[.000]*
* B:Functional Form  *CHI-SQ( 1)=  1.3516[.245]*F( 1, 555)=  1.3428[.247]*
* C:Normality        *CHI-SQ( 2)= 27.6474[.000]*      Not applicable      *
* D:Heteroscedasticity*CHI-SQ( 1)=  2.5707[.109]*F( 1, 558)=  2..6549[.121]*
*******************************************************************************
  A:Lagrange multiplier test of residual serial correlation
  B:Ramsey's RESET test using the square of the fitted values
  C:Based on a test of skewness and kurtosis of residuals
  D:Based on the regression of squared residuals on squared fitted values
```

```
  Exact AR(2) Newton-Raphson Iterative Method Converged after   3 iterations
*******************************************************************************
Dependent variable is  YLOG
560 observations used for estimation from    1 to  560
*******************************************************************************
Regressor          Coefficient      Standard Error       T-Ratio[Prob]
CONST                 1.5258            .15683           9.7287[.000]
KLOG                  .64185            .021226          30.2385[.000]
LLOG                  .35928            .021987          16.3409[.000]
T                   .7869E-3          .0054657          .14398[.886]
*******************************************************************************
R-Squared                   .91847  F-statistic F( 5, 554)    1248.2[.000]
R-Bar-Squared                .91773  S.E. of Regression            .43462
Residual Sum of Squares    104.6489  Mean of Dependent Variable    11.9523
S.D. of Dependent Variable   1.5153  Maximum of Log-likelihood   -325.0218
DW-statistic                1.9945
*******************************************************************************
          Parameters of the Autoregressive Error Specification
*******************************************************************************
U=   .36206*U(- 1)+  -.023218*U(- 2)+E
  (   8.5703)[.000] (  -5.4959)[0.0483]
T-ratio(s) based on asymptotic standard errors in brackets
Log-likelihood ratio test of AR(1) versus OLS   CHI-SQ(1)=  27.1594[.000]
Log-likelihood ratio test of AR(2) versus AR(1) CHI-SQ(1)=   12.7770[0.05]
*******************************************************************************
```

Wald test of restrictions imposed on parameters

****

Based on stochastic initial value(s) AR(2) regression of YLOG on:
CONST KLOG LLOG T
560 observations used for estimation from 1 to 560

****

Coefficients A1 to A4 are assigned to the above regressors respectively
List of imposed restriction(s) on parameter(s):
a3=0.39 Wald Statistic CHI-SQ(1)= 1.9517[.162]

****

Appendix 7.2 : Estimation of Fixed Effects Model for the Manufacturing Sector (Corrected for autocorrelation)

DEPENDENT VARIABLE = Y

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO 549 DF
K	0.58940	0.3659E-01	16.11
L	0.33299	0.2772E-01	12.01
T	0.87213E-01	0.3882E-02	22.47
D31	2.8057	0.3009	9.325
D32	1.5748	0.3137	5.020
D33	1.8601	0.3895	4.775
D34	2.1448	0.3809	5.632
D35	2.3134	0.3309	6.991
D36	2.1738	0.2707	8.029
D37	2.3825	0.3140	7.587
D38	2.4508	0.3771	6.500

R-SQUARE = 0.9819 R-SQUARE ADJUSTED = 0.9815
DURBIN-WATSON = 1.9614
|_Test K + L =1
WALD CHI-SQUARE STATISTIC = 5.7126868 WITH 1 AND 549 D.F.
|_Test L = 0.39
T STATISTIC = 5.4502247 WITH 549 D.F.

Appendix 7.3 : TFP Levels of the Manufacturing Sector

Year	TFP Level
1975	0.64703433
1976	0.70069857
1977	0.73059146
1978	0.73638429
1979	0.83480739
1980	1.12561533
1981	1.18619673
1982	0.96329242
1983	0.86548078
1984	0.83266334
1985	0.73380584
1986	0.78657654
1987	0.86164863
1988	0.95181581
1989	0.87946928
1990	0.80772482
1991	0.78366651
1992	0.68504919
1993	0.69146919
1994	0.66263256

Appendix 7.4 : Estimation of TFP Growth Rate for the Manufacturing Sector

Cochrane-Orcutt Method AR(2) Converged after 3 iterations

****

Dependent variable is LNMANU

20 observations used for estimation from 1975 to 1994

****

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CONST	-.021968	.16182	-.13576[.894]
T	-.014677	.012376	-1.1859[.251]

****

R-Squared	.69973	F-statistic F(3, 14)	10.8750[.001]
R-Bar-Squared	.63539	S.E. of Regression	.097298
Residual Sum of Squares	.13254	Mean of Dependent Variable	-.20799
S.D. of Dependent Variable	.16587	Maximum of Log-likelihood	18.6605
DW-statistic	1.8888		

****

Parameters of the Autoregressive Error Specification

****

U= 1.0365*U(- 1)+ -.45054*U(- 2)+E

(4.4713)[.000] (-2.0409)[.058]

T-ratio(s) based on asymptotic standard errors in brackets

****

Appendix 7.5 : Stochastic Frontier Estimates for the Manufacturing Sector

THE FINAL MLE ESTIMATES ARE :

	COEFFICIENT	STANDARD-ERROR	T-RATIO
INTERCEPT	-0.13115870E+01	0.40980798E+00	-0.32004915E+01
K	0.59526647E+00	0.24285080E-01	0.24511613E+02
L	0.39434923E+00	0.26489110E-01	0.14887221E+02
T1	-0.11052615E+01	0.11157099E+00	-0.99063518E+01
T2	-0.92590228E+00	0.11051628E+00	-0.83779720E+01
T3	-0.77404663E+00	0.11686358E+00	-0.66235058E+01
T4	-0.63288580E+00	0.11666609E+00	-0.54247625E+01
T5	-0.40100390E+00	0.11607574E+00	-0.34546744E+01
T6	-0.17378888E+00	0.11376688E+00	-0.15275876E+01
T7	-0.91564513E-01	0.10747082E+00	-0.85199416E+00
T8	-0.23140874E+00	0.11158717E+00	-0.20737933E+01
T9	-0.27936361E+00	0.10629877E+00	-0.26280982E+01
T10	-0.32187761E+00	0.10416595E+00	-0.30900462E+01
T11	-0.45362102E+00	0.10131539E+00	-0.44773161E+01
T12	-0.37572431E+00	0.10208473E+00	-0.36805145E+01
T13	-0.19458634E+00	0.10335748E+00	-0.18826536E+01
T14	0.20892084E-01	0.10398533E+00	0.20091376E+00
T15	0.91919924E-01	0.10024387E+00	0.91696302E+00
T16	0.57481348E-01	0.10616882E+00	0.54141460E+00
T17	0.60700008E-01	0.10739128E+00	0.56522289E+00
T18	0.12898280E-01	0.10479665E+00	0.12307913E+00
T19	0.23110958E-02	0.10383495E+00	0.22257399E-01
D31	0.38529428E+01	0.33776764E+00	0.11407081E+02
D32	0.33093941E+01	0.33656671E+00	0.98328030E+01
D33	0.33078783E+01	0.33905321E+00	0.97562216E+01
D34	0.35666116E+01	0.34002374E+00	0.10489302E+02
D35	0.38580149E+01	0.34094580E+00	0.11315625E+02
D36	0.36320283E+01	0.33778037E+00	0.10752633E+02
D37	0.36399214E+01	0.33906373E+00	0.10735213E+02
D38	0.35336669E+01	0.34172999E+00	0.10340523E+02
SIGMA-SQUARED	0.26065286E+00	0.49016398E-01	0.53176665E+01
GAMMA	0.53413008E+00	0.17253861E+00	0.30957135E+01

VALUE OF CHI-SQUARE TEST OF ONE-SIDED ERROR = 0.26990435E+04
WITH DEGREES OF FREEDOM = 1

Appendix 7.6a : Decomposition of Output Growth in Manufacturing, 1976-1984

Industries	Output Growth	Input Growth	TFP Growth	Change in TE	TP
311/12	2.737	3.256	-0.519	-2.201	1.682
313	2.522	1.863	0.658	-0.309	0.967
314	2.548	1.634	0.913	0.103	0.811
321	0.087	-1.460	1.547	-0.011	1.557
322	3.156	1.914	1.242	0.257	0.985
323	1.326	1.407	-0.081	-0.693	0.612
324	1.585	2.481	-0.897	-1.816	0.919
331	0.391	-0.262	0.653	-0.438	1.091
332	6.570	6.219	0.352	-0.516	0.867
341	5.491	6.746	-1.255	-2.718	1.463
342	4.637	4.666	-0.029	-0.924	0.895
351	6.658	6.414	0.244	-1.244	1.488
352	5.451	3.002	2.449	1.766	0.683
353/54	1.119	0.885	0.234	-0.540	0.775
355/56	1.395	2.584	-1.189	-2.819	1.630
357	6.049	11.860	-5.811	-8.172	2.361
361/62	2.787	5.378	-2.591	-3.711	1.119
363	3.561	3.995	-0.434	-2.388	1.954
364	0.475	1.373	-0.898	-1.479	0.580
365	17.604	15.681	1.922	1.089	0.833
369	0.837	0.252	0.585	-0.377	0.962
371	2.475	1.928	0.546	-0.527	1.073
372	6.985	7.365	-0.380	-1.919	1.538
381	5.577	6.839	-1.262	-2.325	1.063
382	3.012	3.299	-0.287	-1.107	0.820
383	3.618	2.692	0.926	-0.493	1.419
384	7.015	4.816	2.199	1.223	0.975
385	16.691	11.805	4.886	1.078	3.808

Note: See Appendix 5.1 for information on the manufacturing industry codes.

Appendix 7.6b : Decomposition of Output Growth in Manufacturing, 1986-1990

Industries	Output growth	Input growth	TFP Growth	Change in TE	TP
311/12	0.674	0.171	0.503	-0.173	0.676
313	0.548	1.484	-0.936	-1.342	0.406
314	0.734	-0.326	1.060	0.610	0.450
321	0.958	0.471	0.486	-0.021	0.507
322	0.724	0.540	0.185	-0.185	0.370
323	1.198	0.251	0.947	0.528	0.419
324	0.608	-0.766	1.374	0.603	0.772
331	0.406	-0.517	0.924	0.331	0.593
332	0.448	0.173	0.275	-0.157	0.432
341	1.097	0.537	0.560	0.099	0.462
342	1.036	0.541	0.496	0.035	0.461
351	1.160	0.817	0.343	0.029	0.314
352	0.825	0.135	0.690	0.461	0.229
353/54	1.496	0.297	1.199	0.718	0.481
355/56	0.811	1.436	-0.625	-1.498	0.873
357	1.777	2.413	-0.635	-1.499	0.864
361/62	11.809	32.911	-21.102	-23.114*	2.012
363	-0.014	-1.653	1.639	0.554	1.085
364	1.383	-0.762	2.145	1.460	0.685
365	-0.037	-0.741	0.704	0.151	0.553
369	0.756	0.398	0.357	-0.278	0.635
371	0.726	0.352	0.373	-0.064	0.438
372	1.882	0.996	0.887	0.352	0.534
381	1.211	0.815	0.396	-0.123	0.519
382	0.969	0.729	0.240	-0.268	0.508
383	0.891	1.034	-0.144	-0.617	0.473
384	1.436	1.305	0.131	-0.185	0.316
385	0.867	0.341	0.526	0.188	0.338

Note: *The Pottery and Glass Products industry has unusually high input growth (and hence large negative changes in TE) and this is attributed to the huge increases in labour employed in 1990 resulting from the unusually low levels of employment reported from 1985-88. In fact, Wong (1994) also found that this industry had unusually high negative TFP growth for 1981-90.

Appendix 7.6c : Decomposition of Output Growth in Manufacturing, 1990-1994

Industries	Output growth	Input growth	TFP Growth	Change in TE	TP
311/12	0.462	1.423	-0.962	-1.054	0.093
313	0.321	0.023	0.298	0.186	0.113
314	0.977	1.067	-0.090	-0.135	0.045
321	-0.077	0.014	-0.091	-0.161	0.070
322	-0.245	-0.032	-0.213	-0.277	0.064
323	0.810	1.316	-0.506	-0.554	0.048
324	-0.029	0.039	-0.068	-0.143	0.075
331	-0.129	-0.157	0.028	-0.041	0.069
332	0.375	0.490	-0.115	-0.186	0.071
341	0.473	1.032	-0.559	-0.621	0.062
342	0.739	0.783	-0.044	-0.108	0.064
351	0.187	0.943	-0.756	-0.810	0.053
352	0.574	0.338	0.236	0.204	0.031
353/54	0.263	0.882	-0.618	-0.667	0.048
355/56	0.618	1.160	-0.541	-0.691	0.150
357	0.712	1.596	-0.884	-1.002	0.118
361/62	1.002	0.165	0.836	0.652	0.184
363	0.547	-0.528	1.075	0.937	0.138
364	1.810	0.178	1.631	1.588	0.043
365	0.958	1.457	-0.499	-0.577	0.078
369	0.500	0.201	0.299	0.208	0.091
371	-0.061	0.788	-0.849	-0.915	0.066
372	0.177	1.453	-1.276	-1.336	0.060
381	0.674	3.303	-2.629	-2.701	0.072
382	0.519	0.785	-0.266	-0.343	0.077
383	0.424	0.587	-0.163	-0.249	0.086
384	0.824	0.619	0.205	0.146	0.059
385	0.540	0.871	-0.331	-0.380	0.050

Appendix 7.7 : Decomposition of Retained Imports

The data available on Imports, Exports and Domestic Exports by Commodity from the Singapore Yearbook of Statistics were used. Total exports are made up of domestic exports (comprise of manufactured goods as well as goods which have been transformed or assembled or processed in Singapore, including those imported materials or parts) and reexports (refer to all goods which are exported from Singapore in the same form as they have been imported without any transformation).

ReExports = Total Exports - Domestic Exports

The commodities were first broken down into 3 categories as given below:

Consumption Goods - Food, Beverage & Tobacco,Miscellaneous Manufactured Articles
Intermediate Goods - Crude Materials, Mineral Fuels, Chemicals and Manufactured Goods by Material (non-metal mineral and metal manufactures, iron & steel)
Capital Goods - Machinery and Transport Equipment (electric and non-electric machinery and transport equipment)

Since data on retained imports are not available, the shares were obtained following Aw's method (1991:364, 413):

As reexports are at fob prices, the value added on reexports (which are costs of insurance, freight and custom duties payable to the registration area) have to be excluded.

Retained Imports = Total Imports - ReExports - Value Added on ReExports

But information on the last component above is not readily available and retained imports at export value are taken as a proxy for retained imports at import value. Also, imports were assumed to mainly consist of the 3 categories listed above and the shares of retained imports of each of them was then calculated.

Chapter 8

Total Factor Productivity in the Services Sector

8.1 Introduction

While the manufacturing sector was chosen as an engine of growth in the early 70s, it was only after the 84/85 recession that the services sector was identified as an equally important engine of growth.[1] In the light of the growing argument (Tsao 1982, Young 1992, Krugman 1994, Kim and Lau 1994, and Leung 1997), where the Singapore economy is said to suffer from insignificant TFP growth in the aggregate economy and the manufacturing sector, the question of what the service sector's contribution is in terms of TFP growth becomes central. This issue is investigated in this chapter.

More investigation into the services sector is warranted because of the lack of research in this sector. To date, only two studies have been undertaken to estimate TFP growth in Singapore's services sector. Rao and Lee (1995) considered services as a residual where all data for services were obtained by subtracting the manufacturing sector from the aggregate economy, thereby including utilities and construction as services. They found that TFP growth increased from 0.9% for 1976-84 to 2.2% for 1987-94. Virabhak (1996), on the other hand, attempted the first estimation of sectoral TFP growth for 17 industries in the services sector. Over the period of 1976-92/93, she concluded that TFP growth in the services sector (based on the majority of the service groups and not on any service sector aggregate) hovered about zero and, in general, followed a cyclical pattern. TFP growth's contribution to output growth was, however, seen to increase in the late 80s.

Since both the above studies have used the conventional growth accounting approach, for comparative purposes, the same approach is used here to estimate the Cobb-Douglas production function with new data (panel data for 17 industries between 1975-94) first by pooling, and second, by using the fixed effects model. This is followed by a test for

---

[1] See Report on the Economic Committee (1986).

the functional form and appropriateness of the pooling methodology, and the robustness of the estimation. Then TFP levels and TFP growth estimates are distinguished for analysis. A section on the catch-up process between the manufacturing and services sectors is also undertaken to shed light on the technology gap between these two sectors. Then the improved and recently developed stochastic frontier approach is used to obtain TFP growth estimates for comparison with those obtained by the growth accounting approach. The frontier approach then decomposes output growth into input growth, TP and changes in TE. In addition, Verdoon's law is tested and the relationship between technical progress and changes in technical efficiency is examined.

8.2 Growth Accounting Approach

Measuring TFP Growth

As explained in the previous chapter, the production function is estimated with only capital and labour, as energy and materials inputs are not considered since such information is not available for the services sector and intermediate inputs are relatively minor for services. A time trend was included to remove the effect of time-specific factors.

The Pooled Model of the Production Function

The estimated equation which has been corrected satisfactorily for autocorrelation (the corrected DW statistic was 2.0) by maximum likelihood estimation using Newton-Raphson iterative method is given by:

$$\text{Log } Y = \underset{(0.388)}{0.65^{*}} + \underset{(0.025)}{0.54^{*}} \text{ Log } K + \underset{(0.054)}{0.57^{*}} \text{ Log } L + \underset{(0.15 \text{ X } 10^{-6})}{0.69 \text{ X } 10^{-6}}{}^{*}\, T$$

where Y is value added output in the services sector
K is capital input used
L is number of workers employed
T is the time trend

Standard errors are given in parenthesis and * indicates significance of the estimated coefficients at 5% level of significance. The Ramsey Reset test statistic of 0.03 is below the critical value of 3.84 at 5% level of significance indicating that there is no misspecification of the functional form, nor were there any major problems with heteroscedasticity. In testing the hypothesis that the sum of the input shares does not significantly differ from one, it was found that the hypothesis was accepted. This result is given by the Wald chi-square test statistic of 6.5 which is below the critical value of 6.63 at 1% level of significance (see Appendix 8.1 for details of estimation).

The input shares obtained above are close to those obtained by Rao and Lee (1995) for the period 1976-94 where the capital share was 0.53 and the labour share was 0.47.

Testing for Appropriateness of Estimated Input Shares

It has been shown above that the Ramsey Reset test does not reject the specified functional form; nor does it reject the constant returns to scale condition for the estimated equation.

In order to test if the estimated input shares are not statistically different from those which can be obtained from actual data, it suffices to test whether the coefficient of labour ($\hat{\beta}$) is significantly different from the average share of the wage bill in output. The average share of the wage bill in output is given by the ratio of remuneration[2] paid out to workers to the value added output. Since panel data were used, the average is taken over each industry's ratio in each time period.

The null hypothesis below states that the estimated labour share is not significantly different from the share of the wage bill given by actual data.

Test $H_0: \hat{\beta} = 0.461$

The above test provided a Wald test statistic of the chi-square distribution with 1 degree of freedom, $\chi_1^2 = 3.77$. Since the value is not greater than the critical value of 5.02 at 5% level of significance, the null hypothesis that the coefficient of labour estimated from Cobb-Douglas production function does not differ significantly from the actual average share of the wage bill for the services sector cannot be rejected. This along with the earlier conclusion that constant returns to scale hypothesis cannot be rejected,

[2] Remuneration is as defined in footnote 5 of Chapter 7.

implies that the Cobb-Douglas functional form is an appropriate modelling framework for the present data for the services sector.

The Fixed Effects Model

The production function was reestimated using the fixed effects formulation (as was done for the manufacturing sector) with 3 dummies to group industries according to their single-digit industry codes[3] over the period of 1975-94. Since no constant was included in the estimations, the number of dummies used is equal to the number of grouped service industries. The estimated results, without specifying the dummy coefficients, are provided below.

$$\text{Log } Y_{it} = \sum_{j=1}^{3} \lambda_j^{*} + \underset{(0.026)}{0.20^{*}} \text{ Log } K_{it} + \underset{(0.041)}{0.73^{*}} \text{ Log } L_{it} + \underset{(0.0045)}{0.08^{*}} \, T$$

where i = 1 to 17 , j = 1 to 3, t = 1 to 20

Standard errors are given in parenthesis and * indicates significance of the estimated coefficients at 5% level of significance. The full estimation with the dummy coefficients is given in Appendix 8.2

The above equation was satisfactorily corrected for autocorrelation by the Cochrane-Orcutt iterative estimation, with a DW statistic of 1.87. The heteroscedasticity test statistic of 3.47(based on the regression of squared residuals on squared fitted values) is below the critical value of χ_1^2 = 5.02, indicating that the errors in the regression estimation have a common variance. The test on the appropriateness of the functional form given by the Ramsey Reset test (based on the squared of fitted values) statistic of 2.17, is below the critical value of 3.84 at 5% level of significance, so we cannot reject the null hypothesis that the functional form is not misspecified. The constant returns to scale condition given by the Wald chi-square test statistic of 4.66, is accepted at 1% level of significance, indicating the appropriate use of the Cobb-Douglas functional form.

[3] Using separate dummies for each industry as well as grouping them according to their 2-digit industry codes violated the constant returns to scale condition. However, the latter type of grouping, unlike the former, allowed for statistically significant input shares.

The capital and labour shares are positive and significant. All the dummy coefficients are positive and significant, thus reinforcing the existence of heterogeneity among the service industries.

To check on whether the estimated labour share coefficient is representative of the share of wage bill from actual data, the following hypothesis is tested.

$$H_o: \hat{\beta} = 0.461$$

The t-statistic of 6.63 obtained was above the critical value of 1.96 which suggests that the estimate of the labour share coefficient is not representative of the labour share from the actual data. However, given the advantages of the fixed effects model using industry-specific dummies (which were found to be significant) incorporating panel data, it appears likely that the estimate obtained using this model would be valid.

In comparison with the pooled model, the capital share of this model is much lower and the labour share is much higher. Thus, the inclusion of industry-specific effects shows an increase in the labour intensity of the services industries compared to the pooled model. Like the FE model of the manufacturing sector, factoring out each grouped service industry's technology factor (which is higher than the pooled model's technology factor) has left less output accruing to capital input.

TFP Levels and TFP Growth Rates

To estimate TFP Level, the fixed effects estimation with industry-specific factors is used. The TFP level for each service industry *i* in each time period *t* is given by:

$$e^{\ln \text{TFP Level}} = \text{Log } Y_{it} - \hat{\beta} \text{ Log } L_{it} - \hat{\alpha} \text{ Log } K_{it} - \lambda_j - \delta T$$

Each of the industry's TFP level for time *t* is then weighted by its share in the total value added output of the sector in time *t*. The services sector's TFP level is then obtained for each time *t* by summing the weighted TFP levels of all its industries (see Appendix 8.3 for the estimated TFP levels over the period 1975-1994).

TFP levels in the services sector showed a consistent increase over time, except in the recession period of 1985-87.

To obtain TFP growth rate, two methods are used. One method is the residual method which is obtained for each industry i for each time t as:

$$\text{TFP Growth Rate} = \hat{Y} - \alpha \hat{K} - \beta \hat{L}$$

where ^ refers to growth rates.

The residual method was first used to calculate TFP growth rates of each of the industries in the services sector. Then the weighted average, using value added shares, was used to arrive at TFP growth rate for the service sector as an aggregate. The alternative method using the fitted annual TFP growth rate, by regressing the logs of the aggregated weighted industry TFP levels on a time trend and constant, was also used to check for robustness of the results from the residual method. The coefficient of the time trend gives the fitted annual TFP growth rate for the period concerned.

For the period of 1975-94, the estimated equation satisfactorily corrected for autocorrelation is given as :

$$\text{Log TFP Level} = \underset{(0.114)}{0.576} - \underset{(0.010)}{0.0161}\ T$$

Standard errors are given in parenthesis. See Appendix 8.4 for full estimation details.

It was found that the average annual TFP growth rate of -1.61%. for the period of 1975-94 was not statistically significant. This implies that TFP growth rate is zero which is in line with Virabhak's (1996) conclusion that TFP growth in the service sector (based on the majority of the service groups and not on any service sector aggregate) hovers about zero. As was noted in the previous chapter, the negative value obtained here could be because of the larger influence of the central observations around the recession years of 1984-1986 on the fitted regression line than the observations at the end and thus are not representative of the entire period. In comparison, the residual method gave an average annual TFP growth rate of 0.13% over 1975-94.

<u>Comparison of TFP Estimates with Other Studies</u>

The only other study that could be compared with this exercise is Rao and Lee (1995) and the following results are summarised in Table 8.1.

Table 8.1 : TFP Growth Rates for the Services Sector

Period	Rao and Lee (1995)	Fitted Method	Residual Method
1976-84	0.90	1.60	1.97
1987-94	2.20	2.90	4.13
1981-85	Not Applicable	___	-4.70
1986-90	Not Applicable	___	1.81
1990-94	Not Applicable	___	1.63

Note: The fitted method was not used for the other sub periods as often the convergence rule was violated and there were insufficient degrees of freedom for accurate estimation.

The magnitudes of TFP growth rates obtained in this exercise are higher than those of Rao and Lee (1995), although both exercises used the growth accounting methodology. The differences were explained in the previous chapter. In addition, Rao and Lee used a residual measure (total economy - manufacturing) for services and this included utilities, construction and personal, community and social services, none of which were included in this exercise. However like the Rao and Lee study, both methods of calculation showed that TFP growth has increased from 1976-84 to 1987-94. As expected, TFP growth improved in the recovery period of the late 80s from the recession period of 1981-85. In general, TFP growth was positive but declining throughout the periods of 1976-84, 1986-90 and 1990-94.

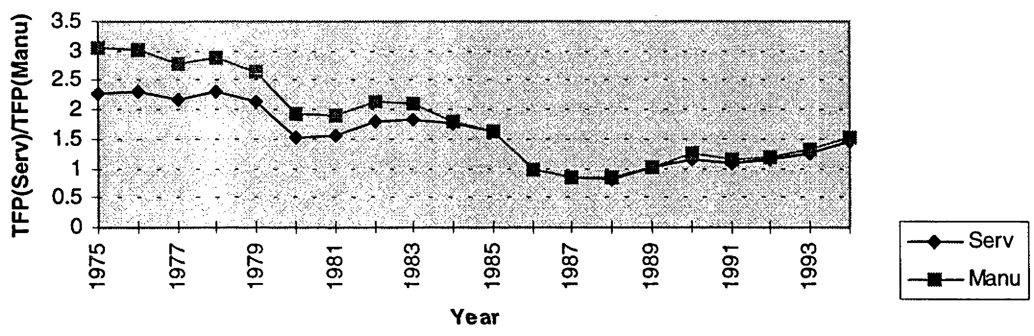
8.3 Technology Catch-Up Between the Growth Sectors

Having estimated the production function for both manufacturing and services sectors, we can now ask how the manufacturing and services sectors fare relative to one another in terms of technology catch-up. Is there a technology gap between the growth sectors, and if so, what can be said about the 'catch-up' process in terms of the technology gap? Wu (1997) explains that changes in TFP levels reflect changes in technical efficiency, which in turn are due mainly to the effects of catching up. Thus, the catch-up process in technology use between the growth sectors is investigated using their relative TFP levels.

Comparison of Relative TFP Levels of the Growth Sectors

To compare the relative TFP levels of the manufacturing and services sectors, differences in nature of technology and output of the sectors must be controlled. Following the method used by Chand and Falvey (1996), the input share values obtained in the pooled model for the service sector are first imposed on the pooled model for the manufacturing sector.[4] The relative TFP level is then computed using the values obtained for TFP levels for each of the sectors. The exercise is then repeated, imposing the share values obtained from the pooled model estimation of the manufacturing sector on those of the services sector, so that the relative TFP levels for each of the sectors can be obtained. Figure 8.1 gives the time plot of the relative TFP level in the two sectors.

Figure 8.1 : Time Plots of Relative TFP Levels



It can be seen that the relative TFP levels of the services sector were lower than those of the manufacturing sector before 1984, after which they converged and showed very slight deviation after 1988. Before 1984, the government policy of encouraging and nurturing the manufacturing sector as the main engine of growth would have led to this sector enjoying higher TFP levels than services.[5] However, the services sector seemed to have caught up as the gap closed. This can be partly attributed to government policy as the services sector was recognised as another engine of growth.[6] The growing importance of producer services and the rapid growth of second-tier NIEs has also increased the demand for services and, with the tight labour market situation, this could

[4] Note that the pooled estimations are used for this exercise because input shares cannot be imposed in the fixed effects estimation due to the existence of dummy variables.

[5] Since the early 70s, the Singapore government has been active in wooing foreign direct investment in manufacturing and has provided many tax incentives to encourage the growth of this sector. This is further fuelled by the strong demand for manufactured goods from the developed countries.

[6] See Report of the Economic Committee (1986), Ministry of Trade and Industry, Singapore.

have encouraged labour-saving innovations in the services sector and enabled 'catch-up' with the manufacturing sector.

8.4 Stochastic Production Frontier Approach

A Cobb-Douglas model similar to that used for the manufacturing sector is used in the estimation of the stochastic production frontier for services. The estimation used the same panel data with three industry-specific dummies as in the growth accounting approach. Time dummies are used for the same reasons as for the manufacturing sector.

Estimation Results

To estimate the model the Fortran program, Tealec, which adopts the maximum likelihood estimation was used. The key estimation results for the services sector are given in Table 8.2 and details of the estimation are provided in Appendix 8.5.

Table 8.2 : Maximum Likelihood Estimates of the Stochastic Production Function for the Services Sector

Variable	Estimates
Constant, ϕ	5.48* (0.529)
Log (K)	0.30* (0.017)
Log (L)	0.69* (0.031)
Time Dummies (19)	18 were significant
Industry Dummies (3)	All were significant
γ	0.70* (0.126)
LR Test of the One-Sided Error with 1 Restriction	0.76×10^3

Note: Figures in parenthesis are the standard errors.
* means that the coefficient is significant at the 1% level of significance.

The input shares were found to be statistically significant and the capital share was higher than that obtained with the fixed effects model using the growth accounting methodology. All industry dummies were significant, indicating that the heterogeneity in the service industries has to be accounted for to obtain unbiased estimates. The significant time dummies indicate that there was variation in technological progress through time. The γ value of 0.7 is high and the one-sided likelihood ratio (LR) test shows that it is statistically significant, thus indicating that the stochastic frontier approach is modelling the services sector production process better than the average (OLS) production function approach for the present data.

Decomposition of Output Growth

Using the parameter estimates of the model, input growth, TP and changes in TE can be calculated according to Equation (5) in Chapter 5. The decomposition of output growth for the services sector was obtained using the same method that was used for the manufacturing sector. TFP growth estimations are summarised in Table 8.3 for selected time periods to enable comparison with the growth accounting exercise and the earlier studies.

Table 8.3 : Decomposition of Output Growth in the Services Sector

Period	Output Growth	Input Growth	TFP Growth	Change in TE	TP
1976-84	2.70	1.93 (71.7 %)	0.77 (28.3 %)	-0.39	1.16
1987-94	2.98	2.12 (70 %)	0.86 (30 %)	-0.73	1.59
1981-85	0.16	2.02	-1.86	-2.28	0.28
1986-90	1.25	0.54 (43.2 %)	0.71 (56.8 %)	-0.17	0.88
1990-94	0.97	0.70 (72.2 %)	0.27 (27.8 %)	-0.27	0.54

Note: Output growth = $(Y_2 - Y_1)/Y_1$
Figures in parenthesis are the contribution to output growth.

From Table 8.3, it can be seen that, similar to Rao and Lee's (1995) results, TFP growth of services has improved from 1976-84 to 1987-94. At the disaggregated industry level, such an improvement in TFP growth was seen for 59% of the 17 industries in the services sector. The trend of TFP growth over the decade of 80s and early 90s is similar to that obtained from the growth accounting methodology. However, when seen over 1976-84, 1986-90 and 1990-94, TFP growth has declined.

In Appendix 8.6 details at the disaggregated level (industries) of the services sector are provided. They show that for 1976-84, there was positive TFP growth for 8 service industries (of which 6 were from financial and business services), and in 1986-90, 14 service industries experienced positive TFP growth. The number fell to 9 in the early 90s. Almost all service industries over time registered growth rates of less than 2%. Except for the early 80s, financial and some business services were able to record modest productivity growth. Singapore's drive to become a major financial centre and business hub has enabled these industries to be productive by exposing them to international competition.

Commerce industry comprising of wholesale and retail trade, and hotels and catering, has recorded some productivity growth over time. After the recession of 1985/86, this industry has benefited from booming tourist trade and intense competition from many firms within the industry wanting to provide good services. The shakeout in retail trade in the early 90s and the recent move towards electronic commerce can be expected to be a further boost to this industry.[7] On the other hand, storage and warehousing, and four types of transport industries have not done well in terms of TFP growth, except for some improvement in 1986-90 after the recession. Although Singapore's Changi airport, her port facilities and local transport system have been rated highly by international standards, they have yet to show up in productivity growth figures. Perhaps, it is hard to expect more growth given that these industries have possibly experienced rapid TP.

Interestingly, information technology (IT) services have always shown a deterioration in TE and registered negative productivity growth. This does not necessarily reflect poor performance of this sector as Gilbert (1990) and Sisodia (1992) claim that Singapore developed quickly by using IT. But rather, the benefits of this sector often accrue to other firms using IT. Another reason could be that the increase in output could not match the rapid fall in the price of IT services caused by high competition in software development and hence the value of output did not fully reflect productivity growth.

Technological Progress

Now, examining one of the components of TFP growth, it can be seen that although positive, TP has consistently decreased over the periods of 1976-84, 1986-90 and 1990-

[7] This has been discussed in Chapter 2 .

94. The falling TP is also found for almost all service industries over these periods (see Appendix 8.6). This is because services are prone to limits in technology use, as often the provision of services requires a personal touch. Or it could be that the effect of TP on services is especially difficult to measure, let alone the difficulty of measuring service output. At a disaggregated level, TP is the dominant source of TFP growth for 47% of the 17 service industries during 1976-84, for 82% of the industries during 1986-90 and 53% of the service industries in the early 90s.

Improvements in Technical Efficiency

Considering the other component of TFP growth for 1976-84 and the early 90s, the change in TE was positive for 4 service industries, and for 1986-90 it was positive for communications and wholesale trade industries only. But telecommunications was able to sustain improvements in TE since 1986, as rising demand from other industries of the economy as well as increasing international demand has exposed this industry to very high levels of competition, which lead to efficient use of resources. Two other services, real estate and legal services, also enjoyed improvements in TE over 1976-84 and the early 90s. With real estate during 1976-84, there was increasing demand for condominiums, five-room apartments, and new housing estates with shopping centres. In the early 90s, competition was high as the property market was intense with rising demand for private housing and even bigger apartments as well as office space. The rise in property prices over the last five years also contributed to the expansion of the financial and business services. Those involved in the property market business had the incentive to improve and provide the best service possible in order to gain customers.

In 1981-85, the deterioration in TE was largest compared to other periods, possibly due to labour hoarding practices and underutilisation of both capital and labour resources during the recession years of 1985/86.

Relationship Between Technological Progress and Changes in Technical Efficiency

82% of the service industries registered a negative correlation coefficient between the two components of TFP growth, while the remaining 8% (comprising wholesale, communications and financial services) had very low positive correlation coefficients not exceeding 0.18. Thus, little improvement in TE coexisted with TP while high rates of TP typically coexisted with deteriorating TE. Nishimizu and Page (1982) explain that this is possible due to failures in achieving technological mastery or due to short-run cost-minimising behaviour in the face of quasi-fixed vintage of capital.

Verdoon's Law

Verdoon's law, which postulates a positive relationship between output growth and TFP growth was also tested for the services sector. The correlation coefficient between the two growth variables are provided in Table 8.4.

Table 8.4 : Correlation Coefficient Between TFP Growth and Output Growth in the Services Sector

Time Period	Correlation Coefficient
1976-1980	0.24
1981-1989	0.08
1990-1994	-0.02

The low and positive relationship between output growth and TFP growth weakened over time and was negative in the early 90s. Thus, output growth and hence economies of scale did not significantly affect TFP growth in the services sector. This is not surprising since services are heterogenous and often have special clientele and established niches. At a disaggregated level, 70% of the service industries had very low correlation coefficient averaging 0.2, over the above time periods.

8.6 Summary and Conclusions

Using new data (panel data for 17 industries over 1975-94) and applying both the conventional growth accounting method and the improved stochastic frontier model, TFP growth for the services sector was shown to increase from 1976-84 to 1987-94, but it decreased (though still positive) over the period of 1986-90 and 1990-94. Input growth was the main source of output growth (except in 1986-90).

However, communications, financial, insurance, real estate and legal services show some promise for the future. Communications industry being strongly depended upon by other industries in the economy, and increasing international demand should continue to provide exposure to very high levels of competition, leading to efficiency improvements and adoption of new technology, and hence TFP growth. Financial services, on the other hand, can expect a boost in performance from government's commitment to deregulate the financial sector, thereby increasing competition in the near future.

In particular, the decompositional analysis of the stochastic frontier approach showed that in the services sector, technological progress was accompanied by a deterioration in technical efficiency and this resulted in low and declining TFP growth. Thus, the services sector must use resources and technology more efficiently to attain maximum possible output.

Unlike the manufacturing sector, TFP growth and output growth were not correlated, suggesting that economies of scale are not important for TFP growth in the services sector. However, similar to the manufacturing sector, for most service industries, TP did not coexist with improvements in TE .

Appendix 8.1 : Estimation of Pooled Model for the Services Sector

Ordinary Least Squares Estimation

****

Dependent variable is YLOG

340 observations used for estimation from 1 to 340

****

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CONST	3.0908	.22294	13.8637[.000]
KLOG	.37571	.018252	20.5841[.000]
LLOG	.53451	.030970	17.2587[.000]
T	.5747E-6	.3745E-6	1.5346[.126]

****

R-Squared	.86896	F-statistic F(3, 336)	742.7137[.000]
R-Bar-Squared	.86779	S.E. of Regression	.51342
Residual Sum of Squares	88.5691	Mean of Dependent Variable	13.1646
S.D. of Dependent Variable	1.4120	Maximum of Log-likelihood	-253.7615
DW-statistic	.42088		

****

Diagnostic Tests

* Test Statistics *	LM Version *	F Version *
* A:Serial Correlation*	CHI-SQ(1)= 213.3355[.000]*	F(1, 335)= 564.2261[.000]*
* B:Functional Form *	CHI-SQ(1)= .027762[.868]*	F(1, 335)= .027356[.869]*
* C:Normality *	CHI-SQ(2)= 5.5222[.063]*	Not applicable *
* D:Heteroscedasticity*	CHI-SQ(1)= 3.8375[.050]*	F(1, 338)= 3.8585[.050]*

****

A:Lagrange multiplier test of residual serial correlation
B:Ramsey's RESET test using the square of the fitted values
C:Based on a test of skewness and kurtosis of residuals
D:Based on the regression of squared residuals on squared fitted values

Exact AR(2) Newton-Raphson Iterative Method Converged after 11 iterations

****

Dependent variable is YLOG

340 observations used for estimation from 1 to 340

****

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CONST	.64811	.38760	1.6721[.095]
KLOG	.53808	.024745	21.7446[.000]
LLOG	.56500	.053567	10.5476[.000]
T	.6960E-6	.1485E-6	4.6876[.000]

****

R-Squared	.96070	F-statistic F(5, 334)	1633.1[.000]
R-Bar-Squared	.96011	S.E. of Regression	.28200
Residual Sum of Squares	26.5611	Mean of Dependent Variable	13.1646
S.D. of Dependent Variable	1.4120	Maximum of Log-likelihood	-49.8271
DW-statistic	2.0005		

****

Parameters of the Autoregressive Error Specification

****

U= .95792*U(- 1)+ -.073059*U(- 2)+E
(17.7105)[.000] (-13.508)[0.041]
T-ratio(s) based on asymptotic standard errors in brackets
Log-likelihood ratio test of AR(1) versus OLS CHI-SQ(1)= 40.62179[.000]
Log-likelihood ratio test of AR(2) versus AR(1) CHI-SQ(1)= 16.508[0.0481]

****

Wald test of restrictions imposed on parameters

****

Based on stochastic initial value(s) AR(2) regression of YLOG on:

CONST KLOG LLOG T

340 observations used for estimation from 1 to 340

****

Coefficients A1 to A4 are assigned to the above regressors respectively

List of imposed restriction(s) on parameter(s):

a2+a3=1	Wald Statistic	CHI-SQ(1)= 6.5459[.011]
a3=0.461	Wald Statistic	CHI-SQ(1)= 3.7693[.052]

****

Appendix 8.2 : Estimation of Fixed Effects Model for the Services Sector (Corrected for autocorrelation)

DEPENDENT VARIABLE = Y

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO 334 DF
K	0.19731	0.2608E-01	7.564
L	0.73192	0.4103E-01	17.84
T	0.81158E-01	0.4488E-02	18.08
D6	2.5216	0.3811	6.616
D7	2.8217	0.3262	8.649
D8	2.7990	0.3266	8.570

R-SQUARE = 0.9790 R-SQUARE ADJUSTED = 0.9787
DURBIN-WATSON = 1.8657
|_Test K + L = 1 WALD CHI-SQUARE STATISTIC = 4.6628851 WITH 1 D.F.
|_Test L = 0.461 T STATISTIC = 6.63142 WITH 339 D.F.

Appendix 8.3 : TFP Levels of the Services Sector

Year	Service Sector
1975	1.407
1976	1.549
1977	1.664
1978	2.073
1979	2.413
1980	2.655
1981	2.908
1982	3.178
1983	3.249
1984	3.270
1985	2.968
1986	2.407
1987	2.581
1988	3.026
1989	3.663
1990	4.165
1991	4.463
1992	4.386
1993	5.070
1994	6.053

Appendix 8.4 : Estimation of TFP Growth Rate for the Services Sector

Exact AR(2) Newton-Raphson Iterative Method Converged after 5 iterations

****

Dependent variable is LNSERV

20 observations used for estimation from 1975 to 1994

****

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CONST	.57604	.11438	5.0361[.000]
T	-.016061	.0095036	-1.6899[.108]

****

R-Squared	.86062	F-statistic F(3, 16)	32.9300[.000]
R-Bar-Squared	.83448	S.E. of Regression	.081830
Residual Sum of Squares	.10714	Mean of Dependent Variable	.39978
S.D. of Dependent Variable	.20113	Maximum of Log-likelihood	22.9189
DW-statistic	1.8728		

****

Parameters of the Autoregressive Error Specification

****

U= 1.2958*U(- 1)+ -.62035*U(- 2)+E

(7.3886)[.000] (-3.5372)[.003]

T-ratio(s) based on asymptotic standard errors in brackets

Log-likelihood ratio test of AR(1) versus OLS CHI-SQ(1)= 18.6984[.000]

Log-likelihood ratio test of AR(2) versus AR(1) CHI-SQ(1)= 9.4058[.002]

****

Appendix 8.5 : Stochastic Frontier Estimates for the Services Sector

THE FINAL MLE ESTIMATES ARE :

	COEFFICIENT	STANDARD-ERROR	T-RATIO
INTERCEPT	0.54838394E+01	0.52882709E+00	0.10369816E+02
K	0.29976251E+00	0.17483213E-01	0.17145733E+02
L	0.69360689E+00	0.31436067E-01	0.22064048E+02
T1	-0.12209581E+01	0.11383134E+00	-0.10726028E+02
T2	-0.10903946E+01	0.11887955E+00	-0.91722644E+01
T3	-0.10223719E+01	0.11725558E+00	-0.87191749E+01
T4	-0.88885189E+00	0.11784476E+00	-0.75425660E+01
T5	-0.78391684E+00	0.12328870E+00	-0.63583834E+01
T6	-0.65381863E+00	0.11014535E+00	-0.59359619E+01
T7	-0.54585564E+00	0.10931774E+00	-0.49932944E+01
T8	-0.47554109E+00	0.11122726E+00	-0.42754005E+01
T9	-0.48787697E+00	0.10840867E+00	-0.45003502E+01
T10	-0.52458084E+00	0.11320579E+00	-0.46338691E+01
T11	-0.65495634E+00	0.11178811E+00	-0.58589090E+01
T12	-0.87338669E+00	0.10663674E+00	-0.81902982E+01
T13	-0.76830293E+00	0.11232707E+00	-0.68398732E+01
T14	-0.61364661E+00	0.10752675E+00	-0.57069206E+01
T15	-0.43712365E+00	0.10367069E+00	-0.42164631E+01
T16	-0.35717781E+00	0.10371581E+00	-0.34438127E+01
T17	-0.30235126E+00	0.10747034E+00	-0.28133460E+01
T18	-0.29167381E+00	0.10223236E+00	-0.28530478E+01
T19	-0.17157332E+00	0.10735208E+00	-0.15982300E+01
D6	-0.22769354E+01	0.50864198E+00	-0.44764993E+01
D7	-0.19614912E+01	0.50362815E+00	-0.38947212E+01
D8	-0.17784078E+01	0.50221892E+00	-0.35411008E+01
SIGMA-SQUARED	0.26720229E+00	0.49959251E-01	0.53484047E+01
GAMMA	0.70160545E+00	0.12564935E+00	0.55838366E+01

VALUE OF CHI-SQUARE TEST OF ONE-SIDED ERROR = 0.76058867E+03
WITH DEGREES OF FREEDOM = 1

Appendix 8.6a : Decomposition of Output Growth in Services, 1976-1984

Industries	Output growth	Input growth	TFP Growth	Change in TE	TP
61	1.373	1.475	-0.102	-0.618	0.516
62	1.028	1.689	-0.662	-1.726	1.065
63	2.555	5.863	-3.308	-5.238	1.930
711	1.610	2.576	-0.966	-2.565	1.599
712	1.053	0.719	0.334	-0.979	1.313
713	1.846	2.117	-0.271	-0.924	0.652
714	2.928	5.888	-2.960	-3.885	0.926
715	3.021	3.485	-0.465	-1.149	0.684
72	2.529	2.328	0.201	-0.679	0.879
81	6.780	2.994	3.786	2.779	1.007
82	2.027	1.715	0.312	-0.713	1.025
831	8.989	5.136	3.853	1.301	2.553
832	4.700	3.829	0.871	0.017	0.854
833	2.908	1.784	1.124	0.045	1.079
834	11.488	13.172	-1.684	-3.501	1.818
835	3.919	2.909	1.010	-0.060	1.069
836/9	5.158	8.06	-2.902	-4.25	1.348

Note: See Appendix 5.1 for information on the service industry codes.

Appendix 8.6b : Decomposition of Output Growth in Services, 1986-1990

Industries	Output growth	Input growth	TFP Growth	Change in TE	TP
61	1.987	0.559	1.428	0.763	0.665
62	1.778	0.796	0.981	-0.302	1.283
63	1.813	1.045	0.767	-0.973	1.740
711	0.844	0.801	0.043	-1.019	1.062
712	0.926	0.249	0.677	-0.134	0.811
713	0.778	0.432	0.346	-0.163	0.509
714	1.329	1.450	-0.120	-3.057	2.937
715	0.889	0.562	0.327	-0.487	0.815
72	1.015	-0.143	1.157	0.483	0.675
81	1.051	0.417	0.634	-0.392	1.026
82	0.999	0.427	0.572	-1.124	1.697
831	0.698	0.786	-0.088	-0.661	0.573
832	0.856	0.135	0.721	-0.009	0.730
833	0.943	0.603	0.340	-0.286	0.626
834	2.451	4.011	-1.560	-2.526	0.966
835	1.120	0.981	0.139	-0.805	0.944
836/9	1.348	0.618	0.730	-0.748	1.478

Appendix 8.6c : Decomposition of Output Growth in Services, 1990-1994

Industries	Output growth	Input growth	TFP Growth	Change in TE	TP
61	0.731	0.646	0.085	-0.233	0.317
62	2.017	0.771	1.246	0.631	0.615
63	0.398	0.432	-0.034	-0.852	0.818
711	0.666	1.056	-0.390	-1.189	0.799
712	0.555	0.753	-0.198	-0.702	0.504
713	0.397	0.554	-0.157	-0.566	0.409
714	1.003	1.325	-0.321	-1.930	1.609
715	1.481	2.122	-0.641	-1.228	0.587
72	0.728	0.350	0.378	0.052	0.326
81	1.423	1.018	0.405	-0.214	0.620
82	1.330	0.566	0.763	-0.232	0.995
831	1.268	0.447	0.821	0.264	0.558
832	1.528	0.844	0.684	0.234	0.450
833	0.782	0.399	0.383	-0.093	0.476
834	2.350	2.491	-0.141	-0.937	0.797
835	1.731	1.584	0.147	-0.525	0.672
836/9	2.034	2.381	-0.347	-1.130	0.783

Chapter 9

Technical Efficiency and its Determinants in the Growth Sectors

9.1 Introduction

One issue of concern from the TFP growth findings, is that deterioration in TE over time was the main cause of low TFP growth in both the manufacturing and services sectors. Thus, improvements in TE are necessary to raise TFP growth. The following questions then need to be addressed. What are the factors that determine improvements in TE and what policy implications can be drawn for Singapore's sustained growth in the manufacturing and services sectors? Many recent studies[1] have attempted to study the determinants of TFP growth using the ordinary least-square (OLS) regression technique but have failed to realise that TFP growth is made up of two components, TP and changes in TE, as highlighted in the stochastic frontier approach. Thus, regressors used in such an estimation of TFP growth may have different effects on these two components and therefore, its overall effect on TFP growth will provide little information for appropriate policy actions.

The stochastic frontier model allows one to investigate, separately, the two components TP and TE to draw more accurate policy options for TFP growth. However, in the model adopted in this study, TP is exogenous, thus investigating the determinants of changes in TE is more relevant, given the empirical evidence that although TP was positive, it was the deterioration in TE that was responsible for low TFP growth. This analytical exercise is the first rigorous attempt using panel data to understand the factors that drive TE in the growth sectors. This chapter is organised as follows. In the next section the concept of TE is explained, followed by a review of previous studies on TE measurement and its determinants. Then, the TE estimates over time for both the service and manufacturing industries are examined. After a brief review of the literature on the determinants of TE, the analytical models and empirical results of the growth sectors are

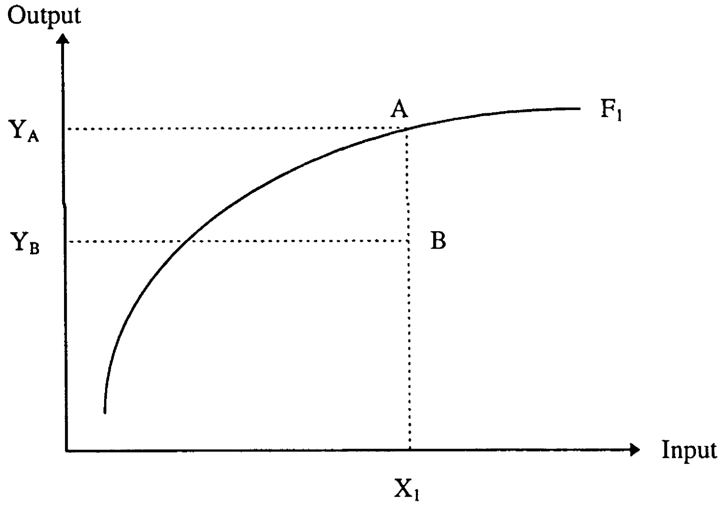
[1] See Wong (1994), Urata (1994), Shimada (1996), Leung (1997) and Tham (1997).

discussed in the light of policy measures. Limitations of such inter-industry TE analysis are also highlighted.

9.2 Technical Efficiency

The stochastic frontier model relaxes the assumption in the conventional growth accounting approach that all firms operate on the frontier as they are assumed to use resources efficiently. Thus, technical inefficiency arises due to one or more of the following factors affecting a firm's production performance: unequal access to information among firms, structural rigidities (for example, pattern of ownership), time lags to learn technology, differential incentive systems, and organisational factors (such as X-efficiency and human capital related variables). Thus, firms often produce output at a level below its potential level of output (see Fig 9.1).

Figure 9.1 : Technical Efficiency



In the above figure, the potential frontier output, F_1, represents the maximum possible output, given the production environment faced by the industries. If a firm/industry produces at B, instead of using all resources efficiently and producing on the frontier at A, then the firm/industry is said to be technically inefficient. Thus, technical inefficiency, due to inefficient use of resources, results in loss of output, given by $Y_A - Y_B$. Technical efficiency is therefore measured by the ratio of actual to potential output:

$$\text{Technical Efficiency} = Y_B / Y_A$$

where firm/industry-specific potential output can be calculated by using the input coefficient (shares) estimated from the stochastic production frontier and the given input level of the firm/industry while actual output is obtained from published data on firm/industry.

Previous Studies on Technical Efficiency

To date, three studies have estimated TE for Singapore's manufacturing sector. The first study by Tay (1992) estimated TE from a stochastic Cobb-Douglas production function using the Corrected Least Square (COLS) technique with data on 11 major manufacturing industries from 1987-89. The COLS estimators were computed from the second and third moments of the OLS residuals. However, there are many problems with this study.

First, neither the appropriateness of the functional form nor the assumed half-normal distribution of the industry-specific stochastic error disturbance was tested. Torii (1992:34) points out that the functional form is important as it can affect the symmetry of the regressors' distribution and any such asymmetry would bias the coefficient estimates, which in turn may influence the estimation of the standard error of the firm-specific stochastic error disturbance. Second, Olson, Schmidt and Waldman (1980) warn that using the third moments of residuals often causes large variance in the COLS estimators which affect the efficiency of the estimators. Third, because the standard errors of both the error components of the disturbance must be nonnegative, the second and third moments of the regression residuals have restrictions on their feasible sets. In fact, this problem was found in Tay's (1992) study as the variance of the industrial chemical industry was negative. Torii (1992:387) states that these biases cause serious problems when used in inter-industry analyses.

Given these limitations, Tay's (1992) results of the TE levels, and hence the analysis of the determinants of TE, are highly suspect. The study also reported that results were mixed for the various industries but the principal determinant of TE was found to be the average wage remunerated.

The second study is by Cao (1995) which estimated TE using the stochastic frontier Cobb-Douglas production function and obtained maximum likelihood estimates with data for 30 manufacturing industries from 1981-1992. There are, however, three main problems with this study.

First, the stochastic frontier model, although is time-varying (the level of TE changes over time), assumes that the rate of change of TE is constant for industries over time.

Second, in the use of data, the value added figures for 1991 and 1992 were those of net value added while those for the other years were census value added. The former figure is a refinement as it deducts other operating costs from the latter. Also, the capital and value added output figures (it is unclear if net or gross values were used) were not deflated, thereby overestimating output and capital input use, leading to inaccurate TE values. The use of depreciation values for capital were not clearly stated in the paper either.

Third, although evidence of industry-specific effects were identified in the paper, Cao postulates, but does not provide any empirical testing of the hypothesis, that the different demand elasticities in the industries are a key cause of the varying TE in their performance. This key cause was argued by simplistically observing estimated TE levels of industries, that are likely to be inaccurate as discussed above.

The third study by Wong and Gan (1995) used TE estimates from Wong and Tok (1994) whereby a stochastic frontier model was used. But these estimates are likely to be inaccurate given the discussion on the problems of the latter study in Chapters 6 and 7. This makes their multi-regression analysis on the determinants of TE doubtful. The regressors used in the regression were not clearly set out in terms of definitions or data sources and no diagnostics tests for the functional form, heteroscedasticity or autocorrelation characteristics underlying the estimation were reported. One also wonders, from their report, if export-orientation and majority-owned foreign ownership variables were tested together, as this is likely to lead to multicollinearity, given that foreign-owned firms in Singapore are often export-oriented. Lastly, the TE level if used as a regressand would not comply with standard normal assumptions of the error term in a multiple regression equation, as it is bounded between 0 and 1. Thus the variable has to be transformed appropriately before use. Hence, their conclusions must be noted with caution.

The TE estimates using a stochastic frontier model in this study are an improvement over the above mentioned studies. In addition to improvements mentioned earlier, the adopted model of this study is without the rigid implicit assumption that all variation in firm effects (technical efficiency) is monotone throughout time and that one rate of change applies to all industries in the sample. Here, the rate of change of TE is allowed to vary for each industry over time.

Technical Efficiency Estimates

Tables 9.1 and 9.2 below provide an overview of the TE levels of the manufacturing and service industries respectively over time, using the improved stochastic frontier model.

Table 9.1 : Technical Efficiency Estimates of Manufacturing Industries

Industries	Average TE	Std Deviation Within Industry Across Time	1976	1982	1988	1994
311/12	0.522	0.039	0.493	0.473	0.555	0.472
313	0.773	0.168	0.858	0.913	0.920	0.643
314	0.939	0.054	0.970	0.983	0.920	0.971
321	0.607	0.125	0.533	0.433	0.752	0.725
322	0.852	0.098	0.842	0.850	0.971	0.668
323	0.901	0.077	0.983	0.880	0.970	0.832
324	0.627	0.145	0.902	0.453	0.466	0.696
331	0.701	0.102	0.760	0.544	0.721	0.801
332	0.821	0.090	0.956	0.771	0.725	0.775
341	0.679	0.124	0.567	0.441	0.788	0.683
342	0.836	0.042	0.926	0.731	0.800	0.896
351	0.710	0.202	0.557	0.467	0.982	0.622
352	0.975	0.005	0.973	0.971	0.984	0.984
353/54	0.907	0.090	0.975	0.973	0.856	0.720
355/56	0.416	0.060	0.509	0.370	0.365	0.419
357	0.417	0.040	0.351	0.358	0.451	0.460
361/62	0.484	0.240	0.741	0.352	0.208	0.573
363	0.521	0.178	0.424	0.602	0.331	0.789
364	0.844	0.212	0.981	0.980	0.459	0.986
365	0.831	0.177	0.996	0.974	0.479	0.683
369	0.775	0.155	0.862	0.970	0.603	0.814
371	0.849	0.150	0.773	0.971	0.978	0.473
372	0.627	0.154	0.539	0.509	0.830	0.464
381	0.702	0.151	0.780	0.718	0.722	0.364
382	0.800	0.122	0.972	0.909	0.662	0.698
383	0.666	0.077	0.585	0.604	0.702	0.667
384	0.889	0.084	0.850	0.692	0.972	0.974
385	0.717	0.342	0.218	0.944	0.971	0.872
Std Deviation Across Industries Over Time			0.224	0.233	0.229	0.179

Note: See Appendix 5.1 for information on the manufacturing industry codes.

For the manufacturing sector, industries 311/12, 355/56, 357, 361/62 and 363 have low TE levels on average while the majority of manufacturing industries have relatively high TE levels. It was also found that some industries in the manufacturing sector, which showed high levels of TE in one period, did not consistently achieve those levels in other periods, such as industries 324, 351, 361/62, 363, 364, 365 and 385. There are not only variations within the same industry across time but also inter-industry variations as shown by the high standard deviations of about 0.2. However, there was no evident pattern in the industries' TE behaviour over time.

Table 9.2 : Technical Efficiency Estimates of Service Industries

Industries	Average TE	Std Deviation Within Industry Across Time	1976	1982	1988	1994
61	0.966	0.024	0.982	0.974	0.971	0.972
62	0.665	0.114	0.765	0.664	0.700	0.661
63	0.435	0.069	0.421	0.363	0.420	0.456
711	0.511	0.081	0.506	0.386	0.648	0.460
712	0.720	0.126	0.617	0.628	0.970	0.657
713	0.882	0.127	0.974	0.564	0.983	0.749
714	0.524	0.262	0.871	0.649	0.282	0.308
715	0.820	0.100	0.970	0.679	0.973	0.621
72	0.852	0.132	0.915	0.858	0.974	0.973
81	0.828	0.148	0.803	0.981	0.589	0.806
82	0.668	0.191	0.781	0.960	0.441	0.613
831	0.737	0.235	0.317	0.739	0.678	0.970
832	0.941	0.066	0.933	0.973	0.929	0.974
833	0.856	0.095	0.740	0.855	0.928	0.918
834	0.585	0.119	0.435	0.609	0.535	0.667
835	0.777	0.124	0.751	0.974	0.716	0.733
836	0.550	0.050	0.596	0.526	0.500	0.626
Std Deviation Across Industries Over Time			0.154	0.260	0.226	0.201

Note: See Appendix 5.1 for information on the service industry codes.

It can be seen that service industries 63, 711, 714, 834 and 836 have low TE levels on average while the majority of the service industries have relatively high levels. However, some service industries, such as 714, 82 and 831, showed high levels of TE in one period, but did not consistently achieve those levels in other periods. Similar to the manufacturing sector, not only are there variations within the same industry across time but also inter-industry variations as given by the high standard deviations of about 0.2.

9.3 Literature Review on Determinants of Technical Efficiency

Many empirical studies have been conducted in a number of countries examining the use of resources (technical efficiency) in manufacturing industries. Some of these include Winston (1971), Paul (1974), Islam (1978), Thoumi (1981), Pasha and Quershi (1984), Goldar and Renaganathan (1989), Srinivasan (1992) and Sheehan (1997).

There are two classic views on the explanation of inefficient use of resources. One argues that, inefficient use of resources is a long-run problem which depends on non-price factors affecting managerial decisions such as economies of scale, market structure, cyclical demand for output and insufficient supply of complementary inputs. Marris (1964), Winston (1971) and Baily (1974) developed their models in line with this argument. The other view is that inefficient use or underutilisation of resources is a short-run problem which is concerned with the determinants of profitability. Increases in profitability would lead to the efficient use of resources. However, this analysis does not include non-price elements (such as market structure and size of firm) as explanatory variables of efficient use of resources. Both Winston and McCoy's (1974) and Betancourt and Clague's (1975) models were based on this view.

Winston (1974) offers two other explanations for the underutilisation of resources. One is that rational entrepreneurs may anticipate future events, but unintended or stochastic factors prevent them from fully utilising resources. The second is that intended excess capacity arises from some form of non-profit maximisation behaviour, such as lack of information, risk aversion and government control, while unintended underutilisation of resources exists due to demand fluctuations, input shortages, technological failures or managerial errors.

While Goldar and Renganathan (1989) argue that resource underutilisation among firms can be analysed through the well-known structure-conduct-performance, Schydlowsky (1973, 1976) offered a number of reasons for inter-firm differences in resource utilisation: factor intensities, relative factor prices, economies of scale, the elasticity of substitution between inputs, the elasticity of demand and the availability of working capital.

The recently developed endogenous growth theory, on the other hand, emphasises the role of human capital on a firm's productive performance. First, management skills are said to strongly influence the firm's ability to produce maximum possible output by fully utilising resources. The utilisation rate increases through the implementation of activities such as maintenance, design and modification, and quality control. Second, expenditure on R&D is said to improve human capital and thereby enable a more efficient use of resources.

Based on the above views, many empirical studies have tested for various determinants of TE and obtained the following results.

It was hypothesised that industries with higher capital intensities are likely to use resources more efficiently because they cannot afford the rental cost of unused capital, and thus have the incentive to economise on the cost of capital as much as possible. Empirical studies such as Winston (1971), Lecraw (1978), Lim (1981) and Sheehan (1997) support this hypothesis, while empirical findings of Islam (1978), Morawetz (1981) and Srinivasan (1992) show otherwise. The latter findings stem from the possibility that if the cost of capital becomes relatively cheap due to subsidised credit at low interest rates, then industries may accumulate more capital than is required and underutilise it.

FDI is another important determinant of TE. Dunning (1988) explains that FDI often stems from ownership advantages like specific knowledge on the use of resources due to R&D experience and/or exposure to international competition. However, Diokno (1974), Morawetz (1981), and Pasha and Qureshi (1989) and Caves (1992) provide mixed empirical evidence of foreign ownership on the efficient use of resources in the host country.

The size of the firm as a measure of economies of scale has often been found to have an effect on TE. Sheehnan (1997:71) explains that, with economies of scale, firms will be able to take advantage of the relative savings of inputs that can be achieved from operating at or close to the minimum efficient scale. Pitt and Lee (1981) suggest that larger firms have higher efficiency due to economies of scale with respect to organisation and technical knowledge, and perhaps due to firms' growth resulting from past efficiency. Their empirical results, and those of Tyler (1979) and Sheehnan (1997), support this hypothesis. But those of Millan (1975), Betancourt and Clague (1977), and Pasha and Quershi (1984) provide evidence of a negative relationship between firm size and technical efficiency. They argue that small firms adopt more appropriate technology, are more flexible in responding to changes in technology, product lines and markets, and foster more competitive factor and product markets, and thus are able to use resources more efficiently.

The number of firms in each industry can also be used as a proxy to identify the type of market structure which encourages better use of resources. In the standard industrial organisation paradigm, Scherer (1986), and Caves and Barton (1990) explain that a high concentration ratio (alternatively, the smaller the firm number) is expected to diminish competitive rivalry among industries with the likelihood of under-utilising the production capacity of resources. This is empirically supported by Esposito and Esposito (1974), Thoumi (1981) and Srinivasan (1992) among others.

On the other hand, Merhav (1970), Winston (1971), Goldschmid (et al. 1974) and Goldar and Renganathan (1989) provide empirical evidence of a positive relationship between high concentration ratio and TE. They reason that a high concentration ratio brings about sufficient greater innovation and technological change, to offset the adverse effects of high concentration, and that concentrated industries suffer less uncertainty of demand than other firms and can plan better for higher utilisation of productive capacities.

More skilled workers can also be expected to raise TE as was shown by the empirical evidence from Klotz, Madoo and Hanson (1980), and Campbell (1984). They argue that higher skill level among workers contribute effectively to acquisition and combination of productive resources and they are more receptive to new approaches to production and management.

Other factors that have been found to affect TE include age of the firm, advertising expenditure, R&D expenditure, import substitution and export orientation. Drawing on the above literature as well as the many empirical studies, data limitations allowed three determinants to be tested on changes in TE for the manufacturing and services sectors.

9.4 Analytical Model and Empirical Results

The analysis was done separately for the manufacturing and service industries.

Model to Study the Determinants of Technical Efficiency of the Manufacturing Industries

First, the capital-labour ratio (K/L) which measures the capital intensity of the industry. This is given by the ratio of capital (estimated by the perpetual inventory method earlier) to the number of workers employed in the industry.

Second, given that Singapore has had a long history as a major recipient of foreign direct investment (FDI) since the early 70s, the extent of the effect of foreign ownership on the use of resources is investigated. A dummy (OWND) is used for industries which have more than 45% of the total number of firms in that industry wholly foreign or joint ventures which are less than half locally owned.

Third, the size of the industry measured by industry sales (SALES) was used to test for the significance of the scale effect on TE.

In theory, industries with large sales are often capital intensive and thus, Sales and K/L ratio may be correlated. Given this possibility, the correlation coefficient of the two variables was first checked. The low value of 0.23 was taken to mean that any multicollinearity effects arising from the inclusion of both these variables in the regression are minimal and would not produce spurious results.

The equation was then estimated in logarithms to measure changes in TE (as deterioration in TE was a major concern in the TFP growth analysis done earlier) but a point to note is that TE levels are bounded between the value of 0 and 1. Consequently, in order to comply with the standard normal assumptions of the error term in a multiple regression equation, it needs to be transformed so as to allow the range of values that the dependent variable may take to be from positive infinity to negative infinity. Hence, the dependent variable, TE level, is transformed to log TE - log (1-TE). When TE is 0 and 1, the transformation gives positive and negative infinite values respectively, thus satisfying the required range and the higher the TE levels, the higher the transformed value. Due to this transformation procedure, the regression coefficients have no direct interpretation but it is possible to calculate the elasticity value from the estimated coefficient.[2] However, due to possible limitations of the estimated TE discussed later in this chapter as well as the proxies used as determining factors, it is logical to examine only the sign and not the magnitude of the coefficients obtained. Also, to remove any time-specific effects, a time trend was first included in the estimations for each sector but as it was found to be insignificant, the estimation was carried out without the time trend. One possible reason for the insignificance is that it has been evidenced earlier from Tables 9.1 and 9.2 that there was no specific pattern in the manufacturing and service industries' TE over time.

The entire sample of 560 observations were used and the estimated results are as follows :

<u>Empirical Results</u>

$$\text{Log TE} = \underset{(0.524)}{-1.36^{*}} - \underset{(0.056)}{0.26^{*}}\ \text{Log (K/L)} + \underset{(0.043)}{0.28^{*}}\ \text{Log (SALES)} - \underset{(0.209)}{0.26}\ \text{OWND}$$

Standard errors are given in parenthesis and * indicates significance of the estimated coefficient at least at 5% level of significance. The Ramsey Reset test statistics indicates that the functional form was not misspecified and there were no major problems with heteroscedasticity. The above equation was corrected for autocorrelation using the Cohrane-Ocutt method and the corrected Durbin Watson (DW) statistic of 2.06 was satisfactory (see Appendix 9.1 for details of estimation).

The $\overline{R}^2$ of 0.69 shows that the analysis is quite satisfactory as the factors identified (or rather for which proxies could be obtained) are able to explain 69% of the variation in TE. But there were no consistent time-series data on important factors such as R&D expenditure or advertising expenditure by industry, proportion of skilled workers to unskilled workers, or any information pertaining to product differentiation to improve on the test for the determinants of TE.

[2] Equating TE/1-TE to the antilog of the estimated coefficient value and solving for TE gives the elasticity value of the variable's effect on changes in TE.

The K/L ratio is negative and significant (with a calculated elasticity value of 0.35). Other studies like Kwak (1994) and Tham (1997) also report negative effects when this variable was investigated on TFP growth. For Singapore, while Wong (1994) found a negative significant correlation between capital deepening and TFP growth, Leung (1997) found a negative but insignificant effect on TFP growth (possibly masked by the positive effect of K/L on TP).

There can be two possible reasons for the result obtained above. First, the rapid rate of transformation in the economy from labour intensive to capital intensive manufacturing operations had enabled the use of embodied technology to increase output significantly, which could have led to sufficient profits such that there was little incentive for industries to use the technology efficiently. Also, in order to qualify for various incentives from the government, many industries may have accumulated capital which they did not have enough knowledge to use efficiently. Second, labour deepening and skill deepening in labour did not commensurate with capital deepening. Shortage of labour has been a problem ever since the early 80s, when the government implemented the foreign worker policy. In fact, the World Competitiveness Report (1990) found that worker turnover was highest in Singapore compared with other NIEs. This is reinforced by the 1992 Singapore Manufactures Futures Survey which reports that 85% of the firms which responded considered labour turnover a significant concern, while 74% and 83% of the firms raised the availability of unskilled labour and skilled labour, respectively, as major problems. Skill deepening did not take place at the desired level either. The National Productivity Board (1994:29) provides evidence that despite improvements by Singapore, its present educational level is still relatively low compared with other NIEs, Japan and USA. The Singapore economy is also said to require 17 000 university graduates by the year 2000, almost double the current output.[3]

Thus, gains from the use of high value added capital could not be realised due to a lack in the quantity and quality of the labour force and thus improvements in TE did not occur. These problems have been recognised by the government and its efforts to improve the situation are in the right direction. These include the recent attempt of Singapore to attract skilled foreign labour and to relax the foreign worker policy; the call to Singaporeans abroad to return home; the removal of restrictions on skilled

[3] See Southeast Asia Business Times (Singapore) 1 Aug 1997.

women's foreign spouses work opportunities and permanent residency. For skill deepening, the government has been increasing its R&D expenditure considerably and the national goal is for companies to spend 4% of payroll on formal training. The education system is being revamped with emphasis on broad education with creative thinking as a subject. Wong (1997) also emphasises the need to enhance workforce productivity. There would also be a third full-fledged university by the year 2000.

The foreign ownership variable is found to be an insignificant determinant of improvements in TE. While Leung (1997) found that foreign ownership had a positive and significant influence on TFP growth, Shimada (1996) provides evidence of more efficient use of capital and labour by foreign capital. But a few points need to be noted with these studies. Leung's (1997) results are not surprising as foreign capital which has embodied capital would have had an overwhelmingly positive effect on TP, such that the overall effect on TFP growth was positive and significant. Also, by using the ratio of exports to total sales, together with foreign ownership in his equation, Leung's results are likely to suffer from multicollinearity as almost all foreign owned firms in Singapore are export oriented.

Shimada (1996), on the other hand, compared the efficiency levels of capital and labour individually. Thus, these partial measures were concerned with capital and labour used per unit of value added. However, in this study the total measure, TE, considers the use of both capital and labour taken as a single resource component and is a far better measure, given that capital and labour need to be used jointly to produce output. Furthermore, Shimada (1996:375) himself has quoted Eng and Tan (1992) as having suggested that, "regardless of the capital type/ownership, the labour force could not absorb the technology embodied in rapid capital accumulation substituting labour force to capital equipment."

Shimada's finding of an increase in the gap of TFP level between foreign and local capital from 1980 to 1988 and a slight decrease since then till 1992 can be interpreted in two ways. Shimada seems to infer that there may not have been spillover effects from foreign firms to local firms, but maintains that foreign firms are more efficient than local firms, based on evidence of higher partial efficiency in the use of resources. Yet another inference could be the following. It is not necessarily true that foreign firms are more efficient than local firms but that limits in TP arising from foreign capital are being reached and now the effects of foreign firms on technical inefficiency are beginning to show up, thereby affecting TFP levels and hence growth. This can also be used to explain Shimada's (1996:377) anxiety "about the stagnant TFP growth on foreign companies since 1989."

Interestingly, Athukorala and Chand's (1997) study show that majority-owned US foreign manufacturing affiliates in Singapore obtained an annual TFP growth of 2.43% over 1982-92, which was low compared to US operations in Hong Kong (6.33%), Taiwan (11.48%) Republic of Korea (3.48%), Belgium (6.21%) and Denmark (5.50%) over the same period. Some factors specific to Singapore could be the cause of this relatively low TFP growth. First, because of poor competition from local firms (due to use of less advanced technology or otherwise), foreign firms may have been able to sustain profits without having to fully exploit their more advanced technology and use resources more efficiently. Second, as suggested earlier, Singapore's labour force is not equipped with sufficient skills and training to enable foreign firms to attain maximum possible output, given limits to acquiring newer and better technology. Thus there is reason to believe that foreign firms are performing below their potential in Singapore.

Drawing on the argument in Byung and Chung (1980:135), because MNCs are accustomed to using relatively capital intensive production techniques, they may have used overly capital-intensive production techniques given the permissive environment of government policy in Singapore, thereby using inefficient factor proportions as was the case in Brazil. Furthermore, Kholdy (1997) provides evidence for Singapore where FDI in manufacturing Granger-causes capital formation but not labour productivity. This also lends support to the negative K/L ratio result. However, the result obtained in this analysis could reflect the use of a dummy variable as a poor proxy for foreign ownership. Better proxies are lacking as data on ratio of skilled workers to unskilled workers, educational level of workers, or the expenditure on workers training are not published separately for local and foreign firms. However, the spillover effects of foreign ownership using firm-level data may show very different results.

In general, regarding foreign ownership, it is time that the government becomes more selective on the basis of MNCs commitment to undertake R&D locally and train their workers employed to ensure that skills are upgraded to meet the technological demands of the industry. The move to attract MNCs to set up R&D centres in Singapore must be compensated sufficiently by incentives and grants from the Economic Development Board. As this scheme has been in operation since the early 90s, benefits can only be expected to be reaped in the long run.

Finally, the last determinant, SALES, is positive and significant (with an elasticity of 0.66), indicating that, with economies of scale, resources are used more efficiently. Thus, the government's policy to grow and groom local, small and medium enterprises (SMEs) into large enterprises, by providing incentives and grants through the Economic Development Board's SME scheme can be expected to lead to improvements in TE in those industries. But being large and thus more capital intensive may not lead to positive changes in TE if labour deepening in terms of quantity and quality does not take off. Thus, there is a need for the various policies mentioned above to work hand-in-hand and complement one another.

<u>Model to Study the Determinants of Technical Efficiency of the Service Industries</u>

Almost all empirical studies investigating the determinants of the level of TE have been centred on the manufacturing sector and this reflects the limited attention paid to the neglected and more difficult services sector.

Given data limitations, three variables were investigated for the services sector. They are the capital-labour ratio (K/L) which is a measure of capital intensity (given by the ratio of capital to the number of workers employed), the number of firms in the industry (FIRMNO) used as a proxy for market structure, and the ratio of professional, administration, management and related workers to total numbers employed in the industry (SKILL). Unlike the manufacturing sector, data on sales of service industries were not available, and so, information on number of firms in each industry was used.

The entire sample of 340 observations was used for the analysis.

<u>Empirical Results</u>

$$\text{Log TE} = \underset{(0.318)}{2.57^{*}} - \underset{(0.036)}{0.10^{*}} \text{ Log (K/L)} - \underset{(0.168)}{0.21} \text{ Log (FIRMNO)} + \underset{(0.084)}{0.30^{*}} \text{ Log (SKILL)}$$

Standard errors are given in parenthesis and * indicates significance of the estimated coefficient at 5% level of significance. The Ramsey Reset test statistic was 1.13 and is below the critical value of 3.84 at 5% level of significance, indicating that the functional form was not misspecified and there were also no major problems with heteroscedasticity. The above equation was corrected for autocorrelation using the exact maximum likelihood method and the corrected Durbin Watson (DW) statistic of 1.9 was satisfactory (see Appendix 9.2 for details of estimation).

The evidence shows that the K/L ratio (with an elasticity value of 0.44) and ratio of skilled workers (with an elasticity value of 0.67) are significant determinants of changes in TE. An increase in the K/L ratio causes a deterioration in TE while an increase in the skilled workers ratio causes an improvement in TE. The limits to increasing embodied capital in new capital clearly reflect the need for an increase in the use of labour when more capital is used. These results support the notion that labour deepening and in particular, skill deepening in labour did not commensurate with capital deepening. Thus, there is a need to use labour more efficiently in terms of quantity and quality in order to obtain improvements in TE. Comparing the coefficient estimate of K/L ratio of both the growth sectors, it can be seen that TE is more responsive to changes in K/L ratio in the manufacturing than the service industries.

The number of firms in a service industry (with an insignificant elasticity value of 0.38) did not affect changes in TE in that industry. This means that improvements in TE can occur in any type of market structure. Competition is not necessary for industries to be efficient in their use of resources. Since services are heterogeneous, having very specific clientele and established niches, they do not allow any significant dissemination of technical influence or spillover among the service industries.

The $\overline{R}^2$ of 0.49 is low with 51% of variations in TE not explained. This is not surprising given the severe data limitations and proxies used for investigation in the services sector. Many other important factors such as product differentiation, advertising effects, managerial quality, ratio of part-time workers etc. could not be included in the analysis. Nevertheless, the exercise above provides important policy implications.

9.5 Limitations of Inter-Industry Technical Efficiency Analysis

Battese and Coelli (1995) claim that the above two-stage estimation (first, calculating the TE levels and then using them as a dependent variable) procedure is inconsistent in its assumptions regarding the independence of the inefficiency effects in the two estimation stages. In the first stage, the inefficiency effects are assumed to be independently and identically distributed, while in the second stage, they are assumed to be a function of a number of firm-specific factors which implies that they are not identically distributed. Recent papers by Kumbhakar, Ghosh and McGuckin (1991) and Reifschneider and Stevenson (1991) noted this problem and specified stochastic frontier models in which the inefficiency effects are made an explicit function of the firm specific factors and all parameters are estimated in a single-stage estimation.

But the above arguments are not valid for two reasons. Following Kalirajan and Shand (1994), first, an estimation of the production frontier ought to include core inputs for production and including determinants of TE would be an incorrect specification as these do not directly affect the production function. Also, it seems inconsistent that two separate model specifications are provided in Coelli's Frontier Version 4.1. One model estimates the production frontier when there is no information on the determinants of TE and the other model allows these determinants of TE to be incorporated. The two models provide different estimates for the production frontier using the same level of capital and labour inputs.

Second, although the two-stage estimation is a bit weak on statistical grounds, it must be remembered that econometrics is merely a tool to explain economic theory and as such, it can be argued that it is a valid estimation.

There are however other drawbacks which must be acknowledged. First, industries may not be homogenous enough to justify such analysis for the broad sector, and if possible, each industry should be studied separately using firm level data. Second, Caves (ed., 1992:141) points out that estimation depends only on the shape of the empirical distribution of output and thus, cannot detect industries consisting of uniformly inefficient firms. These points set the boundaries within which we propose hypotheses and interpret the results. Third, technological progress and technical efficiency are not neatly separable in practice. The distinction that is adopted in the literature is therefore somewhat artificial, but nevertheless it can offer an important added dimension to test whether different factors are at the root of these two indicators of performance.

Another caveat highlighted by Caves (ed., 1992:483) is that, in dealing with microeconomic data (firm level) in a steady-state framework, inefficiency optimally measured could be attributed only to managerial slack. In a dynamic, fairly aggregate setting (industry level), where the production frontier shifts up over time, an additional source of efficiency arises in the lag of adjustment to new technological conditions. This lag partly explains why factors like R&D that push the frontier upward can involve an apparent loss in efficiency.

Lastly, this exercise in particular has used the firm-level efficiency concept to industry-level data. If individual firms were used, the results could have been more effective but unfortunately, such data is not available. Nevertheless, these results can be interpreted as the mean efficiency measures of firms within the industries.

9.6 Some Policy Implications

For the manufacturing sector, it was found that MNC-dominated industries failed to provide sufficient spillover effects and were themselves not more efficient than industries dominated by local firms. The embodied technology in the foreign capital could not be used efficiently either due to lack of training provided to their workers by MNCs or the lack of initiative on the part of the workers to upgrade themselves, or because of the high labour turnover in the workforce. The fact that managers and employers in major decision making positions often do not job hop and stay with the firm for a fair period of time, suggests that they are less interested in firm's short-term performance (that is, to use resources efficiently). Instead, there may have been a willingness to invest in technological advancement which is clearly a long-term interest. The job hopping tendency among workers is another deterrent for managers to invest in workers training. The issue on foreign ownership needs to be studied further using firm-level data.

Empirical investigation also showed that for improvements in TE in the manufacturing sector, increases in capital intensity must be accompanied by increases in the growth and quality of labour force. Expanding output allowed manufacturing industries to reap economies of scale which is in line with a high degree of market concentration which provide incentive and the ability to hire better skilled workers to use resources efficiently.

The foregoing analysis holds a number of policy implications. First, Singapore should step up its efforts to expand its labour force and at the same time, ensure skill deepening. In addition to current efforts to relax the supply restrictions on labour,[4] the levy on skilled workers should be further reduced from $100 (it was reduced from $200 since April 1998) or perhaps even abolished. The possibility of subsidising housing rents for skilled foreign workers should also be seriously considered.

Second, government should encourage and provide more incentives for firms to expand and local firms to work hand-in-hand with existing MNCs, to ensure that training is provided to workers to handle the technology in place. New MNCs coming into Singapore should be carefully selected with regards to such opportunities for training. The national goal of 4% of payroll on formal training is insufficient and more government funds need to be released for workers training. A change in the mindset of managers is required in order to help them see the need for investing in their workers.

Lastly, the government should continue to grow and groom local SMEs into large enterprises, by providing incentives and grants through the Economic Development, given the positive effect of economies of scale on improvements in technical efficiency.

For the services sector, evidence showed that there is an urgent need for labour, in particular skill deepening, to obtain improvements in TE. Thus, the government should step up its efforts to encourage and provide incentives where possible, to ensure that service workers continually upgrade their skills. The pool of non-working mothers still remains an unsuccessfully tapped resource. More mothers need to be enticed to enter the labour force by providing sufficient and high quality child care centres, and opportunities for part-time or flexiwork arrangements must be made more readily available. Such work arrangements would in turn require restructuring the way offices are run. In addition, particular market structures given by number of firms in an

[4] See Chapter 4 of this thesis for an elaboration on these measures to attract workers.

industry, were not found to be conducive to attain improvements in TE since services are heterogeneous having very specific clientele and established niches. This is reinforced by strong evidence that Verdoon's law does not hold for the services sector as economies of scale were not significantly associated with TFP growth.

Appendix 9.1 : Determinants of TE in Manufacturing Industries

```
Ordinary Least Squares Estimation
*******************************************************************************
Dependent variable is  LTE
560 observations used for estimation from    1 to  560
*******************************************************************************
Regressor          Coefficient     Standard Error       T-Ratio[Prob]
CONST                 -1.5527          .49494          -3.1371[.002]
LSALES                 .37540          .044880          8.3647[.000]
LKL                   -.27870         .055319          -5.0380[.000]
OWND                  -1.1349          .18637          -6.0892[.000]
*******************************************************************************
R-Squared               .041076  F-statistic F( 3, 556)  2.2703[.082]
R-Bar-Squared            .022984  S.E. of Regression          .69961
Residual Sum of Squares    77.8223  Mean of Dependent Variable    3.3873
S.D. of Dependent Variable   .70779  Maximum of Log-likelihood   -171.0322
DW-statistic              .46709
*******************************************************************************
                    Diagnostic Tests
*  Test Statistics *     LM Version      *       F Version        *
*******************************************************************************
* A:Serial Correlation*CHI-SQ( 1)= 15.8061[.000]*F( 1, 555)= 16.1200[.000]*
* B:Functional Form   *CHI-SQ( 1)=  .72684[.394]*F( 1, 555)=  .72128[.396]*
* C:Normality         *CHI-SQ( 2)= 43.1612[.000]*     Not applicable     *
* D:Heteroscedasticity*CHI-SQ( 1)=  .33804[.561]*F( 1, 558)=  .33704[.562]*
*******************************************************************************
 A:Lagrange multiplier test of residual serial correlation
 B:Ramsey's RESET test using the square of the fitted values
 C:Based on a test of skewness and kurtosis of residuals
 D:Based on the regression of squared residuals on squared fitted values
```

```
 Exact AR(2) Newton-Raphson Iterative Method Converged after   6 iterations
*******************************************************************************
Dependent variable is  LTE
560 observations used for estimation from    1 to  560
*******************************************************************************
Regressor          Coefficient     Standard Error       T-Ratio[Prob]
CONST                 -1.3616          .52444          -2.5963[.010]
LSALES                 .28299          .043493          6.5065[.000]
LKL                   -.25595         .055559          -4.6068[.000]
OWND                  -.25908          .20868          -1.2415[.215]
*******************************************************************************
R-Squared               .70153  F-statistic F( 5, 554)  73.8018[.000]
R-Bar-Squared            .69202  S.E. of Regression          .39279
Residual Sum of Squares    24.2229  Mean of Dependent Variable    3.3873
S.D. of Dependent Variable   .70779  Maximum of Log-likelihood    -76.5942
DW-statistic              2.0594
*******************************************************************************
          Parameters of the Autoregressive Error Specification
*******************************************************************************
U=    .58067*U(- 1)+    .30160*U(- 2)+E
 (   7.7756)[.000] (   4.0386)[.000]
T-ratio(s) based on asymptotic standard errors in brackets
Log-likelihood ratio test of AR(1) versus OLS   CHI-SQ(1)=  174.3193[.000]
Log-likelihood ratio test of AR(2) versus AR(1) CHI-SQ(1)=   14.5567[.000]
*******************************************************************************
```

Appendix 9.2 : Determinants of TE in Service Industries

```
Ordinary Least Squares Estimation
*******************************************************************************
 Dependent variable is  LTE
 340 observations used for estimation from   1 to  340
*******************************************************************************
 Regressor          Coefficient      Standard Error        T-Ratio[Prob]
 CONST                 3.2500            .42143            7.7117[.000]
 LKL                  -.10617           .053599           -1.9809[.048]
 LFIRMNO              -.12510           .032888           -3.8039[.000]
 LSKILL                .40238            .11495            3.5006[.001]
*******************************************************************************
 R-Squared                  .065406   F-statistic F( 3, 336)   7.8148[.000]
 R-Bar-Squared              .057036   S.E. of Regression           1.4065
 Residual Sum of Squares    662.6914   Mean of Dependent Variable    1.4062
 S.D. of Dependent Variable   1.4484   Maximum of Log-likelihood   -594.6376
 DW-statistic               .69651
*******************************************************************************
                     Diagnostic Tests
*  Test Statistics  *      LM Version       *        F Version       *
*******************************************************************************
A:Serial Correlation*CHI-SQ( 1)= 146.0985[.000]*F( 1, 335)= 252.9627[.000]*
B:Functional Form   *CHI-SQ( 1)=   1.1297[.288]*F( 1, 335)=   1.1167[.291]*
C:Normality         *CHI-SQ( 2)=  24.2220[.000]*     Not applicable      *
D:Heteroscedasticity*CHI-SQ( 1)=   2.9534[.086]*F( 1, 338)=   2.9618[.086]*
*******************************************************************************
  A:Lagrange multiplier test of residual serial correlation
  B:Ramsey's RESET test using the square of the fitted values
  C:Based on a test of skewness and kurtosis of residuals
  D:Based on the regression of squared residuals on squared fitted values
```

```
   Exact AR(1) Inverse Interpolation Method Converged after   6 iterations
*******************************************************************************
 Dependent variable is  LTE
 340 observations used for estimation from   1 to  340
*******************************************************************************
 Regressor          Coefficient      Standard Error        T-Ratio[Prob]
 CONST                 2.5690            .31763            8.0881[.000]
 LKL                  -.10012           .036084           -2.7745[.006]
 LFIRMNO              -.20806            .16771           - 1.2406[.215]
 LSKILL                .30032           .083916            3.5788[.000]
*******************************************************************************
 R-Squared                  .48513   F-statistic F( 4, 335)  78.6778[.000]
 R-Bar-Squared              .47897   S.E. of Regression           1.0455
 Residual Sum of Squares   365.0760   Mean of Dependent Variable    1.4062
 S.D. of Dependent Variable  1.4484   Maximum of Log-likelihood   -493.8898
 DW-statistic              1.9080
*******************************************************************************
         Parameters of the Autoregressive Error Specification
*******************************************************************************
 U=   .67874*U(- 1)+E
   (  17.0172)[.000]
 T-ratio(s) based on asymptotic standard errors in brackets
 Log-likelihood ratio test of AR(1) versus OLS   CHI-SQ(1)=  201.4956[.000]
*******************************************************************************
```

Chapter 10

Conclusions

This thesis is the first comprehensive attempt to analyse and compare the structure and performance of the manufacturing and services sectors of Singapore, in terms of the dynamics and characteristics of employment generation, labour productivity and total factor productivity growth. In addition to investigating the hollowing out effect of manufacturing output and employment, the thesis develops a theoretical framework for a labour demand model and using the two-stage-least-square estimation technique, provides empirical evidence on the determinants of employment growth in the two sectors,

In particular, the thesis addresses key issues in the ongoing debate on Singapore's TFP growth which have generated widespread interest and controversy among researchers. Previous studies have shown inconclusively that TFP growth of the Singapore economy and its manufacturing sector are very low. There is a need to examine the contributions to TFP growth of the manufacturing sector further and that of the much neglected services sector. Hence, an appropriate model using the improved stochastic frontier production methodology, is used to estimate TFP growth and results are compared with the conventional growth accounting methodology. The frontier approach decomposes output growth into input growth and TFP growth (as does the conventional approach), but also decomposes TFP growth into technological progress and changes in technical efficiency. This exercise is the first attempt to apply this decompositional framework to the services sector and to compare it with the manufacturing sector. After applying the stochastic frontier methodology on industry level data of the manufacturing and services sectors, technical efficiency is estimated and determinants of improvements in TE for both sectors are investigated to draw out important policy implications.

The thesis thus makes the following theoretical and empirical contributions to TFP growth analysis in Singapore. In addition to using the conventional growth accounting model, the use of an improved version of the stochastic frontier model:

i) relaxed the assumption under the conventional approach where all firms are efficient and operate on the production frontier.

ii) relaxed the rigid parametrisation in a previous study using the stochastic frontier model for the manufacturing sector where variation of all industry effects (technical efficiency) is monotone throughout time and that one rate of change applies to all industries in the sample. In place of a time trend for technological progress which does not allow for inter-industry differences, industry dummies were used to capture such differences. Constant returns to scale were also not imposed in the estimation.

iii) provided a pure and more accurate measure of TFP growth to compare with the residual measure under the growth accounting approach, where the latter TFP estimate would include all that is not explained, barely providing any useful information.

iv) decomposed output growth into input growth, technological progress and changes in technical efficiency and enabled a comparison within (at industry level) and between the manufacturing and services sectors over time.

v) enabled the estimation of technical efficiency and hence the investigation of factors affecting the efficiency of the manufacturing and service industries.

10.1 Major Findings

In the absence of an agricultural sector in Singapore, the services sector has thrived alongside the manufacturing sector since the early 70s. While there has been no major changes in the GDP shares of these sectors over time, the composition of these growth sectors has changed. The electronics industry took over the petroleum industry's prominence since the late 70s and in the early 90s, design and wafer fabrication replaced assembly line production in the electronics industry. Transport and equipment industry and the industrial chemical industry have also become key industries in the manufacturing sector. In the services sector, the commerce industry's strength in the 70s diminished over time while the transport and communications industry's share increased in the 70s and has stabilised since the early 80s. But since then, the lead sector has been the financial and business services.

Unlike the GDP shares, the employment shares of the growth sectors showed some fluctuations. The manufacturing sector's employment share increased in the 70s and decreased in the early 80s before picking up slightly in the late 80s and then decreased in the early 90s. The services sector's employment share trend was the reverse and since the early 90s, it has risen, led by expansion in the financial and business services.

Comparative analysis of the partial measure of productivity showed that, contrary to popular belief, the labour productivity of services was higher than manufacturing and it remained so until 1993 when this was reversed. However, the labour productivity growth of services slowed down over time and in the early 90s was lagging behind that of manufacturing. Due to insufficient data on foreign workers, an important implication of this finding on the hollowing out of manufacturing employment remains inconclusive. But the two-way causality established between the GDP growth of the manufacturing and services sectors gives some confidence that there is little to fear of the hollowing out of manufacturing output, and even if there is some hollowing out, there is no real need for concern as long as the services sector continues to grow. The economy can still remain healthy if workers continually upgrade their skills to meet the demands of the industries.

The income elasticity of consumers' expenditure on services was found to be 1.08 and statistically significant over 1965-94 (excluding the 1985/86 recession period). Although services are income elastic, the value seems low but similar results were obtained for the US and UK (even before 1980). A breakdown of the various income groups for various types of services can be expected to lead to diverse results.

With employment generation it was found that domestic demand (due to data problems, the effect of foreign demand for services could not be investigated) and remuneration per worker were significant determinants in the services sector. But it is postulated that export services such as producer services (data was not available to test this appropriately), are likely to have played an important role in employment generation. For the manufacturing sector, output was a significant factor in creating employment.

Labour and wage costs were not significant determinants, implying that economic stability and industrial relations may have had a role to play, given the heavy involvement of MNCs in the manufacturing sector. Although an attempt was made to examine the impact of foreign workers on employment, the dummy variable used was a poor proxy (in the absence of data on foreign workers) and thus, the negative impact on employment was statistically insignificant.

The TFP growth analysis of the manufacturing sector, using panel data for the first time, and applying the conventional growth accounting method, showed that from the mid 70s, TFP growth was positive but declined in the late 80s, and was negative in the early 90s. The same result was obtained using the improved stochastic frontier model. With the services sector, although both approaches showed that TFP growth increased from 1976-84 to 1987-94, it was decreasing (though still positive) in the late 80s and early 90s. Input growth was also the dominant contributor of output growth in both sectors and in some periods was the only positive contributor. However, unlike the services sector, Verdoon's law, which postulates a positive relationship between output growth and TFP growth, was found to exist in the manufacturing sector in the late 70s and for the decade of 80s.

The fitted and residual methods under the growth accounting methodology did not vary greatly in the estimation of TFP growth rates but they were larger in magnitude than the TFP growth estimates obtained under the stochastic approach for both the manufacturing and services sectors. In particular, the stochastic frontier method showed that the manufacturing sector had experienced about 1% TFP growth from 1976 to 1984, registered 0.27% growth from 1986 to 1990 and from 1990 to 1994, had negative TFP growth. The structural move to more high tech manufacturing activities, the regionalisation drive, and the slowdown in the electronics industry possibly caused the negative growth in the early 90s.

On the other hand, the services sector showed 0.77% TFP growth from 1976 to 1984, 0.71% growth from 1986 to 1990 and still maintained a positive but low 0.27% growth from 1990 to 1994 when the stochastic approach was used. In particular, the communications, financial, insurance, real estate and legal services show some promise in terms of TFP growth and improvements in TE.

Evidence from the stochastic frontier approach further shows that, although both the growth sectors experienced technological progress, the deterioration in technical efficiency[1] was responsible for the low and declining TFP growth for both sectors. This relates to the concern stated earlier in the thesis that the important point about the cost of achieving high growth rate should not be missed amidst the benefits resulting from growth. This cost is clearly shown here to be the inefficient use of resources and technology by both the manufacturing and services sectors which outweighs the positive effects of technological progress. Overall, however, the dominance of input growth ensured a significant output growth rate over the whole period.

The policy options for Singapore's sustained long-term growth for both the sectors can be summarised as follows:

1. Continuing efforts to secure output growth through input growth. This will require an expansion of the labour force. Till now, using more capital has been the preferred (easiest) option but there is a question of continued feasibility or preference.

2. Placing more emphasis on increases in TFP growth. This in turn offers two options which are not mutually exclusive.

a) The first is to pursue more rapid technological progress through increasing domestic R&D, selecting MNCs which can provide sufficient spillover effects in the adoption of more advanced technology, and shifting progressively to more high tech operations. Imperfections in the market for knowledge, which may hinder the adoption and diffusion of proprietary knowledge, need to be reduced.

b) The second is to obtain improvements in technical efficiency that is, the more efficient use of resources and technology.

The attempt to decompose output growth using the stochastic frontier approach enabled a measurement of the extent of Krugman's (1994) and Young's (1992) postulation that

[1] In general, an improvement in TE occurred less for services than for manufacturing industries but this could well be due to problems in measuring service output.

inputs were not used efficiently in Singapore. The subsequent investigation of the determinants of improvements in efficient use of resources in the manufacturing and service industries enabled the following implications:

i) For both the manufacturing and services sectors, an increase in capital intensity must be accompanied by increases in the quantity and quality of the labour force. Thus, it is imperative that Singapore attract skilled workers in sufficient numbers and ensure continuous upgrading of skills to use technology efficiently.

ii) It pays for a small number of firms to exist in a manufacturing industry as this enables expansion of output leading to economies of scale and hence higher technical efficiency. In contrast, in the services sector, economies of scale were not found to be important in the dissemination of technological influence or spillover among the heterogenous and often personalised nature of these industries.

iii) Contrary to popular belief and other empirical evidence, here, it was found that MNC-dominated manufacturing industries were not more efficient than those dominated by local firms. However, a study using firm-level data is crucial for more conclusive evidence on spillover effects (if any) from foreign-owned firms.

10.2 Limitations of The Study and Suggestions for Further Research

The analysis of the services and manufacturing sectors presented in this thesis hinges on the very definition of services and manufacturing. The line between what is a service and a good has become increasingly blurred due to the existence of producer services and the use of manufactured goods in services. To distinguish between the two, to date, except for input-output tables which are published once every five years, no consistent time-series data exist on such activities. There is also a need to differentiate between imported and local producer services as this has implications for relative factor prices. Lastly, the output measure of services in Singapore needs to be improved by using the double deflation method for which appropriate deflators for inputs of services is lacking. Hence, more accurate measures must be developed for better analysis.

Foreign workers is another area for which more data are required. These workers are important for Singapore, which has serious labour shortages and they provide flexibility by acting as a buffer in recession times. It is necessary to carefully study the impact of these workers on manufacturing employment and the possibility of hollowing out of manufacturing employment. This issue is especially important given the strong possibility that services sector employment is poised for more growth, due to expansion in regional demand and the potential of the services sector to create employment opportunities, as shown by the higher employment elasticity and multipliers of the services sector over those of the manufacturing sector.[2]

For the partial measure of labour productivity and the total factor measure of productivity for manufacturing and services (at the disaggregated industry level), data on workers employed by educational level are not available and this can be expected to affect the results in a significant way. With the TFP measure for services, an attempt to reflect skill was made with various job categories. It was not attempted for manufacturing since Rao and Lee (1995) found no significant differences in their result with and without such an adjustment for labour. It is possible that the job categories do not fully capture skill differences that educational levels might be able to do so. This remains an empirical question.

With regards to the total measure of productivity (TFP), using the stochastic frontier approach, it would be a valuable exercise to do the decompositional growth analysis using firm level data for each manufacturing and service industry. This would not only enable comparison with industry level data used in this study, but at the micro level, it can be expected to be more accurate in terms of drawing policy implications for sustained growth in the long run. Unfortunately, such firm level data are not available as yet.

Thus, the limitations in this study mainly stem from the common lament of economists who have worked on Singapore that, as an advanced developing country, it simply cannot afford to overlook the need for more data to be compiled. Nevertheless, a few extensions of the work done in this thesis are still possible. Investigating the determinants of the partial measure of labour productivity growth in the manufacturing

---

[2] Similar concern was also raised by the senior minister, Mr. Lee Kuan Yew, in 1995.

and services sectors can be carried out to make a comparison with those found for the TFP growth of these sectors, but such an exercise was not carried out here as the focus of the thesis was on the total measure of productivity.

With TFP growth, using the improved stochastic frontier approach, first, similar analysis can be carried out using not only capital and labour but also intermediate inputs such as energy. Second, a study of cost functions of the industries using the stochastic frontier approach could shed light on allocative efficiency and scale effects of the performance of manufacturing and services industries. This would make a good comparison with Elaine-Seow and Lall (1996), the only other study which attempted to estimate the cost function for the manufacturing sector using the conventional approach.

Finally, another recently improved stochastic frontier approach, the random coefficient frontier methodology, could also be used to estimate TFP growth.[3] This approach overcomes the main limitation of the stochastic frontier method used in this exercise, which is the assumption of parallel shifts of production frontier over time. Empirical evidence shows that with the same level of inputs, different levels of output are obtained with different methods of applications. This implies that different methods of applying various inputs will influence output differently and this means that the diversity of individual decisions made by firms leads to parameter variation across firms. Thus, there is no strong theoretical reason to believe in parallel shifts. A non-neutral shift should be considered as is possible using the random coefficient approach.

---

[3] See Kalirajan and Shand (1994) for theoretical discussions and empirical evidence using this approach.

Bibliography

Abramovitz, M., (1956) "Resource and Output Trends in the US since 1870", *American Economic Review* vol.46, no.2: 5-23

Adams, F.G. and Hichman,B., (eds 1983) Global Econometrics: Essays in Honor of Lawrence R.Klein (Cambridge University Press).

Afriat, S. N., (1977) "Efficiency Estimation of Production Functions", *International Economic Review* vol.13, no.3: 568-598

Aigner, D.J.
— and Chu, D.S. (1968) "On Estimating the Industry Production Function", *American Economic Review*, vol. 58: 826-39
— Lovell, C.A.K., and Schmidt, P.J., (1977) "Formulation and Estimation of Stochastic Frontier Production Function Models", *Journal of Econometrics* vol.6, no.1: 21-37

Allen, J., (1988) "Service Industries: Uneven Development and Uneven Knowledge", *Area* vol.20 :15-22

Anderson, P., Dwyer, J., and Gruen, D., (1995) Proceedings of a Conference on Productivity and Growth (Economic Group, Reserve Bank of Australia, Ambassador Press Pte. Ltd, Australia)

Ansari, M.I., (1995) "Explaining the Service Sector Growth: An Empirical Study of India, Pakistan and Sri Lanka", *Journal Of Asian Economics*, vol.6, no.2: 233-246

Arndt, H.W., (1989) "Trade in Services: With Special Reference to ASEAN", *Australia-Japan Research Centre, Pacific Economic Papers* No.173, Research School of Pacific Studies, Australian National University.

Athukorala, P., and Chand, S., (1997) "Trade Orientation and Productivity Gains from International Production: A Study of Overseas Operations of US Multinationals", (Mimeo), Seminar Paper Presented at the Australian National University.

Australian Trade Commission (1994) Intelligent Exports and the Silent Revolution in Services.

Aw, B.Y., (1991) in Papageorgiou, D, Michaely, M., and Choksi (eds), Vol.2 of Liberalizing Foreign Trade: Korea, the Philippines and Singapore (Blackwell Publishers, USA).

Azariadis, C., and Deazen, A., (1990) "Threshold Externalities in Economic Development", *Quarterly Journal of Economics* vol.106, no.2: 407- 443

Bacon R., and Eltis, W., (1978) Britain's Economic Problem: Too Few Producers (London: Macmillan).

Bailey, M.N.,
— (1982) "The Productivity Growth Slowdown by Industry", *Brookings Papers on*

Economic Activity 2 : 423-454
— and Gordon R.J. (1988) "The Productivity Slowdown, Measurement Issues, and the Explosion of Computer Power", *Brookings Papers on Economic Activity* 2 : 347-421

— (1992) Comment on Michael F. Mohr, "Recent and Planned Improvements in the Measurement and Deflation of Service Output and Inputs in BEA's Gross Product Originating Estimates" in Griliches (ed).
— Haltiwanger, J., and Bartelsman, E.J, (1996) "Labour Productivity: Structural Change and Cyclical Dynamics", *National Bureau of Economic Research* Working Paper No. 5503 (New York).

Bailey, P., Aureilo, P., Geoffrey, R., (eds 1993) Multinationals and Employment: The Global Economy of the 1990s (Geneva, International Labour Office).

Baily, M.D., (1974) Capital Utilization in Kenya Manufacturing Industry, Unpublished PhD Dissertation, University of Cambridge.

Ball, R.J., and St.Cyr E.B.A., (1966) "Short Term Employment Fluctuations in British Manufacturing Industry", *Review of Economic Studies* vol.32: 179-207

Barker,T. and Dunne, P., (eds 1988) The British Economy After Oil: Manufacturing or Services? (Croom Helm, New York).

Bauer, P.W.,
— (1990a) "Recent Developments in the Econometric Estimation of Frontiers", *Journal of Econometrics* vol.46, no.1/2: 39-56
— (1990b) "Decomposing Total Factor Productivity Growth in the Presence of Cost Inefficiency, Nonconstant Returns to Scale, and Technological Progress", *Journal of Productivity Analysis* vol.1 : 287-99

Baumol, W.J.,
— (1968) "Macroeconomics of Unbalanced Growth: Comment", *American Economic Review* vol.58, no.4: 896-897
— Blackman, Sue A.B. and Wolff, E.N. (1985) "Unbalanced Growth Revisited: Asymptotic Stagnancy and New Evidence", *American Economic Review* vol.75, no.4 :806-817
— (1985) "Productivity Policy and the Service Sector" in Inman (ed).
— and McLennan K. (eds 1985) Productivity Growth and US Competitiveness (Oxford University Press, New York).
— (1986) "Information Technology and the Service Sector" in Faulhaber (eds).
— Nelson, R.R. and Wolff, E.N. (eds 1994) Convergence of Productivity (Oxford University Press).
— Blackman, Sue A.B. and Wolff, E.N. (1989) Productivity and American Leadership (Cambridge: MIT Press).

Bauer, P.T. and Yamey, B.S., (1951) "Economic Progress and Occupational Distribution", *The Economic Journal* vol.61: 741-755

Battese, G. E.,
— and Corra, G.S., (1977) "Estimation of a Production Frontier Model: With

Application to the Pastoral Zone of Eastern Australia", *Australian Journal of Agricultural Economics*, vol.21: 169-179

— Coelli, T.J., and Colby, T.J., (1989) "Estimation of Frontier Production Functions and the Efficiencies of Indian Farms Using Panel Data from ICRISAT's Village Level Studies", *Journal of Quantitative Economics* vol.5, no.2: 327-348

— (1992) "Frontier Production Functions and Technical Efficiency: A Survey of Empirical Applications in Agricultural Economics", *Agricultural Economics* vol.7 nos. 3/4: 185-208

— and Coelli, T.J., (1992) "Frontier Production Functions, Technical Efficiency and Panel Data: With Application to Paddy Farmers in India", *Journal of Productivity Analysis* vol.3: 159-169

— and Coelli, T.J., (1995) "A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data", *Empirical Economics* vol.20: 325-332

Bell,C.S., (1968) "Macroeconomics of Unbalanced Growth: Comment", *American Economic Review* vol.58, no.4: 877-884

Bergstrand, J.H., (1991) "Structural Determinants of Real Exchange Rates and National Price Levels: Some Empirical Evidence", *American Economic Review* vol.81: 325-334

Berman, E., Bound, J. and Griliches, Z., (1993) "Changes in the Demand for Skilled Labor Within US Manufacturing Industries: Evidence from the Annual Survey of Manufacturing", *National Bureau of Economic Research* Working Paper No. 4255 (New York).

Berndt, E.r, and Christensen, L.R., (1973) "The Translog Function and the Substitution of Equipment, Structures, and Labour in US Manufacturing, 1929-68", *Journal of Econometrics* vol.1, no.l: 81-113

Bernolak, I., (1980) "The Measurement of Output and Capital Inputs" in Bailey, D., and Hubert, T., (eds) Productivity Measurement (Gower Publishing Co. London).

Berry, A., (1978) "A Positive Interpretation of the Expansion of Urban Services in Latin America with some Columbian Evidence", *Journal of Development Studies* vol 14, no.2: 210-231

Bertola, G., (1991) "Labour Turnover and Average Labour Demand", *Centre for Economic Policy Research Discussion Paper* 601

Betancourt, R., and Clague, C.K.,

— (1975) "An Economic Analysis of Capital Utilization", *Southern Economic Journal*, vol.42, no.1: 69-78

— (1977) "The Theory of Capital Utilization in Labor-Managed Enterprises", *Quarterly Journal of Economics*, vol. 91, no.3: 453-67

Bhagwati, J.N., (1984) "Splintering and Disembodiment of Services and Developing Nations", *World Economy* vol.7, no.2: 133-143

Bhati, U.N., (1978) "An Analysis of Aggregate Labour Demand and Supply Relationships for Australian Agriculture", *Quarterly Review of Agricultural Economics* vol. 31: 106-123

Bond, S.R., (1988) " Stabilization, Expected Output and Employment", *Oxford Bulletin of Economics and Statistics* vol. 50, no.2: 139-158

Bosworth B., Collins, S.M. and Chen, Y.C., (1995) "Accounting for Differences in Economic Growth", (Mimeo).

Boyd, J.H. and Runkle, D.E., (1993) "Size and Performance of Banking Firms", *Journal of Monetary Economics* vol.31: 47-67

Bravo-Ureta, B.E., and Pinheiro, A. E., (1993) "Efficiency Analysis of Developing Country Agriculture: A Review of the Frontier Function Literature", *Agricultural and Resource Economics Review* vol.22: 88-101

Brechling, F.P.R., (1965) "The Relationship Between Output and Employment in British Manufacturing Industries", *Review of Economic Studies* vol. 32: 187-216

Bresnahan, T.F.,
— (1986) "Measuring the Spillovers from Technical Advance: Mainframe Computers in Financial Services", *American Economic Review* vol.76, no.4: 742-755
— Milgrom, P. and Paul, J. (1992) "The Real Output of the Stock Exchange" in Griliches (ed).

Breusch, T.S. and Pagan, A.R., (1979) "A Simple Test for Heteroscedasticity and Random Coefficient Variation", *Econometrica* vol.47: 1287-1294

Briscoe, G.,
— and Peel, D.A., (1975) "The Specification of the Short-Run Employment Function", *Oxford Bulletin of Economics and Statistics* vol.37, no.2: 115-142
— (1976) "Recent Productivity Trends in the UK Service Sector", *Oxford Bulletin of Economics and Statistics* vol.38, no.4: 265-280

Browning, H.C. and Singlemann, J., (1975) The Emergence of a Service Society: Demographic and Sociological Aspects of the Sectoral Transformation of the Labour Force in the USA (Springfield, VA: National Technical Information Service).

Bureau of Industry Economics, (1980) Features of the Australian Service Sector, Research Report no.5 (Australian Government Publishing Service, Canberra).

Byung, S.C. and Chung, H.L, (1980) "The Choice of Production Techniques by Foreign and Local Firms in Korea", *Economic Development and Cultural Change* vol.29, no.1: 135-140

Campbell, C., (1984) "Correlates of Residual Growth in New Zealand Manufacturing Industries, 1952-73", Paper Presented to the Economics Section ANZAAS, Canberra.

Campbell, D., (1994) "Foreign Investment, Labour Mobility and the Quality of Employment", *International Labour Review* vol.133, no.2: 185-204

Cao, Y.
— (1995) "Assessing Technical Efficiency of Manufacturing Industries in a Small Open Economy : Singapore", Working Paper Series 23-95, School of Accountancy and

Business, Nanyang Technological University.
— and Quek L.N. (1995) "Financial Growth in Singapore" in Chew and Kendall (eds 1995).

Carlsson, B., (1972) The Measurement of Efficiency in Production: An Application to Swedish Manufacturing Industries, 1968, Unpublished Ph.D Dissertation, Stanford University.

Castle, L. and Findlay, C., (eds)
— (1987) Issues in Services Trade in the Pacific, *Australia-Japan Research Centre, Pacific Economic Papers* No.154, Research School of Pacific Studies, Australian National University, Australia.
— (1988) Pacific Trade in Services, (Allen and Unwin, Sydney).

Caudill and Ford (1993) "Biases in Frontier Estimation due to Heteroscedasticity", *Economic Letters*, vol.41: 17-20

Caves, D.W., Christensen, L.R., and Diewert, W.E., (1982) "The Economic Theory of Index Numbers and the Measurement of Input, Output and Productivity", *Econometrica*, vol.50: 1393-1414

Caves, R.E.,
— (1990) and Barton, D.R., Efficiency in US Manufacturing Industries (Cambridge, Mass: The MIT Press).
— (ed 1992) Industrial Efficiency in Six Nations (Cambridge, The MIT Press).

Chand, S., and Falvey, R., (1996) " A Tale of Two Islands: The Prosperous Mauritius and the Not-So-Prosperous Fiji", (Mimeo).

Chen, E.K.Y.,
— (1977) "Factor Inputs, Total Factor Productivity, and Economic Growth: The Asian Case", *The Developing Economies* vol.15, no.1:121-143
— (1997) "The Total Factor Productivity Debate: Determinants of Economic Growth in East Asia", *Asian-Pacific Economic Literature* vol 11, no.1: 18-38

Chenery, H.B.,
— (1961) "Comparative Advantage and Development Policy", *American Economic Review* vol.51, no.1: 18-51
— Robinson, S., and Syrquin, M., (1986) Industrialisation and Growth: A Comparative Study (Oxford University Press).

Chew, S.B. and Kendall, J. (eds)
— (1995) Regional Issues in Economics, vol 1, Applied Economics Research Series
— (1996) Regional Issues in Economics, vol 2, Applied Economics Research Series (Published by Nanyang Business School, Nanyang Technological University, Singapore).

Cheung, Y.W., and Lai, K.S., (1992) "International Evidence on Output Persistence from Postwar Data", *Economics Letters* vol.38: 435-441

Chng, M.K.,
— Low, L., Tay, B.N., and Tyabji, A., (1986) Effective Mechanisms for the Enhancement of Technology and Skills in Singapore (Published by Institute Of Southeast Asian Studies, Singapore).
— Low, L. and Toh, M.H., (1988) Industrial Restructuring in Singapore For ASEAN-Japan Investment and Trade Expansion (Chopmen Publishers, Singapore).

Chowdhury, A.
— and Kirkpatrick, C., (1987) "Industrial Restructuring in a Newly Industrialising Country: The Identification of Priority Industries in Singapore", *Applied Economics* vol.19, no.7: 915-926
—and Islam, I., (1993) The Newly Industrialising Economies of East Asia, (Routledge, London and New York).

Clark, C., (1957) The Conditions of Economic Progress, (Macmillan Publishers).

Cochrane, J.H., (1988) "How Big is the Random Walk in GNP?", *Journal of Political Economy* vol. 98: 501-518

Coe, M., and Helpman, E., (1995) "North-South RandD Spillovers", *National Bureau of Economic Research* Working Paper No. 5048 (New York).

Coelli, T.,
— (1995a) "Recent Developments in Frontier Modelling and Efficiency Measurement", *Australian Journal of Agricultural Economics* vol.39: 219-245
— (1995b) "Estimators and Hypothesis Tests for a Stochastic Frontier Function: A Monte Carlo Analysis", *Journal of Productivity Analysis* vol.6, no.3: 247-68.

Coen, R.M, and Hickman, B.G., (1970) "Correlated Joint estimation of Factor Demand and Production Functions", *Review of Economics and Statistics* vol.52, no.3: 287-300

Cohen, S.S. and Zysman, J., (1987) Manufacturing Matters, (Basic Books, Inc., Publishers, New York).

Collins, S.M., and Bosworth, B.P., (1996) "Economic Growth in East Asia: Accumulation versus Assimilation", *Brookings Papers on Economic Activity* 2: 135-203

Commission of the European Communities 1993, Employment in Europe 1993, Luxembourg.

Cornwall, J., (1977) Modern Capitalism-Its Growth and Transformation, (Published by Martin Robertson and Company, London).

Cornwell, C., Schmidt, P., and Sickles, R., (1990) " Production Frontiers With Cross-Sectional and Time Series Variation in Efficiency Levels", *Journal of Econometrics* vol.46 no.1/2: 185-200

Daniels, P.W., (1993) Service Industries in the World Economy, (Blackwell Publishers, Oxford).

Delauney, J.C. and Gardey, J., (1992) Services in Economic Thought: Three Centuries of Debate (Translated by Aart Heesterman, Kluwer Academic Publishers).

Delong, J.B, and Summers, L.H., (1991) "Equipment Investment and Economic Growth", *Quarterly Journal of Economics* vol.106, no.2: 445-708

Denison, E.F.,
— (1973) "The Shift to Services and the Rate of Productivity Change", *Survey of Current Business* vol.53, no.10: 20-35
— (1985) Trends in American Economic Growth, 1929-1982 (Published by Brookings Institution ,Washington, D.C).

Department of Statistics, Singapore
— (1992) Analysis of Singapore Input-Output Tables 1973 - 1988
— Census of Services, 1994
— Economic Survey Series: Wholesale and Retail, Hotels and Catering, Transport and Communication, Financial and Business.
— Economic Survey of Singapore
— Occasional Paper Series (1993) Profile of Self-Employed Persons in Singapore.
— Occasional Paper Series (1995a) The Impact of Economic Restructuring on Output, Employment and Income Shifts in Singapore.
— Occasional Paper Series (1995b) Income Growth and Distribution.
— Occasional Paper Series (1995c) The Extent and Pattern of Foreign Investment Activities in Singapore.
— Occasional Paper Series (1997) Multifactor Productivity Growth in Singapore: Concept, Methodology and Trends.
— Report on the Census of Industrial Production, annual issues until 1986
— Report on the Survey of Services, 1974-1989
— Singapore National Accounts 1987
— Singapore Yearbook of Statistics, (Singapore National Printers, various issues).
— The Service Sector 1990-1993

Dessus, S., Shea, J.D., and Shi, M.S, (1995) Chinese Taipei: The Origins of the Economic Miracle, (Development Centre of the OECD).

Dicken, Peter (1992) Global Shift The Internationalization of Economic Activity (The Guilford Press, New York).

Dickey, D.A. and Fuller, W.A., (1981) "Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root", *Econometrica* vol. 49, no.4: 1057-1072

Diebold, F.X., and Rudebusch, G.D., (1989) "Long Memory and Persistence in Aggregate Output", *Journal of Monetary Economics* vol.24: 189-209

Diewert, W. E., and Morrison, C.J., (1986) "Export Supply and Import Demand Functions: A Production Theory Approach" , (Mimeo), University of British Columbia Department of Economics Discussion Paper 86/10

Diokno, B., (1974) "Capacity Utilization in Government 'Favoured' Export-Oriented Firms", *Philippine Economic Journal*, vol.13, no.2: 149-188

Disney, R., and Ho, S.K., (1990) "Do Real Wages Matter in an Open Economy? The Case of Singapore 1966-87", *Oxford Economic Papers* vol.42 : 635-657

Dollar, D., (1986) "Technological Innovation, Capital Mobility, and the Product Cycle in North-South Trade", *American Economic Review* vol. 76, no.1 :177-190

Domar, E.D., (1961) "On the Measurement of Technological Change", *Economic Journal* vol.71: 709-729

Dowrick, S., (1995) "The Determinants of Long-Run Growth" in Anderson, Dwyer and Gruen, (eds 1995) Proceedings of a Conference on Productivity and Growth, Economic Group, Reserve Bank of Australia (Printed by Ambassador Press, Australia).

Dowrie, J.A., (1970) "The Service Ensemble" in Forster, C., (ed) Australian Economic Development in the Twentieth Century (Allen and Unwin, London).

Driver, C., and Moreton, D.
— (1991) "The Influence of Certainty on UK Investment", *Economic Journal* vol. 101: 1452-59
— (1992) Investment, Expectations and Uncertainty (Basil Blackwell Publishers, Oxford).

Drysdale, P.
— Kalirajan, K., and Zhao, S., (1995) "The Impact of Economic Reform on Technical Efficiency: A Suggested Method of Measurement" *Pacific Economic Papers* no.239 (Australia-Japan Research Centre, Australian National University)
— and Huang, Y., (1996) "Technological Catch-Up and Economic Growth in East Asia and the Pacific", (Mimeo), Paper Presented at the Australian National University.

Dunning, J.H.,
— (1988) Multinationals, Technology and Competitiveness (Allen and Unwin, London).
— (1989) "Multinational Enterprises and the Growth of Services: Some Conceptual and Theoretical Issues", *The Services Industries Journal* 9: 5-39

Economic Development Board,
— Report on the Census of Industrial Production, annual issues since 1987
— Singapore Investment News

Economic Planning Advisory Council of Australia, (May 1987) "International Trade in Services", Council Paper No.28

Edwards, A., (ed 1987) Singapore: A Guide to the Structure, Development and Regulation of Financial Services (The Economist Publications, UK).

Eggleston, K., (1997) "The Sustainability of East Asian Growth", *ASEAN Economic Bulletin* vol.14, no.1:14-31

Elaine-Seow, L.H. and Lall, A., (1996) "Technical Change in Manufacturing Industries in Singapore: 1980-91" in Chew and Kendall (eds 1996).

Elfring, T., (1989) "New Evidence of Service Employment in Advanced Economies", *Review of Income and Wealth* Series vol.35: 409-440

Eng, J and Tan,E.K., (1992) " The Supply Side: Total Factor Productivity and Related Issues in the Singapore Economy", Occasional Paper Series 1-92, School of Accountancy and Business, Nanyang Technological University.

Engle, R.F, and Granger, C.W.J.,
— (1987) "Co-Integration and Error Correction: Representation, Estimation, and Testing" *Econometrica* vol.55, no.2: 251-276
— (1991) Long-Run Economic Relationships (Oxford University Press).

Esposito, F.F., and Esposito, L., (1974) Excess Capacity and Market Structure", *Review of Economics and Statistics* vol.56, no.2: 188-194

Evans, W.N., et al., (1993) "Endogeneity in the Concentration-Price Relationship: Causes, Consequences, and Cures", *Journal of Industrial Economics* vol. 41 no.4: 431-437

Falvey, R., and Gemmel, N.,
— (1991) "Explaining Service Price Differences in International Comparisons", *American Economic Review* vol.81: 1295-1309
— (1996) "Are Services Income-Elastic? Some New Evidence", *Review of Income and Wealth* series 42, no.3: 257 -269

Fan, S., (1991) "Effects of Technological Change and Institutional Reform on Production Growth in Chinese Agriculture", *American Journal of Agricultural Economics* vol.73 no.2: 266-275

Farrell, M.J., (1957) "The Measurement of Productive efficiency", *Journal of the Royal Statistical Society A*, General, 120, no.3: 253-281

Faulhaber, G., Noam, E., and Tasley, R., (eds 1986) Services in Transition (Ballinger Publishing Company, Cambridge).

Fels, G., Schatz, K., and Wolter, F., (1971) "The Interdependence between the Structure of Production and the Level of Development", *Weltwirtschaftliches Archiv* vol.106: 240-278

Ferrier, G.D., Grosskopf, S., Hayes, K. J., and Yaisawarang, S., (1993) "Economies of Diversification in the Banking Industry", *Journal of Monetary Economics* vol.31: 229-249

Findlay, C.,
— (1990) "Trade in Services in the Asia-Pacific Region", *Asian-Pacific Economic Literature* vol.4, no.2: 3-20
— (1995) Factor Proportions, Trade and Growth, Ohlin Lectures, vol.5 (Cambridge, MIT Press).

Fixler, D.J., and Zieschang, K.D., (1992) "User Costs, Shadow Prices, and the Real Output of Banks" in Griliches (ed 1992).

Flaig, G and Steiner, V., (1989) "Stability and Dynamic Properties of Labour Demand in West-German Manufacturing" *Oxford Bulletin of Economics and Statistics* vol. 51, no.4: 395-412

Forsund, F.R,
— and Hjalmarsson, L., (1974) "On the Measurement of Productive Efficiency", *Swedish Journal of Economics* vol.72, no.2: 141-154
— Lovell, C.A.K., and Schmidt, P., (1980) "A Survey of Frontier Production Functions and of their Relationship to Efficiency Measurement", *Journal of Econometrics* vol.13, no.1: 5-25

Fransman, M., (1984) "Promoting Technological Capability in the Capital Goods Sector: The Case of Singapore", *Research Policy* Vol.13: 33-54

Freebairn, J.W., (1977) "Do Wages Matter? Their Effect on Aggregate Employment" *Australian Economic Review* 3d Quarter 1977 : 25-35

Freeman, C., (1994) "Technological Revolutions and Catching-Up: ICT and the NICs" in Fagerberg, J., Verspagen, B., and Tunzelmann, N., (eds) The Dynamics of Technology, Trade and Growth (Published by Edward Elgar).

Fuchs, V.R.,
— (1968) "The Service Economy", *National Bureau of Economic Research* Working Paper No. 61 (New York).
— (1969) "Production and Productivity in the Service Industries" *National Bureau of Economic Research,* Conference on Research in Income and Wealth (Columbia University Press).
— (1981) "Economic Growth and the Rise of Service Employment" in H.Giersch (ed).
— (1985) "An Agenda for Research on the Service Sector" in Inman (ed).

Fuller, W.A., (1976) Introduction to Statistical Time Series (New York: John Wiley and Sons).

Galbis, V., (1977) "Financial Intermediation and Economic Growth in Less-Developed Countries: A Theoretical Approach", *Journal of Development Studies* vol.13, no.2: 58-72

Gan, W.B., and Soon, L.Y., (1996) "Input vs Productivity Driven Growth", Paper Presented at the Malaysian Economic Association National Convention on the 7th Malaysian Plan, Kuala Lumpur, Aug 5-7 1996

Gary Rodan (ed 1993) Singapore Changes Guard - Social, Political and Economic Directions in the 1990s (St. Martin's Press, New York).

GATT (1989) International Trade 1988-89 (Geneva).

Gershuny, J.I.,
— (1978) After Industrial Society: The Emerging Self-Service Economy, (Macmillan, London).
— and Miles I.D. (1983) The New Service Economy, (Praeger Publishers, New York).

Giarini, O., (ed 1987) The Emerging Service Economy (Published by Pergamon Press, Oxford (Oxfordshire, New York).

Giersch, H., (ed), (Institut für Weltwirtschsaft an der Universität Kiel)
— (1981) Symposium 1980, Towards an Explanation of Economic Growth.
— (1989) Symposium 1988, Services in World Economic Growth.

Gilbert, A.L., (1990) "Information Technology Transfer: The Singapore Strategy" in M.Chatterji (ed) Technology Transfer in the Developing Countries (London: Macmillan Publishers).

Goh, K. S.,
— (1993) "What Causes Fast Economic Growth?", paper delivered at the Fourth Dr. K T Li Lecture in Harvard University, 13 Oct 1993
— and Low, L., (1996) "Beyond 'Miracles' and Total Factor Productivity", *ASEAN Economic Bulletin* vol.13, no.1: 1-13

Goldar, B., and Renganathan, V.S., (1989) "Capacity Utilization in Indian Industries", *Indian Economic Journal*, vol.39: 82-92

Goldschmid, H., Mann, M., and Weston, J.F., (1974) Industrial Concentration: The New Learning (Little Brown, Boston).

Goldberger, A.S., (1964) Econometric Theory (Wiley Publications, USA).

Goldsmith, R.W., (1969) Financial Structure and Development (New Haven:Yale University Press).

Gordan R.J.
— (1993) "The Jobless Recovery: Does it Signal a New Era of Productivity-Led Growth?" in *Brookings Papers on Economic Activity* 1 : 271-306
— (1995) "Problems in the Measurement and Performance of Service-Sector Productivity in the United States" in Anderson, P. (et al., eds).
— (1996) "Problems in the Measurement and Performance of Service-Sector Productivity in the United States", *National Bureau of Economic Research* Working Paper No. 5519 (New York).

Granger, C.W.J., (1969) "Investigating Causal Relations by Econometric Models and Cross-Spectral Methods", *Econometrica* vol. 37, no.3: 424-438

Greene, W.H., (1980) " Maximum Likelihood Estimation of Econometric Frontier Functions", *Journal of Econometrics*, vol.13: 27-56

Griliches, Z.,
— (1987) "Productivity: Measurement Problems" in The New Palgrave Dictionary of Economics, ed Murray Eatwell (London).
— (ed 1992) Output Measurement in the Service Sectors, *National Bureau of Economic Research*, Conference on Research in Income and Wealth (University of Chicago Press, Chicago and London).
— (1994) "Productivity, R and D, and the Data Constraint", *American Economic*

Review, vol 84: 1-20

Grossman, M.
— and Fuchs, V.R., (1973) "Intersectoral Shifts and Aggregate Productivity Change", *Annals of Economic and Social Measurement* vol 2, no.3: 227-249
— and Helpman, E., (1991) Innovation and Growth in the Global Economy (Cambridge, Mass : MIT Press).

Grubel, H.G., (1987) "All Traded Services are Embodied in Materials or People", *World Economy* vol. 10, no.3: 318-330

Gurly, J.G. and Shaw, E.S., (1967) "Financial Structure and Economic Development", *Economic Development and Cultural Change* vol.15, no.3: 257-268

Haig, B.D., (1975) "An Analysis of Changes in the Distribution of Employment and Service Industries, 1960-70" , *Review of Economics and Statistics* vol.57, no.1: 35-42

Hall, S.G, and Henry, S.G.B, (1985) "Rational Expectations in an Econometric Model: NIESR Model 8", *National Institute Economic Review* No.114: 58- 68

Harberger, A.C.,
— (1978) "Perspectives on Capital and Technology in Less Developed Countries", in Artis, M.J. and Nobay, A.R. (eds) Contemporary Economic Analysis (Published by Croom Helm, London).
— (1996) "Reflections on Economic Growth in Asia and the Pacific", *Journal of Asian Economics*, vol.7, no.3: 365-392

Harmesh, D.S., (1995) "Labour Demand and the Source of Adjustment Costs", *Economic Journal* vol.105 : 620-634

Hartley, K., and Lynk, E., (1983) "Labour Demand and Allocation in the UK Engineering Industry: Disaggregation, Structural Change and Defence Reviews" *Scottish Journal of Political Economy* vol.30, no.1: 42- 53

Hazledine, T.,
— (1974) "Employment and Output Functions for New Zealand Manufacturing Industries", *Journal of Industrial Economics* vol.22, no.3: 161-198
— (1978) "New Specifications for Employment and Hours Functions", *Economica*, vol.45: 179-193

Hill, H. and Pang, E.F., (1991) "Technology Exports from a Small Very Open NIC: The Case of Singapore", *World Development* vol.19, no.5: 553-568

Hill, T.P., (1977) "On Goods and Services", *Review of Income and Wealth* vol.23, no.4 : 315-338

Hirsch, S., (1989) "Services and Service Intensity in International Trade", *Weltwirtschaftliches Archiv* vol.125: 45-60

Hirschman, A.O. (1986) Rival News of Market Society and Other Recent Essays (Elisabeth Sifton Books, New York).

Hobday, M., (1994) "Technological Learning in Singapore: A Test Case of Leapfrogging", *Journal of Development Studies* vol.30, no.4: 831-858

Houthakker,H. and Taylor, L.D., (1966) Consumer Demand in the United States, 1929-1970, (Cambridge, Mass., Harvard University Press).

Hsiao, C.,
— (1979) "Causality Tests in Econometrics", *Journal of Economic Dynamics and Control*" vol.1 : 321-346
— (1986) Analysis of Panel Data, Econometric Society Monograph No:11 (New York: Cambridge University Press).

Huang, Y., Wing, T.W, Kalirajan, K.P, and Duncan R., (1998) "Enterprise Reform, Technological Progress and Technical Efficiency in China's State Industry" Paper Presented at the 'Chinese State-Owned Enterprises Workshop' at the Australian National University, 17-18 Feb .

Huff, W.G., (1994) The Economic Growth of Singapore: Trade and Development in the Twentieth Century, (Cambridge University Press).

Hughes, H., (1995) "The Myth of Asia's Miracle: A Comment on Krugman", *Policy* Autumn Issue:11-12

Hui, W.T., (1992) "Singapore's Immigration Policy" in Low and Toh (eds 1992).

Hulten, C.R.,
— (1973) "Divisia Index Numbers", *Econometrica* vol.44: 1017-1025
— and Wykoff, F.C., (1981) "The Measurement of Economic Depreciation" in Hulten (ed) Depreciation, Inflation and the Taxation of Income from Capital (Published by Urban-Institute Press, Washington D.C.).
— (1990) "The Measurement of Capital" in Bendt, E. R., Triplett, J.E., (eds) Fifty Years of Economic Measurement: The Jubilee of the Conference on Research in Income and Wealth. National Bureau of Economic Research Studies in Income and Wealth vol.54.
— (1992) "Growth Accounting When Technical Change is Embodied in Capital", *American Economic Review* vol.82, no.4: 964-80

Illeris, S., (1989) Services and Regions in Europe (Avebury Publishers, USA).

Inman, R.P., (ed 1985) Managing the Service Economy: Prospects and Problems (Cambridge University Press).

International Labour Office, Geneva.
— (1981a) Employment Effects of Multinational Enterprises in Industrialised Countries
— (1981b) Employment Effects of Multinational Enterprises in Developing Countries
— (1981c) Multinationals' Training Practices and Development
— Yearbook of Labour Statistics 1994

International Monetary Fund, (Washington D.C.)
— International Financial Statistics Yearbook, various issues

— Balance of Payments Statistics Yearbook, various issues

Islam, R., (1978) "Reasons for Idle Capital: The Case of Bangladesh Manufacturing", *Bangladesh Development Studies*, vol.6, no.1: 27-54

Jacobs, R.L., Leamer, E.E and Ward, M.P., (1979) "Difficulties with Testing For Causation", *Economic Inquiry* vol.17, no.3: 401-413

Jenkinson, T.J., (1986) "Testing Neo-Classical Theories of Labour Demand: An Application of Cointegration Techniques" *Oxford Bulletin of Economics and Statistics* vol. 48, no.3: 241-251

Jeanne Lim, K.L., (1995) A Study of Manufacturing Productivity in Singapore, Unpublished Masters Thesis, National University of Singapore.

Johansen, L., (1972) Production Functions (Published by North Holland, Amsterdam).

Johnston, J., (1960) Statistical Cost Analysis (McGraw-Hill, New York).

Jondrow, J., Lovell, C.A.K., Materov, I.S., and Schmidt, P., (1982) "On the Estimation of Technical Inefficiency in the Stochastic Frontier Production Function Mode", *Journal of Econometrics* vol. 19, no.2-3: 269-274

Jorgenson, D.W.,
— Gollop, F.M., and Fraumeni, B.M. (1987) Productivity and US Economic Growth (Amsterdam, North Holland).
— (1990) "Productivity and Economic Growth", in E.R.Berndt and J.E. Triplett (eds 1990) Fifty Years of Economic Measurement (University of Chicago Press, Chicago)

Jung, W.S., (1986) "Financial Development and Economic Growth: International Evidence", *Economic Development and Cultural Change* vol.34, no.2: 333-346

Kalirajan, K.P.
— and Flinn, J.C, (1983) "The Measurement of Firm-Specific Technological Efficiency", *Pakistan Journal Of Applied Economics* vol. 2: 167-180
— and Shand, R.T., (1992) "Causality between Technical and Allocative Efficiencies: An Empirical Testing", *Journal Of Economic Studies* vol. 19, no.2: 3-17
— and Kapuscinski, C.A., (1993) "Growth Variations and the Patterns of Causalities among Major Macro-Economic Indicators: The Experience of Selected Asian Countries", Seminar Paper given at the Research School of Pacific and Asian Studies, Australian National University.
— and Shand, R.T., (1994) Economics in Disequilibrium: An Approach from the Frontier (Published by Macmillan India Limited).
— and Obwona, M. B., (1994) "Frontier Production Function: The Stochastic Coefficients Approach", *Oxford Bulletin of Economics and Statistics* vol.56, no.1: 87-96
— Obwona, M. B., and Zhao, S., (1996) " A Decomposition of Total Factor Productivity Growth: The Case of Chinese Agricultural Growth Before and After Reforms", *American Journal of Agricultural Economics* vol.78 no.2 : 331-338

Kapur, B., Euston-Quah, T.E., and Hoon, H.T., (eds 1996) Development, Trade and the Asia-Pacific, Essays in Honour of Professor Lim Chong Yah (Published by Prentice Hall, Singapore).

Kasper, W. and Parry T.G., (eds 1978) Growth Trade and Structural Change in an Open Australian Economy (Centre for Applied Economic Research, University of New South Wales).

Kawai, H., (1994) "International Comparative Analysis of Economic Growth: Trade Liberalization and Productivity", *The Developing Economies* vol. 32, no.4: 373-397

Kendrick, J.W.,
— and Vaccara B.N., (eds 1980) New Developments in Productivity Measurement and Analysis (University of Chicago Press).
— (1976) "The Formation and Stocks of Total Capital", *National Bureau of Economic Research* No.100, General Series (Columbia University Press).
— (1982) "Measurement of Output and Productivity in the Service Sector", Philadelphia ARA/Wharton Conference, 'The Future of the Service Economy', 19-20 Nov 1982
— (1985) "Measurement of Output and Productivity in the Service Sector" in Inman (ed).

Kholdy, S., (1997) "Causality between Foreign Investment and Spillover Efficiency", *Applied Economics* vol.27, no.8: 745-749

Kim, J. and Lau, L.
— (1992) "The Importance of Embodies Technical Progress: Some Empirical Evidence from the Group-of-Five Countries", Centre for Economic Policy Research Paper No.296, Stanford University, Stanford, California.
— (1994) "The Sources of Economic Growth of the East Asian Newly Industrialised Countries", *Journal of Japanese and International Economy*, vol.8, no.3 : 235-271

King, R.G., and Levine, R., (1993) "Finance, Entrepreneurship, and Growth", *Journal of Monetary Economics* vol.32: 513-542

Kirkland, R.I. Jr., (1985) "Are Service Jobs Good Jobs?", *Economic Impact* no.52: 14-21

Klein, L.R., and Preston, R.S., (1967) "Some New Results in the Measurement of Capacity Utilization", *American Economic Review* vol.57: 34-58

Klotz, B., Madoo, R., and Hanson, R., (1981) "A Study of High Low Labour Productivity Establishments in Manufacturing" in Kendrick, J.W., and Vaccara B.N., (eds 1980)

Knowles, S., (1997) "Which Level of Schooling Has The Greatest Economic Impact On Output?", *Applied Economics Letters*, vol.4, no.3: 177-180

Koh, A.T., (1985) "The Role of Services in ASEAN" in Jomo (ed) ASEAN Economies: Crisis and Response (Malaysian Economic Association, University of Malaya).

Kopp, R.J., and Smith, V.K., (1980) "Frontier Production Function Estimates for Steam Electric Generation: A Comparative Analysis", *Southern Economic Journal* vol.46 no.4: 1049-1059

Krongkaew, M., (1994) "Income Distribution in East Asian Developing Countries", *Asian-Pacific Economic Literature* vol.8 no.2: 58-73

Krugman, P.,
— (1979) "A Model of Innovation, Technology Transfer, and the World Distribution Income", *Journal of Political Economy* vol.87, no.2 : 235-266
— (1990) Rethinking International Trade (Cambridge, Mass. and London: MIT Press).
— (1992) "Comment on Young (1992)", *National Bureau of Economics Research*, Macroeconomics Annual 1992 (Cambridge).
— (1994) "The Myth of Asia's Miracle", *Foreign Affairs* vol. 73 no.6: 62-78
— (1997) "What Ever Happened to the Asian Miracle?", Fortune Magazine (18 August Issue)

Kravis, I.B.,
— (1983) "Services in the Domestic Economy and in World Transactions", *National Bureau of Economic Research* Working Paper no.1124 (Cambridge).
— Heston. A.W. and Summers, R., (1983) "The Share of Services in Economic Growth" in Adams, F.G. and Hichman, B., (eds).

Kumbhakar, S.C.,
— (1987a) "Production Frontiers and Panel Data: An Application to US Class 1 Railroads", *Journal of Business and Economic Statistics* vol.5: 249-255
— (1987b) "The Specification of Technical and Allocative Inefficiency in Stochastic Production and Profit Frontiers", *Journal of Econometrics* vol.34, no.3: 335-348
— (1988) "Estimation of Input-Specific Technical and Allocative Inefficiency In Stochastic Frontier Models", *Oxford Economic Papers* vol.40, no.3: 535-549
— (1990) "Production Frontiers, Panel Data, and Time-Varying Technical Inefficiency", *Journal of Econometrics*, vol.46 no.1/2: 201-211
— (1991) "The Measurement and Decomposition of Cost-Inefficiency: The Translog Cost System", *Oxford Economic Papers* vol.43, no.3: 667-683
— Ghosh, S.C., and McGuckin, J.T., (1991) "A Generalised Production Frontier Approach for Estimating Determinants of Inefficiency in US Diary Farms", *Journal of Business and Economic Statistics* vol.9, no.3: 279-286

Kutscher, R.E. and Mark, J.A., (1983) " The Service-Producing Sector: Some Common Perceptions Reviewed", *Monthly Labour Review*, April vol. 1

Kuznets, S.
— (1971) Economic Growth of Nations (Harvard University Press).
— (1981) "Driving Forces of Economic Growth: What Can We Learn From History?" in Giersch, H., (ed).

Kwak, H., (1994) "Changing Trade Policy and its Impact in the Republic of Korea", *The Developing Economies* vol.32, no.4: 398-422

Lall, A. Tan, Randolph G.K. and Chew, S.B., "Total Factor Productivity Growth

Experience of Singapore: An Interpretive Survey" in Lim (ed 1996).

Langdale, J.V., (1984) "Information Services in Australia and Singapore", *ASEAN-Australia Economic Papers* no.16, (Published by ASEAN-Australia Joint Research Project, Kuala Lumpur and Canberra).

Leamer, E.E., (1981) "Is it a Demand Curve or Is it a Supply Curve: Partial Identification Through Inequality Constraints", *Review of Economics and Statistics*, Vol.63, no.3: 319-327

Lee, C.H. and Naya. S., (1988) Trade and Services in the Asia-Pacific Region, Pacific World Studies Series no.1 (Westview Press, Colorado).

Lee, S.Y., (1990) The Monetary and Banking Development of Singapore and Malaysia (3rd edition, Singapore University Press, National University of Singapore).

Lee, T.Y., (1988) "ASEAN-US Trade in Services: An ASEAN Perspective" in Tan, L.H. and Akrasanee (ed 1988) ASEAN-US Economic Relations, (Institute of Southeast Asian Studies, Singapore).

Lecraw, D., (1978) "Determinants of Capacity Utilization by Firms in Less Developed Countries', *Journal of Development Economics*, vol.5, no.2: 139-153

Leung, H.M., (1997) "Total Factor Productivity Growth in Singapore's Manufacturing Industries", *Applied Economics Letters* vol.4, no.8: 525-528

Leveson, I.,
— (1985) "Services in the US Economy" in Inman (ed).
— (1986) "Services in the US Economy: Myths and Realities", *Economic Impact* no.56: 78-83

Levine,R., and Renelt, D., (1992) "A Sensitivity Analysis of Cross-Country Growth Regressions", *American Economic Review* vol.82, no.4: 942-963

Levitan, S.A., (1985) "Services and Long-Term Structural Change", *Economic Impact* no.52: 29-32

Lim, C.Y.,
— (1984) Economic Restructuring in Singapore (Federal Publications, Singapore).
— and Lloyd, P., (eds 1986) Resources and Growth in Singapore (Oxford University Press).
— (et al., 1988) Policy Options for the Singapore Economy (McGraw Hill Book Company).
— (ed 1996) Economic Policy Management in Singapore (Published by Addison-Wesley Publishing Company).

Lim, D., (1981) "Malaysia: Country Study" in Bautista, R., et.al (eds) Capital Utilization in Manufacturing, (Oxford University Press).

Ling, S.L.M., (1992) Producer Services Development and Trade: Malaysia and ASEAN in the Uruguay Round (Published by University of Malaya and International

Development Research Centre of Canada, Singapore).

Loh, W.M. and Cao, Y. (1996) "Financial Deepening and Growth: A Comparative Study between Hong Kong and Singapore" in Chew and Kendall (eds 1996).

Lucas, R.E., (1988) " On the Mechanics of Economic Development", *Journal of Monetary Economics* vol.22 , no.1: 3-42

Lombard, J.R., (1990) Foreign Direct Investment in Producer Services: The Role and Impact upon the Economic Development of Singapore, Ph.D Thesis, New York University.

Low, L

— Soon, T.W., and Toh, M.H.,(1989) "The Foreign Worker Levy in Singapore's Industrial Sector: Efficacy and Issues", *Southeast Asian Journal of Social Science* vol.17, no.1: 1-20

— and Toh, M.H., (eds 1992) Public Policies in Singapore: Changes in the 1980s and Future Signposts (Times Academic Press, Singapore).

— and Toh, M.H., Soon, T.W., Tan, K.Y., Huges, H., (1993) Challenge and Response: Thirty Years of the Economic Development Board (Times Academic Press, Singapore).

Lowe, P., (1995) "Labour Productivity Growth and Relative Wages: 1978-1994" in Anderson, P., (et al., eds).

Luckett, D., Schulze, D.L., and Wong-Raymond, W.Y., (1994) Banking, Finance and Monetary Policy in Singapore (McGraw-Hill Book Co, Singapore).

Maddala , G.S.,

— (1977) Econometrics (McGraw Hill, New York).

— (1992) Introduction to Econometrics (MacMillan Publishing Company, New York).

Madden, G.M, and Tuckwell, R.H. (1975) "The Output-Employment Relationship in Australian Industry", *Economic Record* vol. 51: 421-427

Mangan, J.,

— (1981) "Labour Hoarding in Australian Manufacturing : An Inter-Industry Analysis", *Australian Bulletin of Labour* vol. 7, no. 4: 219-235

— and Stokes, L., (1984) "The Determinants of Labour Demand in Australian Manufacturing", *Applied Economics* (1984) vol. 16 : 449-459

— and Stokes, L., (1985) "Labour Demand in Australian Manufacturing: A Further Analysis", *South African Journal of Economics* vol.53, no.2: 197-200

Mankiw,G., Romer, D., and Weil, D., (1992) "A Contribution to the Empirics of Economic Growth", *Quarterly Journal of Economics* vol.107, Issue 2:407-437

Maris, R., (1964) The Economics of Capital Utilization: A Report on Multiple Shifts Work (Cambridge University Press).

Mark, J.A., (1982) "Measuring Productivity in Service Industries", *Monthly Labour Review*, June vol. 1: 3-8

Marshall, J.N., (1988) Services and Uneven Development, (Oxford University Press).

Matyas, L., and Sevestre, P., (1992) The Econometrics of Panel Data (Kluwer Academic Publishers).

Maynes, G., Brooks, R., and Davidson, S., (1997) "Education, Human Capital Accumulation, and Economic Growth : The Singapore Experience 1974-96", Paper Presented at the International Australia-Singapore Forum held at the University of Western Sydney, MacArthur, 12 Dec 1997

McCleery, R.K., (1996) "On Continuing Economic Growth in Developing Asia: Is Human Resource Development the Key to 'Pacific Century'"? Paper Prepared for the Conference on Globalisation and Development: Implications for Malaysia, 12-14 August 1996, University of Malaya, Kuala Lumpur.

McKinnon, R.I., (1973) "Money and Capital in Economic Development", *The Brookings Institute*, (Washington D.C.).

Meeusen, W., and Van Den Broeck, J., (1977) "Efficiency Estimation from Cobb Douglas Production Functions with Composed Error", *International Economic Review* vol. 18, no.2: 435-444

Merhav, M., (1970) "Excess Capacity-Measurement, Causes and Uses: A Case Study by of Industry in Israel", *Industrialization and Productivity Bulletin*, vol.15, New York, UNIDO.

Millan, P., (1975) The Intensive Use of Capital in Industrial Plants: Multiple Shifts as an Economic Option, Ph.D dissertation, Harvard University.

Ministry of Finance (1987) Singapore, Report on the Public Sector Divestment Committee

Ministry of Information and the Arts, Singapore Facts and Pictures 1991

Ministry of Labour, Singapore
— Singapore Yearbook of Labour Statistics
— Report on the Labour Force Survey of Singapore, various issues

Ministry of Trade and Industry, Singapore
— Economic Survey of Singapore, various issues
— Report of the Economic Committee (1986) The Singapore Economy: New Directions.
— (1991) The Strategic Economic Plan: Towards A Developed Nation.

Monetary Authority of Singapore Annual Report 1992/93

Morawetz, D., (1981) "Israel: Country Study" in Bautista, R., et al., (eds) Capital Utilization in Manufacturing, (Oxford University Press).

Morrison, C.J., (1992) "Unravelling the Productivity Growth Slowdown in the United States, Canada and Japan: The Effects of Subequilibrium, Scale Economies and

Markups", *Review of Economics and Statistics* vol. no.3: 381-393

Mundlak, Y.,
— (1978) "On the Pooling of Time Series and Cross Sectional Data", *Econometrica* vol.46: 69-86
— (1988) "Endogenous Technology and the Measurement of Productivity" in Capalbo, S.M., and Antle, J.M., (eds 1988) Agricultural Productivity: Measurement and Explanation (Washington, D.C.).
— (1996) "Production Function Estimation: Reviving the Primal", *Econometrica* vol.64, no.2: 431-438

Murindhe, V. and Eng-Fern S.H., (1994) "Financial Development and Economic Growth in Singapore: Demand-following or Supply-leading?", *Applied Financial Economics* vol.4: 391-44

Murray, R., (1992) "Measuring Public-Sector Output: The Swedish Report" in Griliches (ed).

Nadiri, M.I.,
— and Rosen, S., (1969) "Interrelated Factor Demand Functions", *American Economic Review* vol.54, no.4, Part 1: 457-471
— (1970) "Some Approaches to the Theory and Measurement of Total Factor Productivity: A Survey", *Journal of Economic Literature* vol.85, no.4: 1137-77

National Productivity Board (1994), Research and Information Centre, Productivity and Quality Statement 1994 (Magenta Colorprinters Pte Ltd, Singapore).

Nehru, V.,
— and Dhareshwar, A., (1993) "A New Database on Physical Capital Stock: Sources, Methodology, and Results", *Revista Analisis de Economico* vol.8, no.1: 37-59
— Swanason, E., and Dubey, A., (1994) "A New Database on Human Capital Stock: Sources, Methodology, and Results", *Journal of Development Economics*, vol. 46, no.2: 379-401.
— and Dhareshwar, A., (1994) "New Estimates of Total Factor Productivity Growth for Developing and Industrial Countries", *World Bank Policy Research Paper* No. 1313

Nelson, C.R., and Plosser, C.I., (1982) "Trends and Random Walks in Economic Time Series", *Journal of Monetary Economics* vol.10: 139-162

Nelson, R.R., (1980) Commentary in Leveson I. and Wheeler, J.W. (eds) Western Economies in Transition: Structural Change and Adjustment Policies in Industrial Countries (London, Groom Helm).

Newell, A., and Symon, J, S., (1988) " Stylised Facts and the Labour Demand Curve", *London School of Economics Discussion Paper* 322.

Nicolaides, P., (1990) "Services in Growing Economies and Global Markets", *The Pacific Review* vol.3, no.4: 283-295

Nishimizu, M. and Page, J., (1982) "Total Factor Productivity Growth, Technological Progress and Technical Efficiency Change: Dimensions of Productivity Change in

Yugoslavia, 1965-78", *Economic Journal* vol. 92: 920-35

Nordhaus, W., (1988) "Comments and Discussion" in Bailey and Gordan (1988).

Norsworthy J.R. and Jang S.L., (1993) Empirical Measurement and Analysis of Productivity and Technological Change, (Elsevier Science Publishers, North Holland).

Noyelle, T.J.,
— (ed 1990) Skills, Wages and Productivity in the Service Sector (Published by Westview Press).
— and Stanback T.M., (1990) "Productivity in Services: A Valid Measure of Economic Performance?" in Noyelle, T.J.(ed 1990).

Ochel, W. and Wegner, M., (1987) Service Economies in Europe. Opportunities for Growth (Pinter Publishers, London).

OECD, Paris
— (Sept.1984) Employment Outlook
— (1985) Software: An Emerging Industry, (Information Computer Communication Policy Series, No.9)
— (1991) Technology and Productivity: The Challenge for Economic Policy
— (1992) Structural Change and Industrial Performance: A Seven Country Growth Decomposition Study
— (1993) 1993 Issues: The OECD Response
— (1995) Science Technology Industry Review No. 15
— (1996) Services: Measuring Real Annual Value Added

Ofer, G., (1973) The Service Sector in Soviet Economic Growth: A Comparative Study, Russian Research Centre Studies No.71 (Harvard University Press).

Olson, J.A, Schmidt, P., and Waldman, D. M., (1980) "A Monte Carlo Study of Estimators of Stochastic Production Functions", *Journal of Econometrics* vol.13, no.1: 67-82

Osman, J.B., (1988) An Econometric Model of the Financial Sector in Malaysia, Ph.D Dissertation, Rensselaer Polytechnic Institute, New York.

Oster, A., and Antioch, L., (1995) "Measuring Productivity in the Australian Banking Sector" in Anderson (et al., eds).

Oulton, N., and O'Mahoney, M., (1994) Productivity and Growth: A Study of British Industry, 1954-86 (Cambridge University Press).

Pack, H. and Page, J.M. Jr. (1992) "Accumulation, Exports and Growth in the High Performing Asian Economies", Background Paper for the East Asian Miracle, Washington, D.C: World Bank, Policy Research Department.

Pang, A.L., (1993) Employment Functions in Singapore, Unpublished Academic Exercise, National University of Singapore.

Pang, E.F.,
— (1975) "Growth, Inequality and Race in Singapore", *International Labour Review* vol.111: 15-28
— (1982) Education, Manpower and Development in Singapore (Singapore University Press).
— (Nov 1993) "Foreign Direct Investment and Regionalisation: The Experience of Singapore", (Mimeo) Prepared for the Institute of Southeast Asian Studies and the National University of Singapore

Park, Y.C, (1996) "East Asian Liberalization and the Challenge from China", *Brookings Papers on Economic Activity* 2: 357-371

Pasha, H.A., and Quershi, T., (1984) "Capacity Utilization in Selected Industries in Pakistan", *Pakistan Journal of Applied Economics*, vol.3, no.1: 29-56

Patrick, H.T., (1966), "Financial Development and Economic Growth in Underdeveloped Countries", *Economic Development and Cultural Change* vol.14, no.2 : 174-189

Paul, S.B., (1974) "Growth and Capacity Utilization of Industrial Capacity", *Economic and Political Weekly*, vol.7: 2025-2032

Peacock, A., (1981), Comments on Fuchs' article in Giersch (ed).

Peebles, G., and Wilson, P, (1996) The Singapore Economy (Edward Elgar Publishing Ltd, UK).

Petit, P., (1986) Slow Growth and the Service Economy, (Frances Pinter Publishers, London).

Phillips, P.C.B., and Ouliaris, S., (1990) " Asymptotic Properties of Residual Based Tests for Cointegration", *Econometrica* vol.58, no.1: 166-193

Pitt, M. M., and Lee, L.F., (1981) "The Measurement and Sources of Technical Inefficiency in the Indonesian Weaving Industry", *Journal of Development Economics*, vol.9, no.1: 43-64

Pope, R., (1977) "Revaluation: Help or Hindrance to Manufacturers in Australia", *Centre for Applied Economic Research* Paper no.3:1-24, (Australian National University).

Porter, M.E., (1990) The Competitive Advantage of Nations, (New York: The Free Press).

Postlewaite, A., (1985), Comment on the "Provision of Services in a Market Economy" in Inman (ed).

Postner, H.H., (1990) "The Contracting-Out Problem in Service Sector Analysis: Choice of Statistical Unit", *Review of Income and Wealth* series 36, no.2: 177-186

Price, S., (1994) "Aggregate Uncertainty, Forward Looking Behaviour and the Demand for Manufacturing Labour in the UK", *Oxford Bulletin of Economics and Statistics* vol. 56, no.3: 267-283

Quibria, M.G., (1990) "Trade in Services and Asian Developing Economies", *Asian Development Review* vol.8, no.2: 116-143

Rao, C.R., (1965) Linear Statistical Inference and its Applications (New York:Wiley).
Rao, V.V.Bhanoji
— and Ramakrishnan, M.K., (1980) Income Inequality in Singapore (Published by Singapore University Press, Singapore).
— (1988) "Income Distribution in East Asian Developing Countries", *Asian-Pacific Economic Literature* vol.2, no.1: 26-45
— (1990) "Income Distribution in Singapore: Trends and Issues", *The Singapore Economic Review* vol.35, no.1:143-160
— (1993) "A Primer on Income Inequality", *Times Economic Links* Oct-Dec: 5-11
— and Lee, C., (1995) "Sources of Growth in the Singapore Economy and its Manufacturing and Service Sector", Paper Presented at the 20th Federation of ASEAN Economic Associations Conference in Singapore on 7th and 8th of Dec 1995
— (1996) "Singapore Household Income Distribution Data from the 1990 Census: Analysis, Results and Implications" in Kapur (et al., eds).

Reifschneider, D., and Stevenson, R., (1991) "Systematic Departures from the Frontier: A Framework for the Analysis of Firm Inefficiency", *International Economic Review* vol.32, no.3: 715-723

Richmond, J., (1974) "Estimating the Efficiency of Production", *International Economic Review* vol.15, no.2: 515-521

Riddle, D.I., (1986) Service-Led Growth, (Praeger Publishers, New York).

Rodrik, D.,
— (1994) "King Kong Meets Godzilla: The World Bank and the East Asian Miracle" in Fishlow, A., (et al., ed) Miracle or Design? Lessons from the East Asian Experience (Washington D.C., Overseas Development Council).
— (1996) Comment on Collins, S.M., and Bosworth, B.P, "Economic Growth in East Asia: Accumulation versus Assimilation", *Brookings Papers on Economic Activity 2*: 192-197

Romer, P.M.,
— (1986) "Increasing Returns and Long-Run Growth", *Journal of Political Economy* vol.94 , no.5: 1002-1037

Romer, D., (1988) "Comments and Discussion" in Bailey (1988).

Rowthorn, R, and Ramaswamy R., (1997) "DeIndustrialization: Causes and Implications", *IMF Working Paper* 97/42

Sabolo, Y., (1975) The Service Industries (International Labour Office, Geneva).

Sapir, A., "Determinants of Trade in Services" in Waelbroek, J., Praet, P. and Rieger, H.C., (eds 1985) ASEAN-EEC Trade in Services, (Institute of Southeast Asian Studies, Singapore).

Sarel, M.,
— (1995) "Growth in East Asia: What We Can and What We Cannot Infer", Paper Presented at the Conference on Growth and Productivity, organised by the Reserve Bank of Australia in Sydney, July 1995 , also an *IMF Working Paper* 95/98.
— (1997) "Growth and Productivity in ASEAN Countries", IMF Working Paper 97/97

Saxonhouse, G.R., (1985) "Services in the Japanese Economy" in Inman (ed).

Scherer, F.M., (1986) Industrial Market Structure and Economic Performance, (2nd edition, Chicago: Rand McNally).

Schmidt, P.,
— (1976) "On the Statistical Estimation of Parametric Frontier Production Functions", *Review of Economics and Statistics* vol.58, no.2: 238-239
— and Lovell, C.A.K, (1979) "Estimating Technical and Allocative Inefficiency Relative to Stochastic Production and Cost Frontiers", *Journal of Econometrics* vol. 9, : 343-366
— and Lovell, C.A.K., (1980) "Estimating Stochastic Production and Cost Frontiers When Technical and Allocative Inefficiency Are Correlated", *Journal of Econometrics* vol. 13, no.1: 83-100
— and Sickles, R.C. (1984) "Production Frontiers and Panel Data", *Journal of Business and Economic Statistics* vol.2, no.4: 367-374
— (1985/86) "Frontier Production Functions", *Econometric Reviews* vol.4, no.2: 289-328

Schultz, D.L., (1986) "Monetization in ASEAN: 1970-1984", *Singapore Economic Review* vol.31, no.2: 57-66

Schydlowsky, M.D.,
— (1973) "On Determining the Causality of Underutilization of Capacity, Working Note, Department of Economics, Boston University (Mimeo).
— (1976) Capital Utilization, Growth, Employment, Balance of Payments and Price Stabilization, Discussion Paper Series No.22, Department of Economics, Boston University.

Seow, Greg F.H., (1980) The Service Sector in Singapore's Economy: Performance and Structure, *Economic Research Centre Occasional Paper* Series no.2, National University of Singapore (Chopmen Publishers).

Sheehan, M., (1997) "The Evolution of Technical Efficiency in the Northern Ireland Manufacturing Sector, 1973-1985", *Scottish Journal of Political Economy* vol.44, no.1: 59-81

Shelp, R.K., Stephenson, J.C., Truitt, N.S., and Wascow, B., (1984) Service Industries and Economic Development (Praeger Publishers, New York).

Shimada, H., (1996) "Impact of DFI on the Supply Side of the Singapore Economy", *ASEAN Economic Bulletin* vol.12, no.3: 369-379

Shukla, P.R. and Chowdhury, R.S.K., (ed1992) Multnational Corporations, Technology and Development (Akashdeep Publishers, New Delhi).

Simar, L., (1992) "Estimating Efficiencies from Frontier Models with Panel Data: A Comparison of Parametric, Non-Parametric and Semi-Parametric Methods with Bootstrapping", *Journal of Productivity Analysis* vol. 3: 171-203

Sims, C.A.,
— (1972) "Money, Income and Causality", *American Economic Review* vol.62, no.4: 540-552
— (1974) "Output and Labour Input in Manufacturing", *Brookings Papers on Economic Activity* : 695-728 (Published by Brookings Institution, Washington, D.C.).

Singapore (various issues)
— The Straits Times
— The Straits Times Weekly Edition
— The Business Times

Singapore Manufacturers Association, SMA Business Operations Survey 1995.

Singer, P., (1971) cited in Singlemann J.

Singh , A., (1995) "How Did East Asia Grow So Fast", *UNCTAD Discussion Paper* no.97

Singlemann, J., (1978) From Agriculture to Services: The Transformation of Industrial Employment, (Beverley Hills, CA: Sage Publications).

Sisodia, R.S., (1992) "Singapore Invests in the Nation-Corporation", *Harvard Business Review* May-June: 40-50

Sio, S.K., and Yeo, S.L, (Jan 1996) "Employment Trends by Industry", *Statistics Singapore Newsletter* vol.18, no.3

Solow, R.,
— (1982), Comments and Discussion in Bailey (1982)
— (1991) "Policies for Economic Growth", (Mimeo), Lecture at John Hopkins University, Washington D.C.
— (1994) "Perspectives on Growth Theory", *Journal of Economic Perspectives* vol.8, no.1: 45-54

Srinivasan, P.V., (1992) "Determinants of Capacity Utilization in Indian Industries", *Journal of Quantitative Economics*, vol.8, no.1: 139-156

Star, S., (1974) "Accounting for the Growth of Output", *American Economic Review* vol.64: 123-135

Stanback, T.M.,
— (1979) Understanding the Service Economy, (Baltimore, MD: Johns Hopkins University Press).
— (et al., 1981) Services: The New Economy, (Totowa, N.J.:Allanfeld, Osmun and Co.).

Stern, R.M. and Hoekman, B.M., (1988) "The Service Sector in Economic Structure and in International Transactions" in Castle and Findlay (eds).

Stiglitz, J.E., (1992) Comments on Paul Krugman's "Towards a Counter-Counterrevolution in Development Theory" in the Proceedings of the World Bank Annual Conference on Development Economics, 1992 (World Bank).

Stock, J.H., and Watson, M.W., (1986) "Does GNP have a Unit Root?", *Economics Letters* vol.22: 147-151

Summers, R., (1985) "Services in the International Economy" in Inman (ed1985).

Swamy, P.A.V.B.,
— (1970) "Efficient Inference in Random Coefficient Regression Model", *Econometrica* vol.38: 331-323
— (1971), Statistical Inference in Random Coefficient Regression Models, (Published by Springer-Verlag, New York).
— and Talvas, G.S., (1995) "Random Coefficient Models: Theory and Applications", *Journal of Economic Surveys* vol.9, no.2: 165-196

Ta, H.P., and Tan, T.S., (1993) The Singapore Manufacturing Futures Survey 1992

Takenaka, H., (1995) "Changing Asia-Pacific and the Japanese Economy", Keio University, (Mimeo in Japanese).

Tay, S.T (1992) "Determinants of Production Efficiency: An Econometric Analysis of the Manufacturing Industries in Singapore", Working Paper Series No:10-92, School of Accountancy and Business, Nanyang Technological University.

Teck-W.S., and C. Susan Tan (1993) Public Policy and Economic Development, Singapore as a case study on the Lessons of East Asia, (Published by The World Bank, Washington D.C.).

Tham, S.Y., (1997) "Determinants of Productivity Growth in the Malaysian Manufacturing Sector", *ASEAN Economic Bulletin* vol.13, no.3: 333-343

Thoumi, F.E., (1981) "Columbia: Country Study" in Bautista, R., et al., (eds) Capital Utilization in Manufacturing, (Oxford University Press).

Timmer, C.P., (1971) "Using a Probabilistic Frontier Production Function To Measure Technical Efficiency", *Journal of Political Economy* vol.79: 776-94

Toh, M.H. and Low, L.,
— (1988) "Trends and Issues in Service Sector Development: Singapore's Options", *Asian Economic Journal* vol.2, no.1 : 125-159

— (eds 1992) Public Policies in Singapore: Changes in the 1980s and Future Signposts (Times Academic Press, Singapore).
— (1994) Input-Output Tables 1988: Models and Applications, Department of Statistics, Singapore
— (1996) "Differential Total Factor Productivity in the Four Dragons: The Singapore Case", *Journal of International Trade and Economic Development* vol.5, no.2:161-182

Toh, T. S., "Regionalism, Sub-regionalism and Regionalization" in Lim (ed 1996).

Torii, A., (1992) in Caves, R. E., (ed 1992) Industrial Efficiency in Six Nations, (The MIT Press, Cambridge).

Tsao, Y.,
— (1982) Growth and Productivity in Singapore: A Supply Side Analysis, Ph.D Dissertation, Harvard University.
— (1985) "Growth Without Productivity", *Journal of Development Economics*, vol.18 : 25-38
— and Linda Low (1990) Local Entrepreneurship in Singapore Private and State, (Times Academic Press).

Tucker, K.,
— (1978) "Structural Change and the Services Sector", Working Paper No.3, Bureau of Industry Economics, Australia.
— and Sundberg, M., (1986) "Comparative Advantage and Service Intensity in Traded Goods", *ASEAN-Australia Economic Papers* No.23, ASEAN-Australia Joint Research Project 1986, Kuala Lumpur and Canberra.
— (1988) International Trade in Services (Routledge, London and New York).

Tybout, J.R.,
— (1990) "Making Noisy Data Sing: estimating Production Technologies in Developing Countries", *Journal of Econometrics* vol.53: 25- 44
— and Westbrook, D.M., (1995) "Trade Liberalisation and the Dimensions of Efficiency Change in Mexican Manufacturing Industries", *Journal of International Economics*, vol.39: 53-78

Tyler, W.G., (1979) "Technical Efficiency in Production in a Developing Country: An Empirical Investigation of the Brazilian Plastics and Steel Industries", *Oxford Economic Papers* vol.31, no.3: 477-458

United Nations, National Accounts Statistics: Main Aggregates and Detailed Tables 1992 (New York:U.N.).

United Nations Conference on Trade and Development, Trade and Development Report, various years.

Urata, H., (1994) "Trade Liberalisation and Productivity Growth in Asia: Introduction and Major Findings", *The Developing Economies*, vol.32 no.4: 363- 372

Van Eklan, R., (1995) "Accounting for Growth in Singapore", *IMF Occasional Paper* 119

Vernon, R., (1966) "International Investment and International Trade in the Product Cycle", *Quarterly Journal of Economics* vol.80: 190-207

Virabhak, S. (1996) Sources of Growth in Singapore's Service Sector, Unpublished Academic Exercise, National University of Singapore.

Ward, M., (1976) The Measurement of Capital (OECD Publication).

Wieczorek, J., (1995) "Sectoral Trends in World Development and the Shift towards Services", *International Labour Review* vol.134, no.2: 205-226

Winston, G.C.
— (1971) "Capital Utilization in Economic Development", *Economic Journal* vol.81, no.3: 36-60
— (1974) "The Theory of Capital Utilization and Idleness", *Journal of Economic Literature* vol.12, no.4: 1301-1320
— and McCoy, T.O., (1974) "Investment and the Optimal Idleness of Capital", *Review of Economic Studies* vol.41, no.3: 110-125

Wolff, E.N., (1994) "Technology Capital Accumulation, and Long-Run Growth" in Fagerberg, J., Verspagen, B., and Tunzelmann, N., (eds) The Dynamics of Technology, Trade and Growth (Published by Edward Elgar).

Wong, F.C.
— (1994) "Patterns of Labour Productivity Growth and Employment Shift in the Singapore Manufacturing Industries", Working Paper Series no:4, Department of Economics and Statistics, National University of Singapore.
— (1995) Discussion on Michael Sarah's "Growth in East Asia: What We Can and What We Cannot Infer From It" in Anderson (et al., eds 1995).
— and Gan W.B., (1994) "Total Factor Productivity Growth in the Singapore Manufacturing Industries During the 1980s", *Journal of Asian Economics* vol.5, no.2: 177-196
— and Tok, Y.W., (1994) "Technical Efficiency and Total Factor Productivity Growth in the Singapore Manufacturing Industries during 1980s", Paper Presented at the 2nd International Conference on Asia-Pacific Economic Modelling, Sydney, 24-26 Aug 94
— and Gan W.B., (1995) "Technical Efficiency and Productivity Growth in Singapore's Manufacturing Industries" (Mimeo).

Wong, T.C., (1997) "Workforce Productivity Enhancement and Technological Upgrading in Singapore", *ASEAN Economic Bulletin* vol.14, no.1: 46-56

World Bank,
— World Development Report, various issues.
— (1993) The East Asian Miracle: Economic Growth and Public Policy, (New York, Oxford University Press).
— (1996) The East Asian Miracle and Information Technology : Strategic Management of Technological Learning (World Discussion Paper by Hanna, N., Boyson S., and Gunaratne, S.).

World Competitiveness Report 1990, Jointly prepared by the International Institute for

Management Development and the World Economic Forum, Switzerland.

Wren-Lewis, S., (1986) "An Econometric Model of UK Manufacturing Employment using Survey Data on Expected Output", *Journal of Applied Econometrics* vol.1: 297-316

Wright Mills, C., (1951) White Collar, the American Middle Classes, (Oxford University Press).

Wu, D.M., (1983) "Tests of Causality, Predeterminedness and Exogeneity", *International Economic Review* vol. 24, no.3: 784-795

Wu, Yanrui (1997) "Productivity Growth, Catch-Up and Convergence in China's Reforming Economy", (Mimeo), Paper Presented at the Australian National University on 15 April 1997

Yotopoulos, P.A, and Nugent, J.B., (1976) Economics of Development (Harper and Row, New York).

Young, A.,
— (1992) "A Tale of Two Cities: Factor Accumulation and Technical Change in Hong Kong and Singapore", *National Bureau of Economics Research*, Macroeconomics Annual 1992 (Cambridge):13-54
— (1994) "Lessons from the East Asian NICs: A Contrarian View", *European Economic Review* vol.38, no.3-4 : 964-73
— (1995) "Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Growth Experience", *Quarterly Journal of Economics* vol. 110, no.3: 641-80