#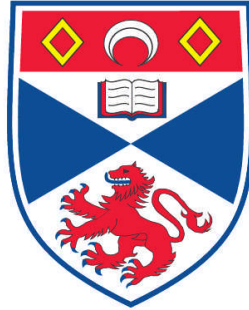 PRODUCTIVITY TRENDS IN THE THAI MANUFACTURING SECTOR: THE PRE- AND POST-CRISIS EVIDENCE RELATING TO THE 1997 ECONOMIC CRISIS

Suwannee Arunsawadiwong

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PRODUCTIVITY TRENDS IN THE THAI MANUFACTURING SECTOR: THE PRE- AND POST-CRISIS EVIDENCE RELATING TO THE 1997 ECONOMIC CRISIS

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Productivity Trends in the Thai Manufacturing Sector: The Pre- and Post-Crisis Evidence Relating to the 1997 Economic Crisis

by

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Abstract

The principal aim of this thesis is to examine the validity of the claim that low productivity led to a decline in Thailand's competitiveness, and hence, to the 1997 economic crisis. For a decade from 1985 to 1995, Thailand was one of the world's fastest-growing economies with an average real annual GDP growth of 8.4 percent. However, such growth was criticized as being simply the result of large inward investment and rapid accumulation of capital, leading to very little productivity growth, and therefore, being unsustainable in the long run. Worse still, the later surges of capital inflows came in mainly as speculative stashes, instead of as foreign direct investments in production and businesses. Hence, as predicted, the boom finally came to a sudden end in 1997. The economic growth statistics recorded severe contraction, financial market collapsed, the currency was battered, domestic demand slumped, severe excess capacity was experienced, employment deteriorated, personal and corporate income diminished, inflation and the cost of living mounted, and finally, poverty surged.

This thesis utilizes a stochastic production frontier approach to verify the claim that low productivity lessened Thailand's competitiveness. This approach, unlike the standard econometric approach, allows the existence of technical inefficiency in the production process. It also, unlike other non-parametric approaches, recognizes that such inefficiency can sometimes occur as a result of external factors that are out of the firms' direct control, such as statistical errors and random shocks. The period covered in this thesis is from 1990 to 2002. This is divided into 2 sub-periods, i.e. the pre-crisis period (1990 – 1996) and the post-crisis period (1997 – 2002). The estimation results indicate a structural shift in the Thai manufacturing sector, from being labour intensive in the pre-crisis period to being capital intensive in the post-crisis period. The productivity level also improved post-crisis, as compared to the pre-crisis level, and is shown to follow an increasing trend. The low productive investment level in the pre-crisis period is identified as having led to the decline in the manufacturing sector's efficiency. The thesis concludes that this low productivity level did indeed lead to the decline in Thailand's competitiveness, and hence, to the decline of export growth, which was at that time the main source of Thailand's economic growth; in turn, playing an important role in precipitating the 1997 economic crisis.

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Acknowledgements

My life during the past 4 years has been one big ride of a roller coaster. I have experienced so many happy moments, yet so many tears. People say *where there is a will, there is a way*, and this doctoral thesis is no exception. It has required a lot of hard work, days of long hours, and numerous sleepless nights. However, the result is worthwhile. As I am finishing this thesis, I looked back at those days, and my gratitude is extending to so many people that have contributed professionally, as well as personally, to this study and to me over these past few years.

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Chapter 1 – Introduction

1.1 Aims of the Thesis

The principal aim of this thesis is to examine the validity of the claim (Chainuvati *et al.* (1999), Laplamwanit (1999), Krugman (2001) and Kraipornsak (2002)) that low productivity has led to a decline in Thailand's competitiveness, and hence, to economic crisis in 1997. Figure 1.1 (overleaf) is a simple sketch of a time-line of this 1997 crisis. It gives a broad diagnosis of the genesis of the crisis, which started with the establishment of the Bangkok International Banking Facility (BIBF) in 1993 that allowed private financial institutions to engage freely in capital account transactions. Stimulated by the outsourcing of manufacturing activity to Thailand from Japan and the Asian Tigers (i.e. Taiwan, Hong Kong, South Korea, and Singapore) in the mid 1990s, massive capital inflows started to flood the country. Unfortunately, the later surges of capital inflow were largely speculative[1], and local investors too were engaging in speculative investment[2], rather than investment in the more productive areas of manufacturing. Therefore, Thailand's productivity was seen to plummet (Tinakorn and Sussangkarn (1996 and 1998)), leading to sharp decline in its competitiveness. By 1997, the economic situation had clearly deteriorated, and the currency was heavily attacked by the currency speculators. Eventually, Thailand had to abandon its fixed exchange rate regime on July 2nd 1997, which triggered the worst financial and economic crisis the country had ever experienced. As a result of this crisis, 58 financial institutions and 4 commercial banks were suspended, leading to an economy-wide collapse of businesses. (A more detailed account of the crisis will be examined in later chapters.)

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[1] Phongpaichit and Baker, (1998)
[2] Vines and Warr, (2003)

Figure 1.1: Time line of the 1997 Economic Crisis (1)
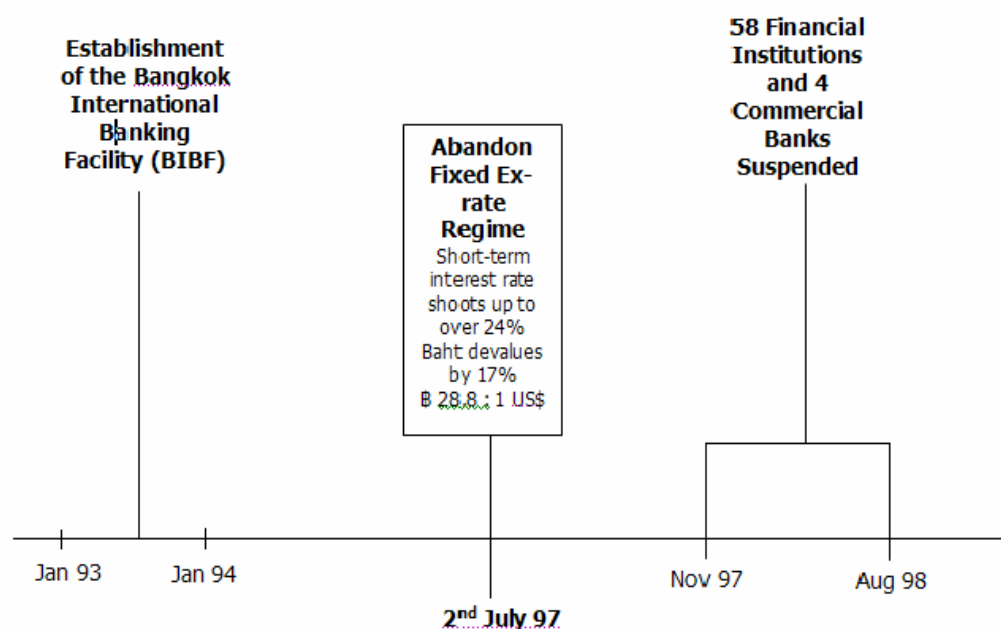
Many analyses (World Bank Report (1993), Marti (1996), Tinakorn and Sussangkarn (1996 and 1998), Collins and Bosworth (1997), Sarel (1997), and Dollar *et al.* (1998)) have been carried out to estimate the pre-crisis productivity growth of Thailand. However, the results of these studies have been lacking in consistency. The empirical studies on the sources of growth of Thailand have created conflicting opinions about the two sources of growth, viz. factor accumulation and productivity growth. While some studies (Marti (1996), Collins and Bosworth (1997), Sarel (1997), and Dollar *et al.* (1998)) have argued that high productivity growth was partly caused by the openness of the Thai economy, many (Tinakorn and Sussangkarn (1996 and 1998), Krugman (2001)) have counter-argued that it was capital accumulation that was the main driving force for such growth. Tinakorn and Sussangkarn (1998) found that after adjusting for the quality of labour, in the period from 1980 to 1995, only 16 percent of the economic growth of Thailand came from the growth in total factor productivity, while the remaining 84 percent came from increases in the factor inputs used. This resulted in conflict with the findings of Sarel (1997), who claimed that 39

percent of the total economic growth in the period from 1978 to 1996 was the result of total factor productivity growth. One of the explanations for such differences could have been the result of the different methodologies used in these analyses.

Most of the studies concerned with the measurement of Thai productivity employed the growth accounting approach (Tinakorn and Sussangkarn (1996, 1998), Sarel (1997)), or in some few cases, the econometric approach (Marti (1996), Sarel (1997). However, both approaches are subjected to some critical drawbacks. The growth accounting approach is usually based on the strong assumptions of constant return to scales and perfectly competitive market, which are often considered too strong for the case of developing countries like Thailand. Likewise, the traditional econometric approach, although it is able to relax these assumptions, is also subject to the limitation of not being able to allow for technical inefficiency in its estimation. This, therefore, implies that the only source of deviation from the estimated production function is caused by statistical noise. Such an assumption might, again, be considered as too strong for the case of Thailand, in particular during the pre-crisis period, in which technical inefficiency was thought to be high and persistent.

Hence, the use of an alternative approach to productivity measurement, which has not been used before in the case of Thailand, is proposed in this thesis. A parametric distance function based approach is proposed, namely the techniques of stochastic frontier estimation (Pitt and Lee (1981), Battese, Coelli, and Colby (1989), Battese and Coelli (1992). The stochastic production frontier is superior to the growth accounting approach in that it allows for greater flexibility in specifying the production technology. It permits the investigation of technical change other than that implied by the Hicks-neutral formulation, on which most growth accounting is based. Also, non-competitive pricing behaviour, non-constant returns, and factor-augmenting technical change can all be incorporated into this parametric distance function approach. This approach is also superior to the traditional econometric approach, in that it allows the technical inefficiency components to be included

in the model. Hence, analyses following this approach are no longer subjected by the common, but scarcely tenable assumptions of the econometric approach, in which producers are always operating on the boundary of their production functions, and technical inefficiencies in their production processes never exists. In brief, the level of inefficiency can be the focus of attention under this new 'frontier' approach.

Another equally, or even more, important objective of this thesis is to measure the actual productivity level in the post-crisis period. Then the comparison between the pre- and post-crisis productivity could suggest the nature and magnitude of adjustments made by the manufacturing sector after the event of the crisis. It can also reveal evidence on whether or not the surviving manufacturers had learnt from the crisis, and had made efforts to improve their efficiency. It could also provide an indication of whether or not the country's authority had worked out the problems taking place in the Thai manufacturing sector and had, as a result, taken appropriate action to remedy such problems. Moreover, in this case it is possible to examine whether a low and slowly improving productivity level was indeed the root problem faced by the manufacturing sector in the mid-1990s. We could then justify those claims mentioned previously that the rapid growth of Thailand was simply a result of factor accumulation, not productivity growth, and therefore could not be sustained in the long run. Hence, a possible preventative measure for avoiding such crisis in the future would be to focus the policy of economic development not just on the nominal growth rate, but on the improvement of the productivity level.

One important concern when making comparisons between the results obtained from two separated sets of productivity measurements is that productivity measurement can be easily influenced by many underlying factors (such as the source of data, and the methodology used in the measurement). Therefore, although there have been a number of productivity measurements made of the Thai economy (both pre- and post-crisis), none could be considered suitable for the purposes of this thesis. Therefore, the final aim of this

thesis is, then, to provide new measurements of productivity/efficiency[3] levels that are more suitable for making objective pre- and post-crisis comparisons. This is to be done by, firstly, the employment of the data from the same source for both periods so as to minimize bias arising from any discrepancy in method of data collection. Then, these two sets of data will pass through the same process and criteria of model selection. Such steps are aimed to help minimize the biases that might occur from the measurement sensitivity, so that the comparison results are more robust.

1.2 Research Questions

The measurement of the pre-crisis productivity level of Thai manufacturing sector is, therefore, an important means of assessing the claim (Chainuvati *et al.* (1999), Laplamwanit (1999), Krugman (2001) and Kraipornsak (2002)) that low productivity was the main reason behind the decline in Thailand's competitiveness, and hence, caused the 1997 crisis. Furthermore, the measurement of the post crisis productivity level is, as well, essential. The comparison between the pre- and post-crisis productivity level could imply improvements that the sector might have achieved since the event of the crisis. It might also be able to reveal some evidences on whether or not the surviving manufacturers had learnt from the crisis and improved their efficiency, as well as, whether or not the country's authority had teased out the problems endemic to Thai manufacturing and had provided them with appropriated policy action.

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[3]Efficiency is a closely related concept to productivity. They are differed in that the term *productivity* refers the ratio that evaluates relationship between inputs and outputs. It is a measurement of the level of production in an absolute term (e.g. how many units of outputs can be produced by a certain set of inputs). On the other hand, the term *efficiency* is a relative concept. It evaluates the degree of acheivement of the maximum productivity at a certain input level. In the case of this thesis, efficiency refers to an index that evaluates the level of productivity attainable to a maximum compared production level defined by a frontier production function. Nevertheless, as productivity and efficiency always move in the same direction, they are often a good proxy for each other.

Unfortunately, although there have been numerous studies on the productivity of Thailand, (i.e. World Bank Report (1993), Marti (1996), Tinakorn and Sussangkarn (1996 and 1998), Collins and Bosworth (1997), Sarel (1997), and Dollar *et al.* (1998), more details on these studies will be discussed in Chapter 2, Section 2.3), most of them only cover the pre-crisis period. And although the Thailand Productivity Institute has been publishing a monthly productivity index since 1995, these indexes are calculated using the growth accounting approach which although it is generally reliable, is still subject to the heavily criticized assumptions of constant returns to scale and a perfectly competitive environment (this will also be discussed in Chapter 2, Section 2.3). In addition, the measurement of productivity can be easily influenced by variations in the approaches of calculation, purposes of study, and sources of data[4]. Hence, results of two separate forms of measurement should not be used for comparison purposes.

Therefore, the objective of this thesis (as mentioned in the last section) is to provide measures of both pre- and post-crisis productivity/efficiency levels that are suitable for statistical comparison. This is to be done, firstly, by the employment of data that come from the same sources (i.e. the Annual Manufacturing Industrial Survey published by the National Statistical Office) for both periods of studies. Then, these two sets of data will pass through the same processing and evaluation criteria of model selection (details in Chapter 8). Such steps are aimed to help minimize the biases that might occur from the sensitivity of the method measurement to data sources and evaluation criteria, so that the resulting comparisons are more robust. In doing so, an attempt will be made to answer three sets of main research questions. These are:

1. What was the productivity/efficiency level of the pre-crisis manufacturing sector? Is it true that the sector had low efficiency, and its productivity level had not been improved throughout the period, despite the growing competition from the newly industrialized countries such as China and Vietnam?

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[4] Dhanani and Scholtrs, (2002),

2. What was the productivity/efficiency level of the manufacturing sector in the post-crisis period? Did it improve, or did it deteriorate during the 5-year period of study?

3. What are the possible explanations for the difference in pre- and post-crisis productivity level? Did capital investment play a significant role in accounting for such difference?

In addition, in order to facilitate the pursuit of answers to these research questions, several sets of hypotheses (H_0) and their alternatives (H_a) are set up including (in narrative, rather than statistical, form):

- H_o: The productivity/efficiency level in the pre-crisis period was reasonably high, as the level of capital investment during that period was also high. Therefore, the deterioration of competitiveness, and hence the 1997 economic crisis, were not caused by low productivity productivity/efficiency levels.

  H_a: The productivity/efficiency level in the pre-crisis period was low, as investment made during that period were concentrated mainly in the unproductive areas. Therefore, the deterioration of competitiveness, and hence the 1997 economic crisis, were indeed caused by low productivity/efficiency level.

- H_o: The productivity/efficiency level in the post-crisis period was lower, when compared to the pre-crisis period.

  H_a: The productivity/efficiency level in the post-crisis period was higher, when compared to the pre-crisis period.

- H_o: The deterioration in the post-crisis productivity/efficiency level was a result of the reduction in the amount of capital investment, due to the problem of the domestic credit crunch during 1997 and 1998.

H_a: The improvement in the post-crisis productivity/efficiency level was partly a result of the increase in the amount of productive capital investment, despite the decline in the total amount of capital investment.

1.3 Thesis Claims

This thesis has aimed to push forward to a significant extent the research area concerning the productivity of Thailand, as well as research on the effects of the 1997 economic crisis. It claims to provide several new contributions to research in these fields. Firstly, this thesis is the first empirical study that provides rigorous measurement of both the pre- and post-crisis productivity/efficiency level, estimated from the same source of data, and through use of the same process of model selection. Therefore, the pre- and post-crisis findings can be used confidently for comparison across periods, knowing that precautions have been taken to limit measurement problems.

Secondly, it opens up a new area of empirical research for Thai productivity measurement, by introducing the use of the parametric distance function based approach. This had never been employed before on Thai data. Most of the existing works on productivity measurements based on the data of Thailand have employed the growth accounting approach (Tinakorn and Sussangkarn (1996, 1998), Sarel (1997)), or in some few cases, the econometric approach (Marti (1996), Sarel (1997). However, as the growth accounting approach has suffered from the strong assumptions of constant return to scales and perfectly competitive markets, productivity level, measured by such approach, might not reveal an accurate empirical representation of the productivity level for Thai economy. Likewise, the traditional econometric approach, although it is able to relax these assumptions, is also subject to a severe problem of not being able to include the technical inefficiency components in the standard models used for such analysis. Therefore, this

motivated the use of the stochastic production frontier approach in this thesis for such estimation. This approach is expected to fulfill the main objective of this thesis, by providing reliable and unbiased measurements of productivity level for the comparison between the pre- and post-crisis periods.

Additionally, the fitting of the stochastic frontier production function to the pre- and post- crisis data will not merely provide satisfactory productivity/efficiency measurements, but will also allow other parameters of the production technology to be explored. Embellishments like the cost-of-adjustment parameters can also be incorporated into the analysis to help explain the residual. In addition, the underlying structure of the sector (including the output elasticities of capital and labour) can also be revealed.

Consequently, the comparison between the pre- and post-crisis production frontier have enabled the examination of the effects this crisis had on the Thai manufacturing sector, i.e. whether or not the crisis had any effect on the elasticities of the capital and labour inputs. Also, by comparing the efficiency estimates of the two periods, it discloses the adjustments that have occurred in the post crisis period, which could be related to the manufacturers' responses toward the economic downturn, the government's economic stimulus packages, the IMF's recovering measures, as well as the economy's self-adjustment process (such as the shakeout).

Finally, if the hypothesis stated previously about the problem of low productivity level and lack of improvement in the productivity is true, one important underlying problem of the economic growth process of the early 1990s (specifically, the issue of over-investment in the unproductive sectors) can then be explored. By employing the technical efficiency effects model (Battese and Coelli (1995)) in Chapter 9, it is shown how to validate the claim that the pre-crisis manufacturing sector of Thailand was hurt by the lack of investment in productive sectors, thus leading to decline in the sector's efficiency level. This therefore implies that the best possible preventative measure for avoiding a future crisis should be carried out by focusing on economic development; not just on the growth rate,

but also on the improvement of the productivity level. Continuity of economic growth that relies solely on the growth of input factors, without the improvement in the level of productivity, is impossible to sustain in the long-run: either the input resources would eventually run out; or the economy would ultimately run into diminishing returns[5]. Hence, in order to generate future sustainable growth, it is important that the relevant authorities focus on economic development, not only on the nominal growth rate, but also on the quality of the growth, i.e. the improvement of the productivity, technical progress, as well as, the efficiency level. Therefore, policy recommendations should be based on this argument.

1.4 Research Findings

The results from the analyses in this thesis reveal that the pre-crisis manufacturing sector exhibited a relatively low productivity/efficiency level. Also, the sector experienced very low, and, in the worst case, no improvement in technical progress at all, during this 7-year period from 1990 to 1996. These results were based on the fact that during the early 1990s, Thailand underwent a period of over-investment in the unproductive sectors (such as the real estate and the stock market), and that therefore the manufacturing sector was suffering from a lack of productive expansion. However, the efficiency level in the post-crisis period improved. Several explanations can be used to justify this finding. Firstly, immediately post-crisis, the manufacturing sector had to go through the shakeout process, in the face of wage rigidity. With the substantial reduction in demand, downward pressures were placed greatly on product price levels; therefore, firms were forced to compete with each other by lowering prices[6]. Firms that had higher production costs, i.e. were less

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[5] Krugman, (1994)

[6] Utterback and Suárez, (1993)

efficient, would be pushed out of the business. This shakeout process continued until all the less productive firms were forced to exit the industry[7], thus leaving the sector with an improved level of productivity.

Secondly, the reformation of the financial market structure imposed by the IMF, as one of the conditions for receiving the rescue package, had also benefited the Thai economy (in particular the manufacturing sector) greatly. Prior to the crisis, financial institutions had the tendency to make decision on loans based on the collateral (such as lands) provided by borrowers[8]. However, in the post-crisis period, real estate prices declined immensely, and therefore, banks turned to investment projects as an alternative criterion for their decision makings[9]. As a result, loans were made only to those most productive investments, viz. those that expected the highest rate of returns. This raised the chances of good manufacturers getting access to loans, as compared to the pre-crisis period.

Finally, after the crisis, the Thai government had implemented several industrial measures which concentrated on solving the structural problems, as well as enhancing productivity, in the manufacturing sector. These measures included the establishment of a number of industrial development institutes, and the introduction of two sizeable economic stimulus packages, one in March 1999 and another in February 2000. They were aimed at one key goal, which was to enhance the long-term competitiveness and efficiency of the domestic industries[10], especially among the small and medium size enterprises, which accounted for 90 percent of the total number of establishments in the country. Such measures were considered to be very important, as the small and medium size firms in Thailand were generally facing common problems of the lack of sufficient funds and of the ability to carry out useful research and development. Soft loans, as well as taxes and tariffs reduction measures, were implemented in order to create incentives for private investment

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[7] Jovanovic and MacDonald, (1994)
[8] Warr and Nidhiprabha, (1996)
[9] Vines and Warr, (2003)
[10] Poapongsakorn and Tangkitvanich, (2000)

in some selective areas. Although not all measures were successful, as a whole, these policies should have, nevertheless, contributed to the improvement in efficiency in the post-crisis Thai manufacturing sector.

Moreover, the results also show that there was a switch of the relative importance of the roles of capital and labour between the pre- and post-crisis periods. In the pre-crisis period, the Thai manufacturing sector was very labour intensive. However, the analysis of the post-crisis data indicated that there was a structural shift, away from being labour intensive, towards being capital intensive. Two additional arguments can be used to explain this finding. The first is the effect of real wage rigidity in the Thai labour market. Given the severity of the crisis, the post-crisis real wage level had not declined as much as one would have expected[11]. Adjustment in the labour market had been largely channelled through quantity, rather than price adjustment. Thus the number of working hours in the manufacturing sector declined rather considerably (including the effect of more prevalent part time working). Hence, the relative dominance of the capital inputs became more evident, and resulted in the structural shift towards higher capital intensity.

In addition, this structural shift could also be explained by the sharp decline in the post-crisis interest rates. After the easing of the monetary measures in August 1998, domestic interest rates declined radically. Combined with rigid real wages, the relative price between capital and labour changed considerably, and thus, labour was substituted by the higher use of capital in many production processes. Unsurprisingly, the manufacturing sector demonstrated the trend toward developing into a capital intensive sector.

1.5 Guides to Contents

This thesis explores the productivity trend between the pre- and post 1997 economic crisis

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[11] Behrman, Deolalikar, and Tinakorn, (2001)

in Thai manufacturing sector in its empirical aspect. Chapter 2 will explore the background to the research. It raises the issue of the decline in productivity as being the main factor leading to the crisis. This chapter also reviews some important empirical works on productivity and growth of the Thai economy. Chapter 3 will provide general background knowledge of the Thai economy. It starts from the period of laying foundation in the 1950s, and ends at the period of economic bubble in the 1990s. This chapter is included in this thesis as it is believed that in order to be able to develop a good understanding of the 1997 economic crisis, it is important not to only comprehend the immediate genesis of the crisis, but also the more fundamental question as to what had gone wrong with the growth process leading to the crisis. The detailed accounts of adjustments in economic policies and political environments in the last five decades will be broken up into three sub-periods, including the period of foundation laying (1950 – 1973), the period of macroeconomic uncertainty, hardship, and turbulence (1974 – 1985), and the decade of extraordinarily high growth, speculation, and bubble (1986 – 1996).

Chapter 4 is devoted to creating a better understanding of the anatomy of the 1997 economic crisis. It discusses the five main causes of the crisis including the slowdown of export growth, mistakes in financial policies, asymmetric information and over-investment, attacks on the currency, and responses to the currency devaluation. The time line indicating the important events taking place during the periods before and after crisis is also presented in this chapter. Then, the impacts of the crisis are examined. They are classified into two areas of consideration: economic growth, and employment. Due to the structure of the Thai economy, the analysis of the employment factor is not only conducted through consideration of the employment and unemployment rate, but also through the underemployment rate in which the definition of the underemployed person is the person who is able to work, and is willing to work, but is working less than 20 hours per week during the week of the survey.

Chapter 5 provides an overview of the conceptual and methodological issues in the topic of productivity. Attention is given to the concept of productivity, its different types, and its approaches in measurement. Productivity will be defined here, at the simplest level, as the ratio of a certain output of goods and services produced to a given a set of inputs. The measurement of productivity is classified in several forms – the single and multi/total factor productivity, as well as the gross output and the value-added productivity, with each of them having their own strengths and weaknesses. Moreover, the chapter will also indicate that there are several approaches in the measurement of productivity, both parametric and non-parametric. They are summarized by four main lines of approach including the growth accounting, the index number, the econometric, and the distance function based approaches. Unsurprisingly, each of them also has its advantages and drawbacks, with one approach being more suitable for some particular objectives. The chapter concludes by noting that the choices between types of measurement, as well as between different measurement approaches, are always dependent on the purpose of the studies, and in many cases, on the availability of the data.

Chapter 6 employs an Exploratory Data Analysis (EDA) approach to examining the underlying structure of the Thai manufacturing sector. The EDA approach was first introduced by John Tukey in 1977. It is an approach for data analysis that is concerned with reviewing, communicating, and using data in which there is a low level of knowledge about its caused system. Following the EDA technique, it is important that before any in-depth analysis on the productivity and efficiency of the Thai manufacturing sector is conducted, a preliminary analysis aiming at the revelation of the underlying structure of this data set is first carried out. According to EDA, it is important to allow the data itself to reveal its underlying structure without making too many assumptions, so that the results would not be contaminated by these assumptions, and hence, could avoid criticisms regarding the neutrality of the findings in the more refined analyses to be conducted later on. This chapter also provides details on the data set that will be used through out the thesis.

Chapter 7 and 8 examine the stochastic frontier production function method in detail. Their concerns are to provide answers to the main research questions posted by the thesis. Chapter 7 starts by examining the further technical development of the production frontier following the more general literature review presented in Chapter 5. This is to begin with the theoretical development of the early literature concerning the frontier estimation proposed by Farrell (1957), which has subsequently been developed into the deterministic frontier, then further extended into the stochastic frontier, where statistical 'noise' is also included in the model construction. The extension from the cross sectional stochastic frontier to the panel data frontier, as well as the extension to the time-invariant panel data frontier to the time varying panel data frontier, are also examined. Then, chapter 8 carries out the empirical analysis of the productivity of Thai manufacturing sector in the pre- and post-crisis periods. Some possible stochastic frontier models are selected and then tested with the Thai data in order to select the most appropriate models for representing the data set of these two time periods. At the same time, the computer software which is used to carry out the frontier estimations are reviewed, and compared. The software being chosen for the estimation in this thesis is called FRONTIER 4.1 developed by Tim Coelli, University of New England, in 1994.

Chapter 9 is concerned with an important issue carried over from Chapter 8, viz. that the post-crisis efficiency level in Thai manufacturing sector improved significantly, when compared to the pre-crisis level; and part of this might have resulted from the higher post-crisis investment in productive capital. Chapter 8 indicates that there exist pre- and post-crisis structural shifts in the manufacturing sector, as well as the significant improvements in the post-crisis efficiency. This suggests that there are some specific causes which affect such variations. Chapter 9 examines the relationship between capital investments and technical efficiency in the Thai manufacturing sector, based on the Battese and Coelli (1995) model, in which technical inefficiency is linked with the variables that could explain the existence of such inefficiency. The post-crisis data on three categories of capital

investments (namely, the increase of investment in land, machinery, and office appliance) are used as explanatory variables. A negative relationship between the increase in a particular type of capital investment and the inefficiency level would imply that the improvement in the post-crisis efficiency level is made possible by the increase in that category of capital investment. It is shown in this chapter that the increase in productive capital investment, such as in machinery and office appliances, has indeed had a negative effect on the inefficiency term, thus verifying the claim made in Chapter 8 that the improvement in the efficiency level was partly a result of the increase in investment in more productive capital.

Chapter 10 elaborates the main findings and implications of the thesis. Furthermore, a summary of contributions, policy recommendations, as well as future research suggestions are also included.

Chapter 2 – Background to Research

"Unsustainable situations usually go on longer than most economists think possible. But they always end, and when they do, it's often painful."

Paul Krugman

2.1 Introduction

This chapter is aimed at explaining the background to this research, and therefore providing rationale for arguments, as well as analyses, which will be discussed later on in the thesis. Although the relationship between the production function and productivity has been analysed since as early as the 1950s (e.g. with the work of Solow (1957)), in Asia, it was not until the 1990s that the link between production and productivity growth has started to receive greater attention from economists and policy makers. This is partly due to the work of Alwyn Young (1992, 1994) and Paul Krugman (1994), who alleged that the so-called 'miracle' economic growth in Asia was driven merely by the accumulation of the inputs in the production process, rather than by increases in productivity. In other word, they (and, in particular, Krugman) believed that the newly industrialized countries of Asia have achieved rapid growth in large part through a remarkable mobilization of resources. The Asian economic miracle was largely attributable to an increase in the quantity, but not the quality, of the factors of production. Therefore, once one accounted for the role of rapidly growing inputs in these countries' growth, one found very little left to explain.

For a decade from 1985 to 1995, according to the World Development Report (1997), Thailand was the world's fastest-growing economy with the average real annual GDP growth of 8.4 percent. However, Thailand had also been criticized (Krugman (2001)) that such growth was simply the result of large inward investments and rapid accumulation of capital, with very little productivity growth. The underlying reason for this rapid growth

had its foundation in the Japanese economy, which in the effort to overcome the adverse effects of the second oil shock, had held down its exchange rate, and concentrated on the export market, in order to balance out the domestic economic downturn. In doing so, Japan managed to build up large trade surpluses against its trading partners, in particular the U.S. Unfortunately, such success had instigated the 1985 Plaza Accords, in which major currencies were realigned, and Japan was pressurized into revaluating (i.e. appreciating) its currency. Consequently, in 4 years after the Accords, the yen was strengthened by 89 percent against the US dollar, resulting in the sharp rise of manufacturing costs, and hence affecting its export greatly.

The Japanese manufacturers, however, found their way out of the trouble by the outsourcing of manufacturing activity away from the country. In 1985 a famous slogan for Japanese firms was 'escape the value of the yen!' Many firms moved their manufacturing directly to the US and European countries, where they marketed the majority of their products. Others searched around for low-cost site in the Southeast Asia (i.e. Thailand, Malaysia, and Indonesia), where the supply of labour, as well as natural resources, were still abundant. Massive rush of manufacturing industries relocation started from then, which was made possible by two other factors: the liberalization of the Japanese financial markets and the government assistance in relocation for enhanced markets and lower production costs.

Later in the late 1980s, the early Asian industrialized countries (i.e. Taiwan, Hong Kong, South Korea, and Singapore) have also followed the pattern leaded by Japan, as they also faced rapid expansion of their export-oriented economies. Similar to Japan, their current accounts have also exhibited large amount of surpluses, which have led to the appreciation of their currencies. Furthermore, the rapid growth of the economy had put much pressure on their labour supply, and hence led to the labour shortage situation as well as the rising production costs. Pressures were put on them to reduce these growing costs; therefore, they followed the Japanese in outsourcing their productions to the Southeast Asian countries. Consequently, the Thai economy benefited from such relocation, and the

process of developing into the light and medium, labour-intensive industrial economy kicked off. The products Thailand specialized at, during that time, were the production of garment, footwear, consumer electrics, and automotive.

While the increase in foreign investment was impressive, the upsurge in local investment was far greater. Foreign investment accounted for only one-eighth of the increased in the total investment between 1985 and 1990 (Phongpaichit and Baker (1998)). Thai export products were no longer limited to textiles and electronics, which were the principal migrants' products from Japan and the Asian Tigers (i.e. Taiwan, Hong Kong, South Korea, and Singapore), but also included jewellery, leather goods, wood products, processed foods, computer components, and auto parts. In a decade from 1985 to 1995, manufactured exports multiplied twelve times and drove up total exports by seven times[1]. Such growth in export was so impressive that in 1993, the World Bank highlighted Thailand as a case which 'shows how openness towards foreign investment, combined with export orientation, can contribute to a dynamic export-push strategy'[2]. However, unlike in the period from 1986 to 1992, the later surges of capital inflows were no longer directed as foreign direct investments in productions and businesses. Most of them, instead, came as portfolio funds, merchant banking loans, and speculative stashes – forms of capital which could move in and out at the speed of an electronic transfer. It was simply for the reason that Thailand, at that time, seemed particularly attractive for such speculative investments. The interest rates were high. The currency was tightly pegged with other major currencies and, therefore, removed any currency risk. Moreover, the economy was growing at one of the most favourable speeds ever seen in history (with the average GDP growth of 9.52 percent per annum). As a result, a bright future was predicted for the country. In early 1995, *The Economist* projected that Thailand would become the world's eighth largest economy by 2020. And even on the eve of the economic downturn in 1997, the IMF was

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[1] World Development Report, (1997)
[2] World Bank Report, (1993)

still praising Thailand as having 'remarkable economic performance' and 'consistent record of sound macroeconomic performance'.

Figure 2.1: Time line of the 1997 Economic Crisis (2)
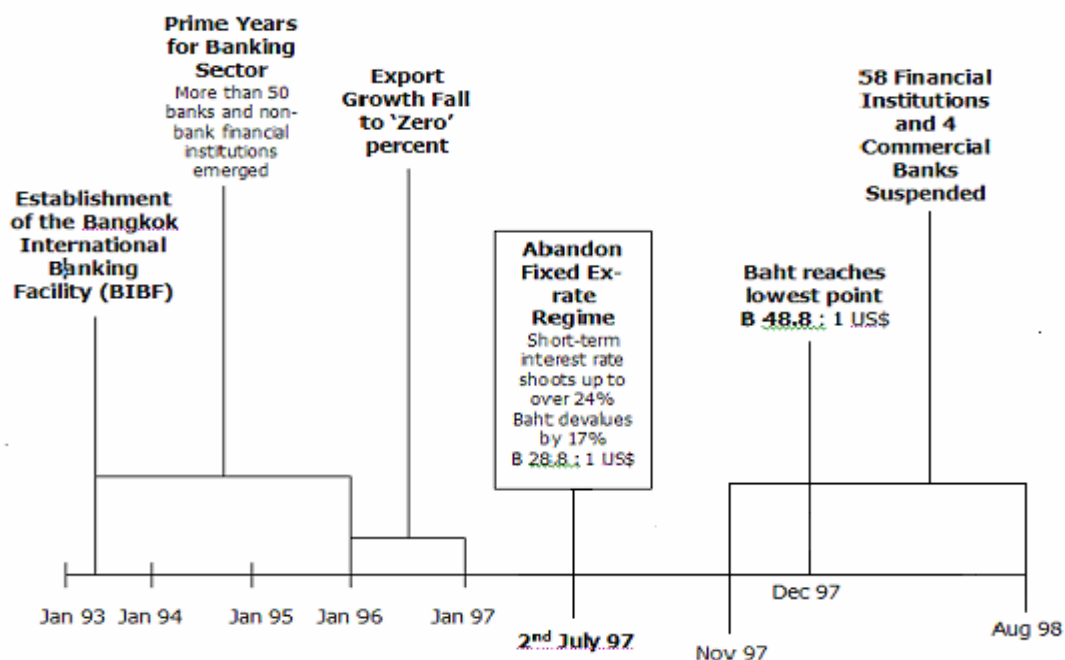
2.2 Genesis to the Crisis

Against the above background, the local financial industry, as well as local firms, gorged on the inflows, as they could not resist the temptation to leverage with loans that appeared so cheap. The situation was worsened when the government at that time failed to control the amount of inflows, and worst of all, failed to direct them towards productive uses. As shown in Figure 2.1, these surges of capital inflow were facilitated by the establishment of the Bangkok International Banking Facility (BIBF) in 1993, with its role to facilitate the flow of foreign currency current account transaction. Foreign capital inflow no longer needed approval from the Bank of Thailand (BOT). Financial institutes with the BIBF license were

allowed to carry out foreign currency account transactions freely. With a large number of private financial institution directly involved in the capital account transactions, it had become much more difficult for the BOT to monitor and regulate such activities.

Moreover, this relaxation of the foreign exchange control combined with the country's fixed exchange rate regime had resulted in a massive wave of foreign capital inflow into the country, following the virtually risk-free currency environment[3]. Financial institutions saw the profit opportunities of borrowing at a much cheaper rate offshore, and then lending them at higher domestic rates. The average discrepancy between the deposit and the lending rate was as high as 4 percentage points (4 times bigger than the spread of less than 1 percent in the banking system of many developed economies). The period from 1993 to 1996 had become the prime years for Thai banking sectors; Thai banks were ranked among the world's most profitable banks. As a result, more than 50 banks and non-bank financial institutions were established during that period. In order to compete with each other, financial institutions lowered their requirements for loans, and started to engage in very risky lending behaviours.

With easy loans, local entrepreneurs plunged into over-ambitious investment schemes, such as gigantic real estate projects. As Pongpaichit and Baker (1998) put it, 'too much was squandered on condos for housing mosquitoes.' Such massive inflows threw the Thai economy off balance, making investors (both domestic and foreign) overlook the fact that Thailand must grow through trade, not through money games and concrete fantasies[4].

Therefore, it was no surprise that the boom finally came to an end in 1996/1997. Only few were mesmerized into believing that Thailand would escape the business cycle, although unfortunately, those few seemed to include quite a large number of Thai entrepreneurs. Many had predicted that Thailand's engine of export growth would falter, because of rising wages, increased competition, and strains on infrastructure and human

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[3] Doner and Ramsay, (1999)
[4] Pongpaichit and Baker (1998)

resources. Hence, the downturn was very much expected. However, it was the severity of it that was astounding. Figure 2.1 shows that in 1996, export growth slumped from over 20 percent to 'zero' percent, as well as the stock market had lost two-thirds of its value. By 1997, the economic growth had recorded contraction with the growth rate falling lower than in any year since the country's reasonable statistics have been compiled. The currency was battered by speculators into a sharp depreciation; and finally on July 2nd, the fixed exchange rate regime had to be abandoned. The currency was severely devalued, from around 25 Baht per US dollar to its lowest value of 48.80 Baht per dollar in December 1997. Fifty-eight financial institutions and four commercial banks were suspended. This large scale failure of financial institutions had led to a very tight liquidity condition, and combined with the decrease in domestic demand, these had caused widespread collapse and insolvency of domestic businesses. Many industries found themselves in severe excess capacity and attempted to shake out employees, which led to an immense increase in the number of unemployment and underemployment[5]. The substantial decrease in income resulted in the reduction of personal consumption, which again reduced the market demand even further. Also, the reduction in personal and corporate income had lessened government revenue and, therefore, government spending, which in turn reduced the total output of the economy. Furthermore, the drastic currency depreciation along with the liquidity crunch brought about inflation and increased cost of living. Finally, by August 1997, the IMF had to be called in to arrange its second-largest-ever bailout in its history.

2.3 The Crisis and Productivity

Among many elements which led to this crisis, the decline in the productivity of Thai economy was most often blamed. Productivity was commonly seen as the cornerstone of

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[5] Paitoonpong, (2002)

the economic growth. Economic growth could come from both an increase in factor accumulation and an increase in productivity level. However, Krugman (1994) argued that as countries become more developed and move closer to their limits of factor accumulation, in order to sustain the economic growth, they had to rely more and more on increasing productivity. Failing to do so would eventually lead to a stagnant growth rate as the increase in inputs would inevitably run into diminishing returns.

In the case of Thailand, unfortunately, by the mid 1990s, the economy had seemed to reach its limit of factor accumulation (Sussangkarn (1998), Phongpaichit and Baker (1998)). The country's saving fell short of financing the massive surge of investments, and hence, driven up the interest rates. Also, the rapid growth of the economy had put strain on the labour supply. Consequently, the growing demand for labour had led to a significant increase in real wage, a phenomenon seen before in Japan and the Asian tiger economies (i.e. Taiwan, Hong Kong, South Korea, and Singapore). A natural way around this problem would be to upgrade the production technology in order to increase labour productivity[6]. As mentioned in a recent World Bank cross-country study of determinants of productivity growth by Ahmed and Miller (2002), they found that investment with additional effects resulting from technological change was the most important determinant of productivity growth for low- and middle-income economies.

Unfortunately for Thailand, during the mid 1990s, the improvement in the productivity was, however, prevented by the immense level of unproductive and speculative investments in the private sector (Phongpaichit and Baker (1998)). Therefore, with neither improvement in productivity nor advancement in the technology, the Thai manufacturing sector lacked the ability to develop into the more technological oriented segments, and thus, was left competing in the labour-intensive sector. With higher cost of labour compared to the newly industrialized economies (i.e. China and Vietnam), the competitiveness of Thai

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[6] Paitoonpong (2002)

manufacturing sector inevitably declined. As suggested in the Nukul's Commission report[7], the weakening in export growth of 1996 had sent a clear signal to the international currency speculators that the Thai economy was facing deep-rooted fundamental problems, and the rapid growth of the economy would soon come to a halt. Seizing such opportunity, currency speculators launched severe attacks on the Baht, as it was expected that the Thai authorities would soon adjust the exchange rate, in order to deal with the economic difficulties. On July 2nd 1997, the fixed exchange rate regime was abandoned and the country plunged into the deepest economic recession in its history.

2.4 Total Factor Productivity Measurements in Thailand

As mentioned earlier in section 1.1, many analyses had been carried out in order to examine the productivity growth of Thailand in the pre-crisis period. However, the results of these analyses were far from unison. This section is devoted to the review of these works, and also, to suggest possible explanations for the divergent in these findings.

The empirical studies on the sources of growth during the period from 1985 to 1995 have created a conflicting view between factor accumulation and productivity growth. While some studies (i.e. Sarel (1997) and Dollar *et al.* (1998)) recognized high productivity growth associated with openness as part of the explanations for Thailand's rapid growth, others (including Tinakorn and Sussangkarn (1996, 1998)) argued that it was the capital accumulation that played the significant role. Table 2.1 shows some results from the previous studies. Tinakorn and Sussangkarn (1996) found that after adjusting for the quality of labour, during the period from 1978 to 1990, only 16 percent of the economic growth came from the growth in total factor productivity, while the remaining 84 percent came

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[7] Nukul's Commission Tasked with Making Recommendations to Improve the Efficiency and Management of Thailand's Financial System, (1998)

Table 2.1: Total Factor Productivity Growth in Thailand

Source	Time Period	Whole Economy		Manufacturing		Methodology and Type of Data	Remarks
		TFP	Contribution to Growth	TFP	Contribution to Growth		
World Bank (1993)	1960-1990	2.5	N/A	N/A	N/A	Parametric, Time Series	Full Sample
	1960-1990	0.5	N/A	N/A	N/A	Parametric, Time Series	High-Income
Marti (1996)	1970-1990	1.6	42.5	N/A	N/A	Parametric, Panel Data	
Tinakorn & Sussangkarn (1996)	1978-1990	2.7	36	0.4	4.4	Growth Accounting, Time Series	1972 Prices
		(1.2)	(16)	(-0.4)	(-4.1)		Adjusted*
	1981-1990	3.1	39	1.2	13.1	Growth Accounting, Time Series	1972 Prices
		(2.5)	(32)	(0.9)	(9.1)		Adjusted*
	1981-1990	2.8	37	1.9	19.0	Growth Accounting, Time Series	1988 Prices
		(2.2)	(29)	(1.6)	(15)		Adjusted*
Collins and Bosworth (1997)	1960-1994	1.8	36.0	N/A	N/A	Parametric, Panel Data	
Tinakorn & Sussangkarn (1998)	1981-1995	2.1	26	1.1	10.5		Unadjusted
		(1.3)	(16)	(-0.1)	(-1.2)		Adjusted*
	1986-1990	N/A	N/A	3.8 (4.0)	N/A		Unadjusted Adjusted*
	1991-1995	N/A	N/A	-0.6 (-3.1)	N/A		Unadjusted Adjusted*
Sarel (1997)	1978-1996	2.0	39	N/A	N/A	Econometric/ Growth Accounting, Panel Data	
	1991-1996	2.3	35	N/A	N/A	Econometric/ Growth Accounting, Panel Data	

Source: Tinakorn and Sussankarn (1998) and SME Technical Working Paper Series, No. 8

from the increase in factor inputs used. Repeating this exercise with the revised data for the period from 1980 to 1995, Tinakorn and Sussangkarn (1998) found that the unadjusted total factor productivity growth contributed around 20 percent to the overall GDP growth, and declined to just 10 percent in the manufacturing sector. When adjusted for the increase in labour quality, this figure turned into a negative value for the manufacturing sector, indicating the worsening of productivity. In contrast, Sarel (1997) indicated a much more respectable productivity growth for the period from 1978 to 1996. He estimated that productivity was growing at the rate of 2 percent per annum, and accounted for 39 percent of the aggregate economic GDP growth. Re-estimating for the period from 1991 to 1996, the productivity growth rose to 2.3 percent, and explained 35 percent of the total economic growth. Another study by Dollar *et al.* (1998) found that the total factor productivity among the manufacturing establishments grew by 25 percent between 1994 and 1996.

There are several reasons that could explain such divergent findings of the pre-crisis productivity level, including approaches in the estimation, sources of data, periods of study, and assumptions assumed. The first problem to be mentioned is concerning the methodology of the estimation. For total factor productivity, unlike in the case of GDP and GNP calculations, there is not yet an international standard, guideline, or methodology in which researchers can follow. Therefore, depending on the specification adopted, TFP often measures different things in different cases[7]. For example, the TFP calculated from gross output data could give an entirely different set of results from the one calculated using value added data. Details regarding this issue will be mentioned in Chapter 5, Section 5.2.3.

Second, in most cases, the TFP computation demand a rather rich set of time series data on capital stock (preferably by sector) which are often lacking in developing countries, including Thailand [8]. Therefore, these studies on Thai productivity growth employed different sets of data from difference sources, and hence, leading to divergent outcomes. As

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[7] Dhanani and Scholtrs, (2002)
[8] Dhanani and Scholtrs, (2002)

a result, the comparability between these studies suffers greatly from the problem generated by data sensitivity. Moreover, the TFP estimates are also very sensitive to the time periods of study. As seen from Table 2.1, these studies all estimated TFP for different time periods, and therefore, diverging results are not unexpected.

Finally, many TFP specifications assume constant returns to scale and perfect competition, two neoclassical assumptions that do not apply in many developing countries. Dhanani and Scholtes (2002) alleged that, in fact, economies of scale occurred in the modern and large-scale production facilities were a major source of productivity growth. In addition, market power has also been found to be a fairly important determinant of the productivity estimations, as Kee (2002) suggested that when adjusted for the factor concerning the market power, the estimates of the average productivity growth in Singapore was doubled. These problems could, nevertheless, be solved by the use of the econometric approach in productivity measurement, in which the assumptions of constant return to scales and perfect competition are not necessary.

Even with the assumptions of constant return to scales and perfect competition being relaxed, this still cannot guarantee an unbiased measurement of productivity. The traditional econometric approach is, nonetheless, subjected to a limitation of not being able to include the technical inefficiency components in the model used for estimations. The conventional estimation techniques associated with the traditional econometric approach (i.e. ordinary least square, generalized least square) usually assumed 'zero' mean error component[9]. Therefore, this implies that the only source of deviation from the estimated production function is due to the statistical noises[10]. However, when considering the case of Thailand, in particular in the pre-crisis period in which the technical inefficiency is expected to be high and persistence, this assumption might be considered too strong. Hence, an alternate approach, namely a stochastic production frontier approach (Pitt and Lee (1981),

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[9] Green, (1993b)
[10] Hulten, (2000)

Battese, Coelli, and Colby (1989), Battese and Coelli (1992), is proposed for the estimations

in this thesis (details for such approach can be found in Chapter 7).

Chapter 3 – Background in the Thai Economy and Polity

"Policy can influence growth, either for good or ill, in many ways. The task is thus to try to exploit as many as possible of these avenues for good."

Arnold C. Harberger

3.1 Introduction

The purpose of this chapter is to provide detailed accounts of the development of the Thai economic policies as well as the political environments for the past five decades, from the rapid development of the 1950s to the bubble economy in the 1990s. The economic crisis that broke off in Thailand in 1997 was the result of a complex set of deep-rooted problems. Therefore, in order to develop a good understanding of it, it is very important not only to comprehend the immediate genesis of such crisis, but also the more fundamental question as to what had gone wrong with the growth process leading to the crisis. Among many different explanations, some (Siamwalla (1996), Chainuvati, Nakavachara, and Kunjara Na Ayudhya (1999)) claimed that it was the result of the subtle imbalance in macroeconomic management, while some (Chalamwong (1995), Krugman (2001)) blamed it on the inadequate technological advancements in the right direction. Many others (Phongpaichit and Baker (1998), Laplamwanit (1999), Poapongsakorn and Tangkitvanich (2000)) also suspected that there were flaws in the design and operation of the political and social institutions, which thereby resulted in the overall economic system becoming vulnerable to major economic shocks. The final answer to this question is difficult to obtain and agree upon; however, a better understanding of the historical development of the Thai economy should be the first step in pursuing such an answer.

The economic history of Thailand has been surprisingly global. Thailand has joined the openness of the world economy since it signed the Bowring Treaty in 1855. This treaty

had greatly limited the fiscal autonomy of Thailand by limiting its import duty on general merchandise to only 2 percent *ad valorem*. Siamwalla (1997) alleged that it was precisely this inability to protect its industry which had delayed the Thai economy from industrializing until as late as the 1960s, despite it being involved in the 'globalization' of the world economy so early on. On the political side, throughout most of its modern history, Thailand had endured heavy military involvement in its political affairs. The political history since World War II has been punctuated by a succession of military coups and attempted coups, sometimes followed by relatively democratic periods, sometimes not[1]. However, in the 1970s, the role of the military in civilian matters had become increasingly contentious as a result of the country's growing urban, educated middle class, who began to demand democratic reform and reduced role of the military in the country's affairs, both economically and politically.

Despite the political instability, the general conditions of living for the populace were rather unaffected. This internal stability results largely from three main reasons[2]. First, Thais are united by a popular monarchy, who although has no direct involvement in politics, has always been able to stop, or at least calm down, any potential turmoil. Second, the majority of Thais share the same religious belief (i.e. Buddhism), which therefore reduced the possibility of any dispute to develop into religious conflict. And third, unlike some neighboring countries, throughout its history, Thailand has experienced very little racial conflicts. Ethnic Chinese constitutes a large minority group heavily concentrated in Bangkok, and despite some early discrimination, they are treated as Thais, and the country has immensely benefited from their entrepreneurial abilities.

Despite the political instability, the economic policy formation of the country was the opposite. Despite many military coups, Thai policymakers have been following the same economic philosophy of committing to economic growth. They all share equal belief that

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[1] Warr and Nidhiprabha (1996)
[2] Warr and Nidhiprabha (1996)

market forces combined with prudent public sector infrastructure investment should be the principle means for achieving the ultimate goal of economic growth. Therefore, although Thai economic policies have been far from *laissez-faire*, the prevailing view in Thai political circles has always been that the government should play only a limited role in the economy[3]. Hence, Thai bureaucracies have been maintaining the continuity of the country's economic policies along these values.

Until the early 1990s, Thailand had followed relatively conservative macroeconomic policies shaped by a strong aversion to inflation. The inflation rate of Thailand had remained below 5 percent since after World War II, except for two brief surges associated with the oil shocks of the 1970s. Even then, inflation was quickly brought under control by stringent monetary contractions. It was common knowledge among the Thai financial circles that the Bank of Thailand (BOT) would contract the monetary policy whenever the inflation rate rose above 6 percent and would persist with this policy until the rate fell below that threshold. Such stringent monetary discipline is only made possible by the independent status of the Bank of Thailand. The Thai constitution has made clear that the status of the Bank of Thailand has to remain as an independent agency, where decisions on the monetary policy could not be intervened with by political pressures of any kind. As a result, Thailand's monetary policy had always remained creditable, and the record of monetary management was exceedingly impressive. Another central policy objective of the Bank of Thailand was to maintain a stable exchange rate. The Baht was maintained at fixed parity with the U.S. dollar (although in some periods, with currency baskets comprising of other major currencies such as Pound Sterling, Deutsche mark, and Japanese Yen).

By and large, up until the early 1990s, the monetary policies of Thailand had been countercyclical and stabilizing. The amount of capital flows and the level of interest rates were very much controlled within the targets of the Bank of Thailand. However, the capital market reformation of the early 1990s (which was originally thought would help to enhance

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[3] Phongpaichit and Baker, (1998)

the country's capital mobility, and hence, facilitate the rapid growth of the economy) had reduced the Bank of Thailand's ability to exercise its stabilizing role[4]. Regrettably, this mistake has put an end to the country's long history of monetary stability.

On the fiscal policy side, the bureaucrats of Thailand had always placed as a high priority the building of necessary infrastructures (such as road, ports, telecommunications, and electricity and water supplies), as they believed that only with good basic infrastructure could the rapid economic growth be assured. Besides, although the country's authorities had been believed in market economy, some manufacturing protection policies had also been imposed in order to protect young and weak industries. The protection, for the past four decades since the 1960s, has been biased against the agro-based industries, and toward the industrial manufacturing goods[5]. Import substitution policy was used since the late 1950s and remained until the early 1970s, before it shifted away toward export promotion policy with the imposing of the new Investment Promotion Act of 1977. Although it could not be claimed that Thailand had been practicing unmitigated free trade, its protection levels were reasonably moderate and stable.

As stated at the beginning of the chapter, the purpose of this chapter is to provide the detailed accounts of the development of Thai economic policies and political environments for the past five decades, as the understanding of such developments is potentially crucial in developing the understanding on the genesis of the 1997 economic crisis. For this purpose, in this chapter, the economic and political history will be divided into three important sub-periods:

1. The period of laying foundations: 1950 - 1973

2. The period of macroeconomic uncertainty, hardship, and turbulence: 1974 - 1985

3. The decade of extraordinary high growth, speculation, and bubble: 1986 - 1996

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[4] Nukul's Commission Report, (1998)
[5] Jitsuchon, (2002)

Each sub-period would be examined in details. Section 3.2 examines the period from 1950 – 1973, when some important economic foundations were laid that had later resulting in rapid economic growth. Section 3.3 considers the period of hardship which was triggered mainly by the two oil price shocks in the 1970s, and the policies response by the Thai authorities. Finally, section 3.4 considers the ten-year period of speculation and bubble, which had directly led to the economic crisis of the 1997. However, section 3.4 only provides an overview of the situation during that period, further discussion on the sources of the crisis and the mistakes in the economic management will be provided in Chapter 4.

3.2 The Period of Laying Foundation: 1950 – 1973

This period should probably best be described as the period of laying many important foundations, which had later brought about the high and stable economic growth for the country in the later periods. Throughout the 1950s, the Thai economy found itself in the state of recovering from the damages left over by the Second World War. The economic management during the most part of the 1950s could be described as eccentrically diverse, in which it was trying to serve many goals that did not seem to add up[6]. It was not until the late 1950s before the high economic growth of the post-war years really began, when Field Marshall Sarit Thanarat took complete control of the power through a *coup d'etat* in 1958.

3.2.1 Economic Stability and Capital Formulation

Sarit brought with his premiership a vision to run the country according to the international standard[7]. One of his first and foremost policies was to establish economic stability, which

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[6] Jitsuchon, (2002)
[7] Wyatt, (1984)

at that time was influenced by the arrival of the World Bank advisory mission in 1957, as well as the World Bank report on Thai economy sent to the Thai authority in 1959. The World Bank report found very receptive audiences in the government of the time, particularly in Sarit himself, and since then, many significant changes in the economic policy followed. This report had influenced Thai economic policies in two important ways[8]. First, it recommended that Thailand was in need of a fundamental shift in the nature of how the public sector involved in the economy. More specifically, it advised that government interventions should be shifted away from direct production (i.e. the extensive and highly inefficient public enterprises) toward investments in the public infrastructures necessitated for the economic development, such as investments in roads, ports, telecommunications, and electricity supply. Second, the report also recommended that the government should change its method in promoting private investments; it should rely less on the direct price control, and focus more on the provisions of the taxes and tariffs incentives, as well as on the introduction of investment promotion schemes.

In response to these recommendations, Sarit presided over a period of rapid institutionalization of various public units that was thought to be vital for the economic development. Two new units were established, namely, the Budget Bureau in 1959 and the Fiscal Policy Office in 1961. Also, two existing institutions, the National Economic Development Board (NEDB), later called the National Economic and Social Development Board (NESDB), and the Board of Investment (BOI), were revamped. The Budget Bureau, the Fiscal Policy Office, the NESDB, and the Bank of Thailand were assigned to jointly determine the country's annual budget.   This is done for the reason of preventing imprudent behaviour that might occur in one particular authority. Such vision had later been proved to be a very important factor ensuring the country's stable economic policy, in spite of the following political unstabilizing periods. The government budgets at that time were

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[8] Warr and Nidhiprabha (1996)

drawn up with the highest priority being given to development projects, primarily in infrastructure constructions.

However, economic stability by itself, while necessary, was insufficient to generate such high growth experienced in Sarit's era. Siamwalla (1996) alleged that economic stability after the Sarit reformation was, however, allied with another process, the process of capital formation. It was with the extensive capital formation coinciding with the lengthy period of political stability that such rapid growth could have taken place. The key to these changes, he claimed, was the incorporation of the Chinese entrepreneurs as a class into the Thai society after the closing off of mainland China in 1949. Prior to that, because of the more aggressive Chinese-Thai nationalism regime, the process of assimilation was somewhat more difficult. The nationalism arose because of the fear that the communism regime from China would spread into the country, and therefore, the military government of Thailand at that time put forward the anti-Chinese policies, limiting the Chinese entrepreneurs from engaging in various key businesses. The Chinese commercial communities, hence, adapted to the situation by forming business alliances with military top men (and it is these alliances that have laid foundations for business-bureaucrat relationship that exists throughout Thailand's economic development history). It was this repression against Chinese businesses that had resulted in the outflows of a large proportion of the accumulated wealth from the Chinese immigrants to China. Fortunately for Thailand, the closing off of mainland China after 1949 and the *modus vivendi* achieved with the Thai political leadership had set the stage for Chinese entrepreneurs to redirect their energy back to the Thai economy. In such process, they set up commercial banks which have greatly help facilitate the process of capital accumulations, certainly for themselves, and as a by-product, for the national economy.

3.2.2 National Development Plan

With the combined effects of capital accumulation and economic stability, private investments began to surge. The newly formed National Economic and Social Development Board (NESDB), in response to this increased investment, began to formulate the regular five-year development plans, started in 1961. These development plans could be best described in relation to the economic conditions existing at the time they were formulated. The underlying philosophy of this economic planning is a commitment to the market economy, and therefore, the planning had been directed mainly toward securing a smooth functioning of markets with minimal direct government interventions and controls.

The goal and means of economic development engineered by Sarit's government were officially declared in the country's first National Economic and Social Development Plan. This First National Development Plan (1961 – 1966) had the main objective in encouraging economic growth in the private sector through the provision of basic infrastructure. The principle thrust of government involvement was therefore concentrated on expanding infrastructure facilities in transport, communications, power, social and public services, and agriculture. Attempts were also carried out in reducing the role of military founded monopolies, which were low in efficiency. The results from this plan were exceedingly remarkable[9]. The economic growth resulting from the First Plan period was both rapid and broadly based, with the average annual growth rate of 8.1 percent. A new surge of public investment in infrastructure had taken place. Private investments also multiplied as a result of the Board of Investment's used of a combination of various investment promotion schemes, tariff policies, tax regimes, and trade as well as price controls. And although most of the public enterprises then in existence still remained in place, their role became much less significant as the private sector economic activity in manufacturing grew.

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[9] Warr and Nidhiprabha, (1996)

The Second Plan (1967 – 1971), similar to the first, was still largely concentrated on the public expenditure program. It continued the First Plan's task in building infrastructure, particularly in those areas considered conducive to development. However, the pattern of public expenditure under this plan revealed the government's increased emphasis on the slower growth areas, especially the rural sector. And although it incorporated manpower planning, it still made no attempt to direct resource allocation among sectors. The growth rate of GDP during this Second Plan was less impressive than it had been during the First, with an average rate of growth at 7.5 percent per annum. Output continued to expand rapidly in infrastructure and services, but less in industrial.

The Third Plan (1972 – 1976) reflected a moderate shift of emphasis in development thinking among the Thai bureaucrats. This shift clearly reflected a growing awareness among the NESDB planners on the increasing problem of regional disparity and poverty in the rural areas. It was clear to the authority by the time of planning this plan that the benefits of industrial expansion were not reaching the majority of the populace. Furthermore, it was also recognized that the impressive aggregate growth since the First Plan had been achieved at the expense of a rapid deterioration in Thailand's land, forest, water, and marine resources. Therefore, although still aiming for higher growth, the Third Plan set specific priorities for reducing the growing disparities between urban and rural areas, and also between sectors. The emphasis of the plan was no longer simply on improving public infrastructure and maintaining economic stability, but also on achieving a more equitable distribution of income and social services.

3.2.3 Agriculture Led Growth

Resulting from the government's heavy investment in infrastructure, the growth in the 1960s was dominated by the expansion of road networks, irrigation, power supplies, and telecommunication systems. The expansion of the road network in the 1960s was tacitly

linked to an American-supported counterinsurgency program. It had a considerable impact on agricultural development, as well as on the overall economic growth. By providing farmers with direct access to external markets, it had rid the need for middlemen, and thus, had significantly increased the farmgate price for cash crops. However, more importantly, the expansion of the road network had also provided an access to a vast amount of previously uncultivated land further away from rivers and railway lines. Combined with the government's policy in the clearing of forest lands in order to expand the agricultural land frontier, this had become instrumental for the agricultural growth of the 1960s.

Furthermore, and equally important, the building of a large-scale irrigation system had facilitated the dry season cultivation of rice, most notable in the central region. Prior to this, the cultivation of rice could only be made once per year during the rainy season. However, after the irrigation system was built, it had become possible for the second cultivation season, and therefore, doubled the production of rice. This rapid growth in the agricultural sector had become an important instrument in supporting industrial sector growth. The foreign revenue derived from the accelerated export of agricultural products, combined with the increase in government revenue from the increased agricultural production, had provided the necessary resources for early industrialization in the 1960s.

During the 1960s and 1970s, strong import substitution policy was imposed in order to create a favorable market condition for early industrialization. Import tariffs were raised significantly to protect local industries, with the strongest incentives directed at the production of final products based on imported intermediate and capital goods. However, despite the very favourable atmosphere, the commercial sector and investment demand were never the major contributors to the high economic expansion, which recorded at 7.2 percent per annum between 1958 and 1973 (Jitcushon (2002)). Thailand was still very much an agricultural country, with the agriculture sector being the primary engine of growth.

Jitsuchon (2002) claimed that the dynamics of agricultural production in this period is a good example of how economic growth in Thailand has been driven by increasing uses

of inputs instead of advancing technology. Siamwalla (1996) supported this argument by alleging that when corrected for land expansion and irrigation provision, he found no real gain in production yields from the period of 1958 to 1973 at all.

In summary, the key to the success of Thailand's early modern economic development is owed very much to the combination of capital accumulation, increase in production inputs, as well as the vision of the country's leader in promoting economic growth through sound macroeconomic management, promoting a favorable business environment, and institutional strengthening. Without any single one of these factors, such remarkable growth would have never been made possible.

3.3 Political Uncertainty and Economic Turbulence: 1974 - 1985

The period from 1974 to 1985 had been dominated by both the domestic political uncertainty and the world economic turbulence. Quite coincidentally, the economic and political stability of Thailand ended on the very same week in October 1973, when domestically, the military Thanom Kittikajorn government resigned amidst the massive protestation from the general public, and internationally, the six-day war broke out in the Middle East and marked the beginning of the first oil price shock. Economic hardship was felt most in the latter part of this sub-period, when as a result of the two oil price shocks, the windfalls from the world commodity price boom in the 1970s was finally over. This period can, however, be considered as a period of transition, both on the political and economic ground.

On the political side, this period was marked by the transition from the absolute military regime toward the western democratic system. The military influence, which had dominated Thai politics for over half a century, was replaced by a new force from the urban society, specifically, an urban middle class. While on the economic aspect, this period

witnessed a major structural change from the agricultural-led-growth economy toward the industrialization of the domestic sectoral production. Although the overall economic performance in the sub-period was rather disappointing, it should nevertheless be fair to allege that it was these adjustments from this period that had later laid the foundation for the new economic structure as well as the rapid growth of the economy of the next sub-period.

3.3.1 Political and Economic Uncertainty

As mentioned, the economic hardship that occurred in this period was the result of two main incidents happening separately, with one occurring domestically and one internationally. Domestically, the outburst of political freedom, long suppressed under the military power regrettably coincided with the triumph of communists in the Indo-Chinese neighbors. During the 1950s and 1960s, Thai politics was very much suppressed under the military ruling. However, since the early 1970s, many Thai students returned to the country from their education in the democratic western world. They brought back with them the belief in the freedom and equality of the democratic system, and therefore, started the democratic movements[10]. Unfortunately, the triumph of the communist party in Vietnam generated fear among the military rulers that Thailand would soon follow the pattern of Vietnam and be taken over by the communist movement. Therefore, political freedom among civilians was strictly limited. However, such suppression had created an even greater urge among the new thinkers in overthrowing the military authority. Consequently, the period from 1974 to 1976 was marked as the period of the most vigorous confrontations between the lefts and the rights in the country's history[11]. The confrontation ended

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[10] Siamwalla, (1996)
[11] Jitsuchon, (2002)

tragically in October 1976, when the right-wing military once again took over the power, forcing many educated, young left-wingers to flee the country.

Internationally, the Arab-Israeli conflict had triggered the first oil price hike in October 1973. And later in 1979, the Iranian revolution set off the second, and worse, oil crisis. Thailand, although, was fortunate enough not to be affected much by the first oil price shock (helped by the commodity prices boom during 1972) was not so providential this time, when the second oil crisis hit. The government of the time was already facing the problem of a soaring budget deficit arising from the increased government expenditure on the country's rapid infrastructure investment. Coinciding with the need for the government to counter the economic slumps that followed the two sharp oil price hikes, as well as the world recession of early 1980s, the problem of budget deficit and public debt mounted. By the first half of the 1980s, such budget deficits had eventually led to one of the most serious public debt problems of the Thai history.

To make matters worse, the Thai economy at that time was also greatly affected by the rapid movements in some of the world major currencies, an experience the country had not been prepared to deal with before. After the collapse of the Bretton Wood system in 1971, Thailand chose to continue pegging its currency with the U.S. dollar. This decision had later proved to be very costly to the country, when the U.S. dollar appreciated against other major currencies between 1978 and 1985[12]. As a result, the Thai Baht was *de facto* appreciated, which drastically lessened the country's competitiveness. The Thai government was therefore forced to devalue the currency by 15 percent in 1981, and went on to abandon the single-currency fixed exchange rate for the basket system in 1984, which amounted to an effective devaluation against the U.S. dollar by another 15 percent.

As seen before in many countries, the economic hardship was always the major cause of changes in politics, and Thailand was no exception. Finally in 1980, General Prem Tinnasulanon took the office of Thailand's premiership. Although General Prem himself had

risen to the post by the promotion from the headship of the army, he had been running the country in a very democratic manner. After the end of his 4-year term, a country-wide general election was conducted, in which his party and its coalitions won the majority vote and General Prem himself was backed for the premiership. His 8-year term could be considered one of the most stable political periods in the Thai history. On economic achievements, his government managed to restore fiscal discipline between 1982 and 1985, which was very remarkable considering the rapidly changing economic conditions during that period. On the political achievement, his government marked the new era for Thai politics. For the past forty-seven years, Thailand had been ruled by the military powers; however, his political vision was focused mainly on the development of Thailand's democracy, i.e. constitutional reform and administrative decentralization.

3.3.2 Economic and Social Development Plan

With the economic hardship Thailand was facing during the 1970s, the Fourth Economic and Social Development Plan (1977 – 1981) focused its immediate objective at revitalizing the domestic economy from the effects of world recession[13]. The role and the influence of the public sector - particularly of the core agencies controlling macroeconomic policy – had been increased. Although the private sector remained the central source of economic dynamism, the government had become more active in economic affairs. Large public expenditures had been invested in an attempt to maintain the economic growth momentum. Furthermore, the Fourth Plan also set its core objective at implementing the social structural adjustments. The Plan was intended to address the growing disparity between urban and rural areas, as well as the rapid deterioration of the nation's natural resources left from the

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[12] Pongpaichit and Baker, (1998)
[13] Warr and Nidhiprabha, (1996)

rapid growth in the previous sub-period. At the heart of this plan, there was an attempt to switch from a growth orientation economy toward greater social awareness.

The performance of the economy during the Fourth Plan period, despite being affected by the unfavorable external conditions (e.g. the rising oil prices, high international interest rates, declining demand and prices of Thai export commodity), was still satisfactory. Warr and Nidhiprabha (1996) claimed that this achievement was partly a result of the government's attempts to maintain the growth momentum by expanding public investment despite a drastic deterioration in domestic savings.

The Fifth Plan (1982 – 1986), continued from the Fourth Plan, had the main concern in economic restructuring so as to reduce the disparity between the urban and the rural. This was meant to be achieved by placing more emphasis on the quality of growth rather than the rate of growth. In this process, a reform of the public development administrative system was required in order to better facilitate rapid economic development. The main force driving the economic growth was planned to rely upon industrial development, which share of output was projected to reach the share of agricultural by the end of the planning period. The implementation of this objective was carried out through two main policies: the dispersion of manufacturing from urban to rural areas, and the shift in public investment from infrastructure to development projects.

In response to this Plan, by the 1980s, the national public provision had changed significantly. The emphasis of public investment had shifted away from infrastructure toward development projects. The reason for such a shift came from the economic hardship arising from the external shocks Thailand faced in the 1970s. Therefore, strategic industries were planned to be developed in order to help strengthen the economy's ability to absorb external shocks, as well as to provide a foundation for resource-based industrialization. Many new development projects such as the fertilizer project, the steel project, and the Eastern Seaboard project were created following this Plan.

Moreover, the economic and investment policy had also been focused on decentralizing the industrial development to areas outside of the heavily concentrated Bangkok Metropolitan Area (BMA). Incentives such as income tax and import tariff exemptions were given to those manufacturers located outside BMA. However, despite these efforts to direct industries to provincial areas and to encourage economic growth in regional cities, the BMA continues to be the dominant economic, social, and administrative center of the country. One of the primary problems preventing this decentralizing growth is the fact that infrastructure facilities in targeted regions were very severely lacking. Although investments in infrastructure had always been the main objective of the previous Development Plans, the Thai economy had been growing very rapidly during the past decade, and the country's infrastructure growth failed to adequately catch up with the speed of industrial expansion.

3.3.3 Export Promotion Policy

This sub-period had also witnessed a major structural change in sectoral production[14]. The agricultural sector, which expanded rapidly in the 1960s and into the early 1970s, had been faced with two major obstacles to further growth. First, the price of the agricultural products in the world market, which was at that time Thailand's main source of income from abroad, had been declining since 1980. And second, the forest areas which were suitable for agricultural production had been dwindling rapidly. By about the same time that the rapid growth in agriculture could no longer be counted upon as reliably as in the past, the idea of shifting the country's industrial policy from import-substitution to export-promotion began to gain momentum[15]. The hallmark of this policy shift was the announcement of the 1977 Investment Promotion Act.

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[14] Siamwalla, (1996)
[15] Martin and Warr, (1990)

With the passage of the Investment Promotion Act of 1977, the emphasis of industrial policy then supposedly shifted away from import-substitution toward export-realization. Export-promotion had since become the central theme of efforts in promoting private investment in industries. Particularly, with the economic recession caused by the internal political turbulence faced in the 1970s, Thai authorities had become more focused on the promotion of export-oriented industries in the attempt to maintain economic and financial stability. The Board of Investment, the Ministries of Industry, Commerce, and Finance, as well as the Bank of Thailand, jointly formulated and administered policies that directly affect industrial development, with these policies being ostensibly aimed at export promotion[16]. Like many other developing countries, Thailand had favoured supporting infant industries that were expected to be capable of becoming successful export industries after a short period of protection.

However, the success of the new industrial policy was, nevertheless, obstructed by three important factors. First, the unfavourable world economy at the time had resulted in the decline in demand for Thai exports, therefore, discouraging further investment in the private sector. Moreover, the Baht was over-valued during 1981 to 1984 as a result of the artificially strong US dollar. Hence, Thai exports became much more expensive compared to those of other developing countries. And finally, the tight fiscal policy the government imposed since 1982 to restrain the public debt had resulted in domestic economic recession, and hence, limited the private sector's ability as well as incentive to invest.

3.4 Economic Boom, Speculation, and Bubble: 1986 - 1996

In contrast with the previous period, the period from 1986 to 1996 could be considered as the most prosperous time in the history of the Thai economy; however, only if attention was

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[16] Industrial Management Corporation, (1984)

paid simply to the aggregate growth figures. The average GDP growth in this period was as high as 9.58 percent per annum, with the highest growth being at 13.29 percent in 1988. This good time, however, was argued to be triggered by external events, and not from the development in the domestic economy[17]. On the political ground, this period was marked by moderate political stability. Although the period involved one failed coup as well as one successful one, five Prime Ministers, and many more major re-organizations of the cabinet, the transitions had been largely smooth and peaceful, with only one strong demonstration.

3.4.1 Factors behind the Economic Growth

The first external event that was claimed to be the main driving force for the rapid economic growth of this period came with the 1985 Plaza accords that effectively realigned major currencies in which the Japanese yen as well as the US dollar were devalued. The Thai Baht, with the US dollar representing almost 90 percent of the share weighted, depreciated likewise. Therefore, the country's labour-intensive manufacturing products, as well as the agricultural products, became much more competitive in the world market. The second external factor was the sharp decrease in petroleum products since 1986, which had revived the world economy from great recession in the earlier period. Both accounts on the external front had greatly benefited Thai exports, especially the manufactured ones. Therefore, Thai export growth expanded immensely. Between 1988 and 1995, Thailand had experienced a substantial exports growth rate as high as over 20 percent per annum.

Another important by-product of the exchange rate realignment was the relocation of industrial productions from other industrialized countries, i.e. Japan, Taiwan, and Hong Kong. The Japanese manufacturers started to lose their competitiveness as a result of the yen appreciation. Combined with the rising wage rate in these countries, they recognized

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[17] Jitsuchon (2001)

the need for a more cost-effective relocation. Consequently, investment capital in the form of foreign direct investment flooded into Thailand at an unprecedented magnitude.

The stable political atmosphere in this period had also been another important factor inducing high economic growth. The relatively stable political scene during the eight-year period of the Prem government was followed by a smooth transition to the Chatchai government in 1988. Although the Chatchai government was overthrown in the 1990 coup, the transition to the new government led by Anand Panyarachun was also peaceful. The Anand government did not have a problem getting acceptance from the public. In fact, most of the public supported this 1990 coup, citing the highly corrupt ministers and scandals in the Chatchai government as the justifiable pretext. However, such approval was short-lived. In 1992, the military top men had attempted a direct control over the government at that time, which had led to another strong opposition and board demonstration among urbanites. When the demonstration finally ended with the defeat of the military power, Thailand entered the era of real democracy. An amendment of the constitution had been made, which compelled that all governments from then onward have to gain their power through parliamentary process. Therefore, all governments of Thailand since 1992 have gained their power through public elections. The Prime Ministers and key ministers were either coming from civilian bureaucracy or business background. And although each government had not remain in office for very long, the transitions had always been smooth. Hence, it could be reasonably concluded that between 1992 and 1997, Thailand experienced a period of moderate political stability.

As a result, the manufacturing productions surged in response to the growing export and investment demand, as well as the favorable political climate. This was further helped by the sluggish agricultural production in 1986 and 1987, which had led to the release of a large number of cheap and unskilled labours suitable for working in the light and medium industries. Consequently, the transition from the agrarian economy to the industrial economy was, thus, completed.

3.4.2 Speculation and Bubble

During this sub-period, Thailand was fortunate enough that despite the tendency among politicians and military rulers to engage in big-scale corruption, the fiscal discipline had remained largely intact. Jitsuchun (2002) provided three possible reasons for such achievement. First, the memory of the hardship associated with tight fiscal policy in the first half of 1980s (which was the result of lax fiscal policy during the 1970s) was still very fresh. Second, fiscal budget balance and surplus was regarded as a political achievement by the government at the time. Third, the foundation of the budgetary process put in place since the early 1960s by the Sarit government had successfully prevented systemic imprudent fiscal spending by the government.

However, while financial prudence in the public sector was evident, it was regrettably missing in the private sector. Speculation in real estate was taking place at an alarming rate. The same phenomenon was also observed in the stock market, where both domestic and foreign investors rushed in without involving a proper risk analysis. Therefore, the bubble in the real estate and stock market was lucid.

Another interesting point worth noting in this period is the shift in infrastructure build-up policy. Unlike in the 1960s, when the governments were entirely responsible for providing basic infrastructure (i.e. road and irrigation, to the economy), the policy in the 1980s and the 1990s was to give private companies concessions to build, and sometimes to operate, these infrastructures. The telecommunications and expressways stood as good examples. In principle, the positive side of this policy is the reduced burden on public spending, increased efficiency, and more timely constructions. However, in reality, not all of them were realized. As described by Jitsuchon (2002), 'the negotiations between public personals and private companies often resulted in the marriage between the worst of both worlds, namely, the inefficiency and delays of the public sector and the greed of the private sector'.

In sum, although this sub-period experienced a remarkable growth rate, this growth mainly resulted from the accumulation of factor inputs, not the so-called 'efficiency-lead sustainable growth'. Therefore, it is not surprising that from the supply side growth accounting, Jitsuchon (2002) found that the major source of growth during this period was clearly coming from the accumulation of capital stocks, increasing at an average of 10.3 percent per annum during 1986-1996, which accounted for almost 80 percent of the contribution to growth during 1991 – 1995. While the TFP growth, adjusted for changes in human capital, was merely 0.4 percent during the same period, reduced from 31.3 percent during 1981 – 1986. These figures clearly reflected the fact that the capital accumulations of this period had been used very inefficiently as a result of the speculative behavior.

Chapter 4 – The Economic Crisis of 1997

"When everyone feels that risks are at their minimum, over-confidence can take over and elementary precautions start to get watered down."

Ian Macfarlane

4.1 Introduction

The aim of this chapter is to create a better understanding of the anatomy of the 1997 economic crisis. Before the financial and economic crisis hit Thailand in July 1997, the Thai economy had long enjoyed immense economic growth. For a decade preceding 1995, the Thai economy had been growing at the very impressive rates; its total GDP growth per annum was ranging from 8 to 13 percent of (Table 4.1). The country's development regime was regarded internationally (by the IMF, the World Bank, as well as the *Economist*[1]) as a success case and was often used as a model for the less developed countries to follow. The growth of the Thai economy could be traced back to the 1970's, when the Board of Investment (BOI) began offering a range of export incentives, such as cheap credits for export producers and income tax exemption for qualified exporters. Combining with the shifting of comparative advantage from Japan and many other industrial countries, Thai export sectors soon took the major share of the country's GDP.

To many economists, the crisis in 1997 had taken place by surprise. Paul Krugman expressed his opinion on this issue as the following:

"It seems safe to say that nobody anticipated anything like the current crisis in Asia. True, there were some Asia sceptics – including myself- who regarded the claims of an Asian economic miracle as overstated, and argued that Asia was bound to run into diminishing returns eventually. ..... But even pessimists expected something along the

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[1] Details in this was previously referred in Chapter 2, Section 2.1

lines of a conventional currency crisis followed by at most a modest downturn, and we expected the longer-term slowdown in growth to emerge only gradually. What we have actually seen is something both more complex and more drastic: collapses in domestic asset markets, widespread bank failures, bankruptcies on the part of many firms, and what looks likely to be a much more severe real downturn than ever the most negative-minded anticipated." [2]

Table 4.1: GDP Growth Rate

Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
GDP Growth (%)	9.519	13.288	12.191	11.167	8.558	8.083	8.251	8.987	9.238	5.901

Year	1997	1998	1999	2000	2001	2002	2003
GDP Growth (%)	-1.371	-10.510	4.431	4.637	1.798	5.426	7.218

Source: IMF International Financial Statistics (IFS)

Table 4.2: Inflation Rate

Year	1991	1992	1993	1994	1995	1996	1997
Inflation (%)	5.7	4.07	3.36	5.19	5.69	5.85	5.61

Source: IMF International Financial Statistics (IFS)

Table 4.3: International Reserves

Year	1990	1991	1992	1993	1994	1995	1996	1997q2
Int'l Reserves (million US $)	16,478	21,265	24,245	31,664	37,009	46,504	45,833	41,074
Int'l Reserves (months of Import)	5.22	5.82	6.32	6.75	6.79	6.30	6.55	5.77

Source: Bank of Thailand

Prior to the crisis, Thailand had been one of the Asia's most outstanding economies. The fundamentals of the economy were very sound. The GDP growth rate was high, inflation rate was low for the standard of emerging markets, ranging from 3.36 to 5.85 percent (Table 4.2).   Domestic savings accounted for as much as 34 percent of GDP,

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[2] Krugman, (2001)

unemployment rate had been low, the government had run fiscal surpluses in nine out of the last ten years, and the international reserves were a healthy 5 to 7 months of imports (Table 4.3). These indicators contrast sharply to those of Mexico prior to the peso collapse in December 1994, where domestic savings were low, GDP growth was sluggish, and the country was still experiencing the residual effects of the triple digit inflation rate in the late 1980s. Therefore, the interesting question posted by many economists was '*what could possibly go wrong with the Thai economy that has brought about a sudden overturned of its fate in such a short period of time?*'

As stated earlier, this chapter is devoted to create a better understanding of the anatomy of this 1997 economic crisis. Therefore, in doing so, the chapter starts, in section 4.2, with the analysis of the five main causes leading to the crisis. Then section 4.3 focuses on the consequences. Section 4.3.1 examines the effects of the crisis on economic growth; section 4.3.2 considers the effects on the employment issues, including the employment, unemployment, underemployment, and real wage. Finally, a brief conclusion is presented in section 4.4.

4.2 The Causes of the Crisis

The answer to the question on the causes of the crisis is not a simple one, and surely there is not one single explanation or cause, but a complex set of problems that precipitated the crisis of such intensity. Many studies (Moreno (1997), Nukul's Commission Report (1998), Phongpaichit and Baker (1998), Sussangkarn (1998), Chainuvati, Nakavachara, and Kunjara Na Ayudhya (1999), Doner and Ramsay (1999), Laplamwanit (1999), Sussangkarn (1999), Acharya (2000), Na Ranong (2000), Krugman (2001), Diao, Rattsø and Stokke (2005)) have provided numerous explanations. However, they could be classified into five main categories: (1) the slowdown of export growth; (2) the mistakes in financial policies; (3) asymmetric

information and over-investment; (4) attacks on currency; and (5) responses to the currency devaluation.

4.2.1 Export Growth Slowdown

Between 1988 and 1995, Thailand had experienced a substantial exports growth rate of over 20 percent per annum. At that time, Thailand possessed strong comparative advantages in labour intensive manufactured goods such as textiles, electronic products, and semi-conductors, but was weak in the areas involve higher value-added products. The strong export growth was mainly driven by the two most important assets the Thai economy owned, namely the cheap labours and the extensive natural resources. Unfortunately, by 1996, these two assets seemed to reach their limits.[3] Between 1982 and 1994, Thai real wages raised immensely with an approximate 70 percent increase between these 13 years. To worsen the situation, from mid 1990s onward, Thai export sector experienced increased competition from other developing Asian countries such as China and Vietnam, who had recently opened up their economies (with abundant resources and much cheaper labours) for foreign direct investment. In normal circumstance, a natural way to solve the problem of declining competitiveness would be to upgrade the economy toward the more capital and technology intensive industrial sectors. However, this was not an easy option for Thailand at the time. During the early 1990s, because the Thai economy was growing so favourably, local and foreign investors flooded the country with massive and countless investments. Consequently, the country's national savings failed short of financing these projects, driving the domestic interest rate to very high levels (with fixed saving rate reaching more than 14 per cent per annum). As a result, the majority of investments made during that period were concentrated in the speculative sectors such as real estate and stock market, which were simply the only sectors that could possibly generate sufficient rate

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[3] Jitsuchon, (2002)

of return.[4] As a result, the manufacturing sector was struggling to acquire sufficient funds for the necessary upgrades.

Furthermore, another important factor which had led to the downfall of Thai export involved the exchange rate. At the time, the Thai Baht was pegged to a basket of currencies in which the US dollar was weighted at 80 percent of the total basket. With the sharp rise of dollar against other currencies in the mid 1990s[5], the Baht became over-valued, and hence, led to export difficulties for Thai producers. To add severity to the problem, the time prior to the 1997 crisis was the period of worldwide export downturn in which demand for Asian exports dropped considerably. In addition, the Japanese market, one of the Thai major export destinations, was facing yet another economic recession; as a result, this led to the further decline in demand for Thai products.

Therefore, by the second half of 1996, Thailand's export growth rate had dropped from over 20 percent per annum in the previous year to zero percent. The exports of labour intensive manufactured products (the major source of export growth from the mid 1980s to early 1990s) declined by approximately 14.6 percent through the first 11 months of 1996.[6] With the main driving force of the economy facing such a sluggish condition, the Thai economy was inevitably turning into the recession.

4.2.2 Mistakes in Financial Policies

Three financial policy errors could largely be held responsible for the financial meltdown in mid-1997: (1) the premature liberalization of financial institutions; (2) the financial liberalization with a fixed exchange rate; and (3) the failure to prudently supervise the financial institutions.

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[4] Kittiprapas, (2000)
[5] The US dollar strengthened by about 38% against the Japanese Yen and about 27% against the Deutsche Mark between April 1995 and June 1997.
[6] Laplamwanit, (1999)

Prior to 1990, the Bank of Thailand (BOT) had a strong plan to propel Thailand into the regional financial hub. The Nukul's Commission Report (1998) described the reasons underlining this plan as; first, it would help facilitate and support investment funding, and therefore, enhanced the competitiveness of the country. Secondly, it would help stabilize the country's monetary and economic systems, and hence, created a better environment to facilitate economic growth. However, it was recognised at that time that Thailand was still lacking some concrete fundamental elements to support this plan, and therefore, some measures are needed to be implemented. In the BOT letter No. 545/2533 dated March 30, 1990, endorsed by former Central Bank Governor Chavalit Thanachanan, it was proposed that the highly regulated foreign exchange controls at the time should be relaxed so as to facilitate foreign capital flows and to boost foreign investor confidence. It also suggested the government to accept the International Monetary Fund's (IMF) agreement No. 8, which stated that the Thai government would not limit any payment or money transfer overseas. This announcement would officially signify to the world that Thailand had abandoned all foreign exchange controls. In order to implement this plan, the Bangkok International Banking Facility (BIBF) was initiated in 1993 with its role to facilitate the flow of foreign currency current account transactions. Such a scheme was implemented with the anticipation that the large amount of investment funds flowing into the country would make available the resources for upgrading a firm's export capacities, improving congested infrastructure, as well as, training and educating the labour force.[7] As a result, 42 BIBF licenses were granted to commercial banks and non-bank financial intermediaries allowing them to engage freely in a number of foreign exchange activities.

However, this liberalization of the foreign exchange and capital flow came with costs. With a large number of private financial institutions directly involved in capital inflow and outflow, it had become much more difficult for the BOT to monitor and regulate such activities. The freeing of foreign exchange controls should have been accompanied by the

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[7] Nukul's Commission Report. (1998)

strengthening of financial institutions in order to develop confidence among the foreign investors, as well as, to prevent the problem associated with bad lending behaviours. Statutes of practice must be set, at least to meet the international standards, particularly in the area of capital base adequacy, asset quality, management efficiency, and data base development. Unfortunately, measures to achieve these goals were never accomplished. In fact, the BOT relaxed, rather than tightened, measures which would have led to the strengthening of local financial institutions.[8] First, the BOT permitted financial institutions to maintain the capital adequacy ratios below the requirements of the Bank for International Settlements (BIS). At the time, these requirements were thought to be too strict, and would obstruct the economic growth. Second, the BOT allowed the existing below-international-standard non-performing loan's definition to persist. And finally, the Financial Institution Regulation and Supervision department of the BOT failed to impose strong guidelines for the BIBF's operations, and permitted the boundless lending and borrowing behaviours to continue.

The relaxation of the foreign exchange control and the BIBF's establishment combined with the country's fixed exchange rate regime (which fluctuated very narrowly between 24.91 – 25.59 Baht per US Dollar) had resulted in a massive wave of foreign capital inflows into the country, following the virtually risk-free currency environment.[9] Local investors sought foreign funding sources as the national savings failed to finance the fast growing investment expansion. Financial institutes saw the profit opportunities of borrowing at the much cheaper rate offshore and lending them at the higher local rates. By 1995, the number of BIBF borrowers increased to a much higher level than the BOT had expected. In 1995 alone, Thailand had a net capital inflow of 14.239 billion US Dollar, accounted for 14 percent of the total GDP, and increased by more than one hundred percent from its net

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[8] Nukul's Commission Report. (1998)
[9] Doner and Ramsay, (1999)

capital inflow in 1992 before the liberalization of capital account and the establishment of BIBFs.

However, although foreign capital inflows were high, foreign direct investment was minimal. Capitals flowing into the country were primarily for credit extensions, not investment. This, therefore, led to rapid growth of the country's external debt. The total outstanding external debt rose from 43.11 billion US Dollar in 1992 (accounted for 38.58 percent of GDP) to 83.38 billion US Dollar in 1995 (accounted for 49.38 percent of GDP) (Table 4.4). There are two important points that needs to be mentioned here; first, almost all of the increase in debts during that period were generated by the private, not the public, sector.[10] During the first half of the 1990s, the Thai government was always running budget surpluses; therefore there was no pressure for the government to borrow offshore. Second, more than half of the country's outstanding credits were short-term in nature, with maturity of one year or less.[11] This would later prove itself to be an important factor in accelerating the tempo of the crisis in 1997.

Table 4.4: Foreign Debt

Year	1990	1991	1992	1993	1994	1995	1996	1997q2
Long-term (% to GDP)	18,594 (21.77)	22,147 (22.52)	23,976 (21.46)	26,948 (21.43)	32,236 (22.28)	37,029 (21.93)	50,609 (27.32)	53,124 NA
Short-term (% to GDP)	10,239 (11.99)	15,307 (15.57)	19,134 (17.12)	23,410 (18.62)	33,319 (23.03)	46,354 (27.45)	43,737 (23.61)	40,567 NA
Total (% to GDP)	28,833 (33.75)	37,454 (38.09)	43,110 (38.58)	50,358 (40.06)	65,555 (45.30)	83,383 (49.38)	94,346 (50.94)	93,691 NA

Source: IMF International Financial Statistics (IFS)

Nevertheless, this severe financial melt down could have been lessened, if not avoided, if at least one of the three policy mistakes was well taken care of. Without the premature liberalization of the financial institutions, they would have time to develop more expertise in the area and would be able to avoid making these serious mistakes. And even if

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[10] Krugman, (2001)
[11] Laplamwanit, (1999)

the premature liberalization of the financial market could not be avoided, the problem could still be contained if it was not because of the fixed exchange rate regime Thailand adopted at that time. Huge amount of capital inflow resulting from the capital market liberalization would have driven the currency to appreciate, and hence, hurting the export sector as well as the balance of trade. Therefore, the incentive for capital inflow would eventually decline. But with the fixed exchange rate regime, this automatic stabilizer of the economy was overwritten, making the Thai financial market a virtually risk free market for profit earning. Finally, even with the premature liberalization of the financial institution in the market with fixed exchange rate regime, the severity of this problem could still be limited if the authority involved had managed to provide prudent supervision of the financial institutions. The problems of overlending, non-performing loans, and risky investment behaviours could have all been avoided.

4.2.3 Asymmetric Information and Over-Investment

In the past, the Thai public sector had a rather effective control system for the size and the maturity structure of its foreign debts by using the combination of foreign debt ceiling, currency mix, and the management of the repayment schedules. However, in mid-1990s when most of the foreign debts were private, the Thai authority made a major mistake by failing to impose sufficient disciplines for controlling debt creations. Along with the problems of asymmetric information, the deep-rooted financial trouble originated.

In economics, information asymmetry occurs when one party to a transaction has more or better information than the other party. George Akerlof used the term *asymmetric information* in his 1970 seminal work, "The Market for Lemon." On the most abstract level, asymmetric information refers to a market process in which bad results occur due to information asymmetries between buyers and sellers, i.e. the 'bad' products or customers

are more likely to be selected.[12] There are generally 2 problems that could occur as a result of asymmetric information[13]: moral hazard and adverse selection. Moral hazard is a concern generally arising in the post-contract (e.g. an insurance policy, a debt guarantee) context. It refers to the increase risk emerges from problematical behaviours a participant may be engaged in, if that participant does not suffer the full, or any, consequences of his/her action. [14] In the case relating to debts, rescue operations carried out by governments, central banks, or consortiums of financial institutions can often encourage risky lending, if creditors realize that they will not have to take losses in case some serious problems occur.[15] Adverse selection, in contrast, concerns the pre-contract context of signalling and screening.[16] In a financial market where there is non-perfect information (i.e. loan making), it is often that the borrowers have better information about their risks and the financial institutions are pressed to make loans based on the information provided by the borrowers. In such cases, borrowers with high risk tend to be better off, as they will be able to put forward a business plan with higher rate of returns, and thus, increase their chance of securing the loan.[17] As a result, the market ends up with investors with high risk, causing the financial market to become very sensitive to economic shocks.

For the case of Thailand in 1997, the problem of moral hazard in the banking sector could be viewed from two different perspectives[18]: the creditors and the lenders. From the bankers' point of view, because they believed that the BOT would always bail them out if things went wrong; they became less careful about lending to risky and speculative projects. While from the depositors' viewpoint, as they were aware of the BOT's implicit guarantee of their deposits, they realized less need in observing the behaviour of their banks. Hence,

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[12] Economic A-Z, Economist.com
[13] Frexias and Rochet, (1997)
[14] Lipsey. (2004)
[15] Fisher, (2001)
[16] Economic A-Z, Economist.com
[17] Laplamwanit, (1999)
[18] Williams and Nguyen, (2005)

moral hazard in the banking sector resulted in an even more severe problem of over-investment in the unproductive and speculative sector of the economy.[19]

Nukul's Commission Report (1998) alleged that the BOT had, historically, always taken the role of the lender of last resort for failed financial institutes, especially between 1983 and 1986, when many commercial banks ran into trouble as a result of the second oil crisis. Several banks including Asia Trust, Siam City Bank, and First Bangkok City Bank, as well as several finance companies, faced serious financial trouble and needed government assistance under the April 4th 1984 lifeboat scheme. Subsequently, in 1985 and 1986, the government also assisted another two commercial banks, i.e. Bank of Asia, and Krung Thai Bank.

However, a more recent case of Bangkok Bank of Commerce (BBC) had been the case that greatly enhanced the public belief on this role of the BOT. The problem of the BBC was first discovered in a bank examination ran by the BOT on April 30th 1991, which revealed the non-performing loans as high as 18.2 billion Baht, accounting for 26.73 percent of its total assets; 3.6 times above the industry average. However, no strong action was imposed. Although the BOT was empowered to order the BBC to write off bad assets or reserve against those assets, the BOT merely ordered the BBC to draw up a strict plan to increase its capital. By March 1993, the situation of the BBC had worsened. The non-performing loans had risen to 38.5 billion Baht (39.57 percent of its total assets). Further examinations showed that many of these non-performing loans were the results of fraudulent behaviours, for example the approval of overdraft loans to BBC senior executives without any contracts or collaterals, or the approval of loans valued higher than the authorised level. Reacting to these problems, the BOT drew up a capital increasing plan for the BBC so that it had to increase capital by 3 billion Baht by June 1995, and another 3.7 billion by the end of 1996. However, the capital increase was slow, while the non-performing loan problem rose even further. On August 5th 1996, the BOT had to order the

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[19] Frexias and Rochet, (1997)

BBC to increase its capital by another 22.5 billion Baht, but still without requiring prior capital write-down, and ordered the Financial Institutions Development Fund to buy all the new shares in the interim.

The BOT rationalised its actions by explaining that, at the time, the BBC was the only bank facing problems, and the economy was still in good condition. Therefore, the BOT would be better off employing a soft solution with the attempt to recover debts and dealing with the management of the bank quietly in order to prevent public from fears and panic. However, when the news spread, these actions further confirmed the public belief that the BOT would always bail out any financial institute, and hence, depositors' money would be safe.[20] On From the commercial bank point of view, although the creditors of these financial institutes did not receive explicit guarantees from the government, they did believe that they would be protected from the risk, an impression reinforced by the strong political connections between the owners of such institutions and the politicians.[21]

To most economists (whom Paul Krugman was among one of them), the combined conditions of the public belief that the BOT would bail out financial institutions in trouble and the premature liberalization of the financial market would undoubtedly pose a serious problem of moral hazard. The case of Thailand was not an exception. It was not long before Thai financial institutes began to engage in risky lending behaviour. Banks and financial companies competed with each other in extending loans and one of the ways of doing so was by lowering the requirements for loan applications.[22] As a result, the credit to deposit ratio for commercial banks had risen from the level well below 1 in 1990 to 1.35 in September 1996.[23] The period from 1993 to 1996 became the prime years for Thai banking sectors. More than 50 banks and non-bank financial institutions were established. Most of them were doing so well that Thai banks were ranked among the world's most profitable

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[20] Nukul's Commission Report, (1998)
[21] Laplamwanit, (1999)
[22] Laplamwanit, (1999)
[23] Nukul's Commission Report, (1998)

banks as they could charge up to 4 percentage points difference in interest rate for loans and deposits, a discrepancy which was 4 times bigger than the spread of less than 1 percent in the banking system of many developed economies. Thailand reached the lending boom phase; the average debt/equity ratio among the listed non-financial companies rose from 1.58 to 1.98 between 1994 and 1996.

The BIBF operations and the skyrocketing loan extensions initially caused local interest rates to fall from 1992 to 1994. The interbank rate fell from above 10 percent to only around 7 percent. This interest rate cut helped ease domestic liquidity, thus, encouraged further investment. However, with the problem of adverse selection in the banking sector (in which investors have better information on their investment projects, and therefore are able to deceive financial institutes to make loans to risky projects that can offer higher rates of returns), a large proportion of those BIBF capital inflows went into speculative and non-productive investments (such as in the real estates and stock market), therefore, sending asset prices, including land and stocks, to abnormally high levels. Only a small fraction of the total capital inflows at that time could be categorized as foreign direct investment, the main objective of the financial liberalization in the first place. Consequently, the share of foreign direct investment declined over time, from 33.57 percent of the total current account financing in 1990 to 15.90 percent in 1996.[24]

This euphoria of bad investments and risky lending behaviours became more severe as time went by. Financial institutes preferred lending to firms that use real estate as collateral, since land prices were rising so rapidly it was almost a guarantee that the increase in prices of those assets would catch up with the accumulation of interests. By 1995, the Bangkok office vacancy rate was around 20% and yet real estate developers continued to borrow and build. It was planned that another 32,087,730 square meters of office unit would be entering the market before the end of 1997.[25] By this time, concerns

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[24] Bank of Thailand
[25] Dollar and Hallward-Driemeie, (2000)

had been raised to the Bank of Thailand stating that no matter how fast Thailand's growth was, it would be very difficult for those additional spaces to be filled. This plethora of bad investment projects provided a clear warning sign that the economy was overheating, and the bubble in the economy was developing.

To amplify the problem, the prolonged economic boom, the bubble in real estate and stock market, and the large inflows of foreign funds had all contributed to the raising of the domestic inflation, and the price level. Therefore, in the viewpoint of producers, it became more attractive to produce products for domestic consumption, rather than to produce for exports that would require competing in the more competitive world market. Hence, much of those non-speculative investments went into domestic protected sectors and non-tradable sectors (such as steel and petrochemicals), instead of the tradable sectors. Therefore, the country's competitiveness decline, the national volume of exports reduced, and consequently, Thailand's balance of trade deteriorated.

4.2.4 Currency Attacks

It was not until 1995 before the Bank of Thailand started to realize the problem of overheating economy, especially in the real estate sector. Attempts to slowdown the economy were carried out by the tightening of the monetary policy through increasing interest rates. However, as the interest rates increased, the spread between the local and foreign interest rates became even higher, giving greater incentive for foreign investors to bring more funds into the country. As a result, this measure not only failed to decelerate the economy, but instead, caused foreign borrowing to increase even more rapidly.[26]

After the second half of 1996, concerns about the sluggish export growth, the bubble economy, and the over-valued currency had become widespread. Currency speculators started some sporadic attacks on the Baht, as they expected Thai authorities

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[26] Nukul's Commission Report, (1998)

would soon adjust the exchange rate in order to deal with the economic difficulties. However, the Bank of Thailand sought to resist these depreciation pressures, albeit it was clear that cheaper Baht would increase the Thai export competitiveness. In the Federal Reserve Bank of San Francisco Economic Letter of November 1997, it was mentioned that this decision of resisting depreciation by the BOT was done due to several reasons. First, the long-term stability of the Baht had led many Thai borrowers to believe that there was no currency risk associated, and thus, they borrowed offshore without hedging their foreign currency exposure. The depreciation of the Baht would increase their debt burdens. Concerning the huge amount of foreign debt outstanding at the time, such an action would put too much pressure on the economy as a whole, and therefore, currency depreciation was not a feasible option both economically and politically. Second, a sharp depreciation of the Baht could lower the risk assessing of the country, and therefore, could have an effect on the cost of foreign borrowing in the future as foreign lenders would demand a higher risk premium for Baht volatility. Finally, a weaker Baht would tend to increase domestic inflation, hence, reducing the domestic purchasing power; an effect the Bank of Thailand did not wish to see at that time.

Confronted with these dilemmas, the Bank of Thailand chose to resist the depreciation pressures in a number of ways.[27] First, the BOT defended the Baht using international reserves and swap contracts. Second, the BOT also raised domestic interest rates in order to attract more capital inflow as well as making the Baht more expensive to borrow for the speculators. Finally, the BOT imposed measures that would restrict foreigners' access to Baht, so as to limit the amount of Baht they could dump into the market. However, these defences proved to become very costly to the economy later on. Under the fixed exchange rate system, the BOT needed international reserves to maintain the exchange rate at the desired level. These reserves could be classified into three accounts: foreign exchange reserve, exchange equalization fund reserve (EEF), and general

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[27] Nukul's Commission Report, (1998)

reserve. In Thailand, foreign exchange reserves are governed under the Foreign Exchange Act 1958 which required the BOT to have reserves in order to print currency notes. These reserves can be comprised of gold, foreign currency, foreign securities, or local promissory notes. Nevertheless, the domestic promissory notes must not exceed 20 per cent of the total amount. The Foreign Exchange Act 1958 also stated that these foreign exchange reserves must be separated from other assets of the BOT and could not be used for any other purposes except issuing notes. The second part of the international reserves, the EEF reserves, has the objective to maintain the stability of the foreign exchange rate to accommodate the economic and financial situation of the country. Broadly speaking, the BOT only uses the EEF as a "window" for trading in foreign currencies on a day-to-day basis. The EEF would be used to match the demand and supply of foreign exchange, and buy and sell the surplus or deficit in order to maintain the currency rate according to the basket weight. Finally, the third element of the international reserves, the general reserves, was the reserves that the BOT could use for direct intervention in the currency markets in case of currency attacks. On February 13th, 1997, the general reserve level was at 16.64 billion US dollar, accounted for 43.05 percent of the total reserve value of 38.65 billion US dollar.

However, during the period of defending the Baht (from July 1996 to July 1997), the general reserve was not the main instrument used by the BOT. Instead, the BOT preferred buy-sell swap contracts, where the BOT would initially buy US dollars and pay for them with Thai Baht, and after the agreed maturities, buy back the Baht with US dollar. Immediately after the speculation attacks, the BOT would use US dollar it acquired from the swap agreements to buy up the Baht that had been dumped into the market. In the BOT point of view, the swap contracts were a better instrument compared to the spot market as they wouldn't affect the amount of Baht in the circulation. Also, the swap system could conceal the impact on the foreign exchange reserves, and thus, prevent the public from awareness of the declining reserves. Unfortunately, this measure proved fruitless, as the swap commitments were abnormally large in size so that it was very noticeable to the public.

To make matters worse, the swap contract was not only unable to conceal the public from the fact that Thai Baht was being attacked, it also cancelled out the effect of the other Baht defending measures the BOT employed at the time. In normal circumstance, with any free market system, the market itself would be built with an automatic stabilizer that will ease out the effects of economic shocks. This same rationale also applies to the currency markets. Under the spot market system, if the BOT bought all the Baht dumped by speculators, the amount of Baht in the circulation would reduce, causing a tight money situation, and therefore, would result in the increase of interest rates. Combine with the BOT's measure of raising domestic interest rates, eventually, the interest rates would shoot up so high that the profits made from speculating Baht would no longer cover the opportunity costs losing from the interest rate forgone. However, swap contracts enabled the BOT to prop up the Thai Baht without reducing the Baht in circulation in the current period, as the Baht would be injected back into the system in the first leg of the swap activity. Thus, this overruled the market's automatic stabilizing process, as well as, the effect of the high interest rate policy imposed by the BOT itself. Furthermore, the swap analysis also overwrote the BOT's measure in restricting foreigners' access to Baht. Again, under the spot market system, the BOT's attempts in buying up Baht would suck Baht out of the system. In order for the speculators to attack Baht, they needed Baht on hand in order to dump it in the market, and thus, creating pressure for the Baht to depreciate. However, with less and less Baht in the market, the speculators would find it more difficult, as well as expensive, to acquire Baht, and would eventually have to abandon the attack. Unfortunately, with BOT releasing Baht in the first leg of the swap, Baht become available again in the offshore currency market. As a result, the swap neutralized any of the BOT's intervention attempts.[28]

Nevertheless, the worst consequence of using swap contracts was the fact that they are a forward commitment, and did not have an immediate affect on the figures of the

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[28] Nukul's Commission Report, (1998)

foreign exchange reserves account. Swap contracts allowed the BOT to borrow foreign currency to defend the Baht, and thus allowed the BOT to use more reserves than the sum of EEF and the general reserves, without violating the Foreign Exchange Act 1958. As a result, the BOT built up swap obligation valued almost as much as the total foreign reserves in its attempts to defend the Baht. The Nukul's Commision Report (1998) showed that by early June 1997, the total foreign reserves fell to 30.9 billion US Dollars, with 23.4 billion Dollars obligated to be delivered in the forward market over a 12-month period, leaving the net official foreign reserves to a mere 7 billion US dollar. The situation got worse during June and, by June 30th, the country's net official foreign reserves collapsed to only 2.9 billion US dollar. While the country had about 36.5 billion US dollar short-term foreign debt, and the current account deficit was running at about one billion US dollar per month. Moreover, the rising interest rates started to cause adverse effects on the economy as it dampened the economic activities, as well as, increased the cost of funds for existing borrowers. By the time Thailand abandoned the fixed exchange rate regime on July 2nd 1997, interest rates had risen to an exorbitant level. The steep increase in interest rates caused many firms with outstanding loans to fail to service their loans. Consequently, financial institutes suddenly faced with the problem of massive amounts of outstanding non-performing loans, as well as, the sharp decline in the demand, hence, prices of their collaterals. Therefore, the financial market suddenly plunged into great chaos.

4.2.5 Responses to the Currency Devaluation

Within the first 48 hours after the abandonment of the fixed exchange rate system on July 2nd 1997, the Thai Baht was devalued by 17 percent, from around 25 Baht per US dollar to 28.80 Baht per dollar. It then continuously went down since then until it reached its bottom at 48.80 Baht per dollar in December of the same year. With net official foreign reserves falling to only 2.9 billion US dollar and the short-term foreign debt figure a massive 36.5

billion US dollar, Thailand was, in principle, bankrupted. Given its foreign currency obligation, Thailand simply could not participate economically in the international community without sufficient foreign reserves. Therefore, seeking assistance from the International Monetary Fund (IMF) became unavoidable.

In order to facilitate the economic recovery, tackling the problem of the almost complete depletion of foreign reserves had to be put as the main priority.[29] The IMF put together a lending package of 17.2 billion US dollar, with 4 billion coming from the IMF's own funds, and the rest being contributions from other sources, including countries from Asia Pacific Region, the World Bank, and the Asian Development Bank. However, the IMF package was meant only to be a relatively short-term liquidity support, with repayment for each drawing due in three years. Thus, IMF had imposed a stringent reform package aimed at turning around the foreign reserve position of the country in a short period of time. With the belief that a strong and stable financial sector is a pre-requisite for economic recovery, the IMF imposed many measures to restructure and reform the financial sector, including the passing of new laws on bankruptcy procedure and foreclosure, as well as, upgrading the prudential regulations (in particular on definitions and classifications of NPL, provisioning requirements, and capital adequacy ratios). As a result, between November 1997 and August 1998, fifty-eight troubled non-bank financial institutes were suspended and, in addition, 4 failing commercial banks were also forced through the acquisition procedures. These measures created a panic across depositors and creditors.[30] Eventually, the government had to impose a full deposit insurance system in order to contain tranquillity in the financial market.[31] However, because of the cash flow situation of the time, depositors of those failed institution would only receive their money back through a 5-year repayment schedule. Therefore, the problem of tight liquidity was still unavoidable.

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[29] Lane *et al.*, (1999)
[30] Stiglitz, (2001)
[31] Laplamwanit, (1999)

Apart from the closure of financial institutes, the IMF also imposed austere monetary and fiscal policies. Such policies would later be heavily criticized as having shoved the economy even deeper into recession. IMF had successfully recovered the crises in Latin America in 1980s (when bloated public deficits and loose monetary policies had led the countries to runaway inflation) by employing the same package of fiscal austerity and rigid monetary policies. However, given the totally different fundamental problem in Thailand, where the mistakes were not created by the imprudent government, but rather the imprudent private sector, as well as, where the government had already been running budget surpluses, monetary policy had already been so tight that the deposit saving rate was as high as 12 percent per annum, and inflation was at the respectable rate of 5 percent, the IMF's remedy package was inevitably been criticized as a "one medicine cure all" approach. Joseph E. Stiglitz pressed his concern in his article "What I Learned at the World Economic Crisis"[32]:

> *"Under such circumstances, I feared, austerity measures would not revive the economies of East Asia--it would plunge them into recession or even depression. High interest rates might devastate highly indebted East Asian firms, causing more bankruptcies and defaults. Reduced government expenditures would only shrink the economy further."*

As a result, by September 1997, short-term interest rates increased by almost three folds from the pre-crisis levels, and stayed at a high level until the third quarter of 1998 (Table 4.5, overleaf). Also, the tight fiscal policies led to the significantly worsening of the socio-economic condition, especially in the social safety net programs, education, and infrastructure, which are the essentials for the economic growth. Unemployment shot up from 497.6 thousands person before the crisis to 1,423.3 thousand in 1998, whilst the underemployment also increased from 580.7 thousands to 938.4 thousands in 1998. Tight monetary and fiscal policies combined with the closure of financial institutions created

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[32] Stiglitz, (2001)

severe credit crunches in the financial market. Many surviving firms (lucky enough not to be affected by the debt problems) saw the new opportunities created by the improvement in competitiveness due to cheaper Baht, but nevertheless, had to face this new set of credit problems which prevented them from further investments. As a result, the economy failed to benefit from the improvement in competitiveness as it should have. Thailand GDP growth declined from 5.9% in 1996 to -1.8% in 1997, and slumped down to -10.4% in 1998.

Table 4.5: Interest Rates (per cent per annum)

		Repurchase Rate	Inter-Bank Rate	Prime Rate
1997	April	9.06	8.75	12.75 - 13.0
	May	11.37	12.13	12.75
	June	12.75	15.10	12.75
	July	17.26	18.66	13.75
	August	14.89	15.43	13.75
	September	23.28	23.87	14.25
	October	14.74	18.72	14.75
	November	17.99	19.99	14.75
	December	22.36	21.73	14.63
1998	January	22.94	21.51	15.75
	February	20.81	19.83	15.75
	March	21.00	20.57	15.75
	April	18.81	19.11	15.75
	May	16.38	16.40	15.75
	June	17.43	18.58	15.75
	July	14.18	11.72	15.75
	August	10.35	9.81	15.25
	September	7.09	7.02	15.00
	October	5.37	5.35	14.25
	November	4.62	3.55	12.25
	December	3.75	2.63	11.5 – 12.0
1999	January	3.37	2.73	11.0 – 11.5
	February	3.18	3.09	10.0 -10.5
	March	2.15	2.25	9.5 – 10.0

Source: Bank of Thailand

Finally, by late 1998, the IMF admitted that it had badly misjudged the severity of the economic downturn of Thailand.[33] The first Letter of Intent that the Thai government signed with the IMF in August 1997 expected a positive real GDP growth of 3.5 percent, a current account deficit of 5.3 billion US dollar, and a capital account surplus of 1.8 billion US dollar for 1998. Unfortunately, these numbers turned out to be completely opposite to the

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[33] Ghosh and Phillips, (1999)

actual figures, with the real GDP growth of - 8.4 percent, a current account surplus of 14.3 percent, and a capital account deficit of 9.6 percent. It was clear by this time that the IMF had too much faith in the market confidence that would result from its program. It expected the economy to run current account deficit as it did not expect the depreciation of the Baht to continue and worsen. Also, it expected surpluses in the capital account as it had seriously overestimated the rollover of the country's short-term external debt. With such expectation on the current account deficit, the IMF believed that the ways Thailand would recover its foreign reserves were through 1) the employment of stringent fiscal and monetary policies in order to control the current account, 2) the generation of a high rollover rate of short-term foreign debt, and 3) the attraction of new medium- and long-term investments through foreign buyouts of domestic enterprises and privatization of state enterprises.

If the IMF had predicted the economic scenario closer to what subsequently happened, it would have chosen much easer fiscal policies (particularly for the social safety net programs) so the reduction in the GDP, the increase in unemployment, and the underemployment would not have been so severe.[34] In addition, the monetary policy would have been tight in order to control inflation (so that the potential benefits of a weaker Baht would not be wiped out), but not so much that it would harm the investment environments, which actually happened during that period. The current account surplus would have been higher as firms became more competitive from the Baht devaluation. On the other hand, a looser monetary policy, and hence, a small reduction in the interest rate, would not affect much net capital outflow, as the high interest rates were hardly sufficient to create incentives for the markets to keep their money in a country where the net foreign reserves have almost been depleted.

Unfortunately, by the time the IMF admitted its mistakes and adjusted its policies, the Thai economic crisis had already worsened. Given the substantial time lags for both

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[34] Stiglitz, (2001)

fiscal and monetary instruments, it meant that the Thai economy had to suffer an unnecessary severer and lengthier effect of the crisis than what it should have been.

4.3 Impacts of the Economic Crisis

The economic impact of the 1997 crisis affected Thailand very broadly and deeply, though the impacts have been uneven between different sectors. The Thai economy experienced severe adjustments in many ways; the more obvious examples are the exchange rate regime and the restructuring in the financial sector. The economic growth had recorded contractions, which was the condition that the Thai economy had not experienced for the past 15 years. This was partly the result of the declining domestic demand, both on the consumption and investment side. The failure of financial institutions had also led to the tight liquidity condition, combined with the decrease in demand; this had resulted in the widespread collapse and insolvency of domestic businesses. Many industries found themselves in severe excess capacity and attempted to shake off employees, which had led to an immense increase in the number of unemployed and underemployed. The substantial decrease in income had brought about the reduction in personal consumption, then again, reduced the market demand even further. Also, the reduction in personal and corporate income lessened government revenue, and therefore government spending, which sequentially reduced the total output of the economy. Finally, the drastic currency depreciation, along with liquidity crunch, brought about inflation and increase cost of living.

Figure 4.1 sketches the detailed time line of the 1997 economic crisis. Using July 2nd 1997 (when the fixed exchange rate regime was abandoned) as a divider, the incidents on the left hand side were explained previously in Section 4.2, as the genesis of the crisis. Also, the incidents between July 2nd 1997 and August 1998 were explained in Section 4.2.5 as the mistakes in authorities' response to the currency devaluation that had shoved the economic

Figure 4.1: Time Line of the 1997 economic crisis (3)
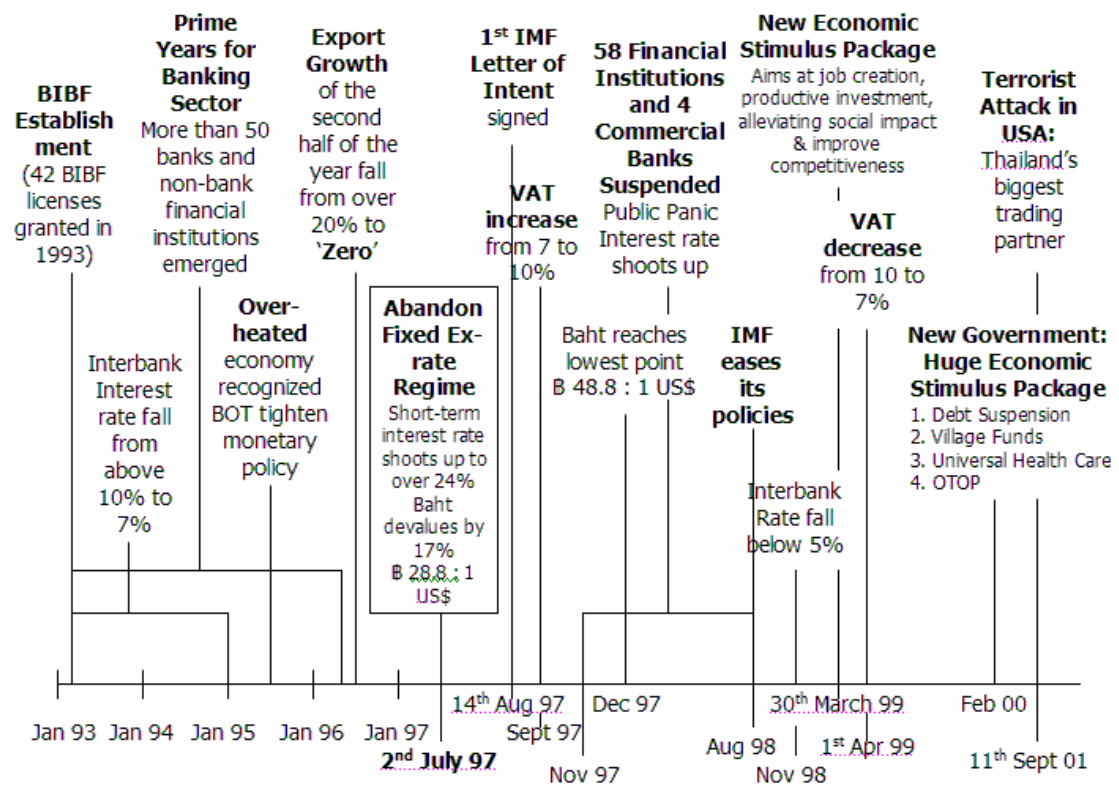
recession into the economic crisis. Nevertheless, this crisis had generated some positive factors for which they alleviated the adverse effects on the economic condition. First, the export expansion, resulting from Baht depreciation, had prevented the economy from contracting even further. In addition, the currency depreciation had made import goods became relatively more expensive, thus reduced demand for imports, and therefore improved the balance of trade. The improved balance of trade, combined with the low domestic demand, helped restraining the inflation rate from rising too much. Combined with the assistance from the two economic stimulus packages the Thai government imposed on March 1999 and February 2000, Thai economy started to recover. However, such recovery was punctuated briefly by the September 11th terrorist attack in the United States (Thailand's biggest trading partner), which resulted in another round of world economic recession.

The following sections will examine the impacts of the crisis on two important issues: economic growth, and employment.

4.3.1 Economic Growth

The overall GDP growth (Table 4.1) declined significantly from 5.9 percent in 1996 to -1.37 percent in 1997, and further to -10.51 percent in 1998. The non-agricultural sectors had experienced much larger negative impacts than the agricultural sector. Among the non-agricultural sectors, the construction sector experienced the largest negative impact in the period following the crisis. The manufacturing sector had also been heavily hit, though the impacts were uneven within the sector.

4.3.1.1 <u>Agricultural sector</u>

The agricultural sector had registered slight negative growth from the third quarter of 1997 until the second quarter of 1998 compared to the same quarter in the previous year (Figure 4.2), but has continued to grow after that, despite some periods of weather disturbance (i.e. drought, flood). It had experienced less turbulence from the crisis due to the beneficial of Baht devaluation, resulting in the increase in export volume from 160,312 and 167,131 millions Baht in 1995 and 1996, respectively, to 183,962 and 211,092 millions Baht in 1997 and 1998, respectively. However, by 1999 the affect of the devaluation faded away, and the export volume fell to 184,947 millions Baht. In order to promote the recovery of the economy beyond the benefits of Baht devaluation, on February 1999, the Ministry of Agriculture had implemented a recovery package involved measures to enhance production efficiency, export competitiveness, and management system[35].

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[35] Details can be found in the Bank of Thailand's Annual Economic Report 1998, p. 12-14

Figure 4.2: Quarterly Gross Domestic Product at 1988 Price

Agriculture
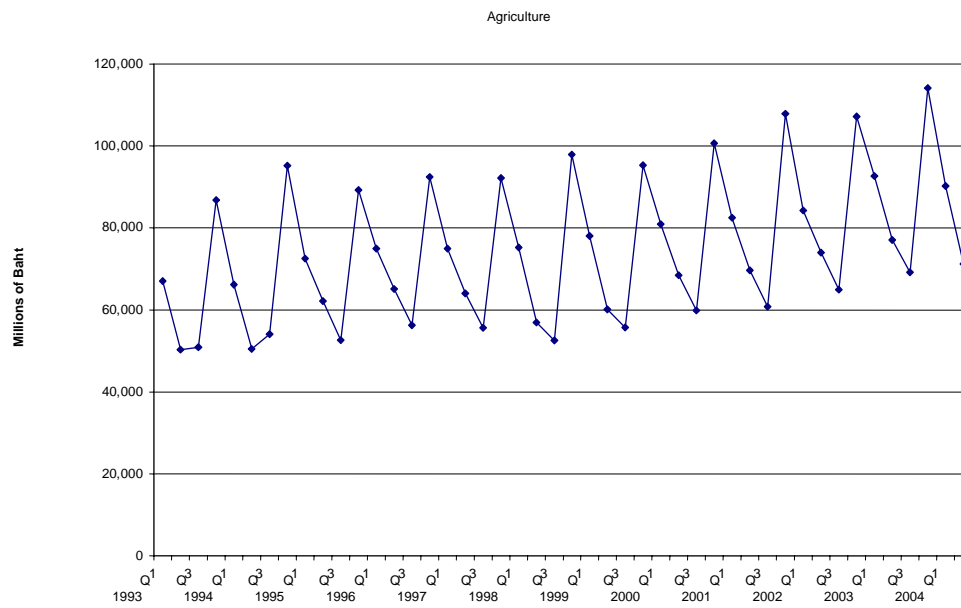
Source: Bank of Thailand

Figure 4.3: Quarterly Gross Domestic Product at 1988 Price

Non-Agriculture
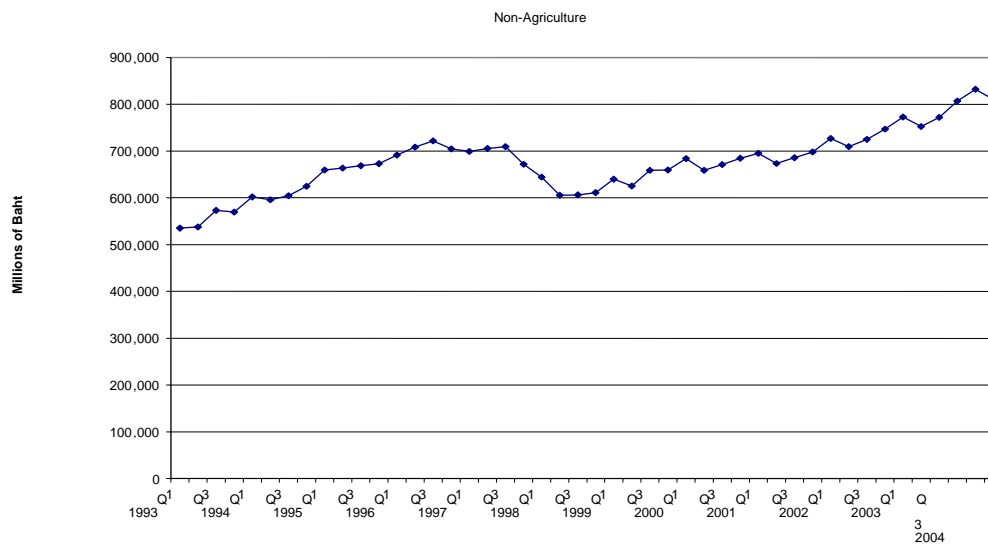
Source: Bank of Thailand

4.3.1.2 <u>Construction sector</u>

This was the sector that experienced the most severe negative impact from the economic crisis. Since the late 1980s up until before the crisis in 1997, the construction sector had experienced dramatic growth, as a result of growth in real estate sector. However, by early 1996, the supply in this sector had become much higher than the real, non-speculative demand. The office vacancy rate was more than 20 percent in Bangkok municipal area, while other types of construction were also facing with similar problems. By the time of crisis in July 1997, it had become clear to the public that there exist a large gap between the demand and supply of this sector. With the huge amount of excess capacity, the vanishing speculative demand, the contraction in real demand (as a result of high domestic interest rate), and the liquidity shortage (faced by consumers seeking mortgages), the bubble in the real estate sector had finally busted. Many building projects were discontinued because of the liquidity shortage, as well as because there was not enough demand to keep them continued. Many unfortunate companies were forced to declare bankruptcy as they could not service their higher external debts resulting from the devaluation of the Baht. Thai construction sector experienced the first decline in its GDP share for more than a decade. The construction sector contracted considerably by 21 percent in 1997, and then by 35.9 percent in 1998.

However, the sign of recovery in the construction sector came in 1999. Although the growth rate of the sector was still in the negative region, the devastated effect of the economic crisis has started to fade out. The GDP of the sector contracted by around 8 to 9 percent in both 1999 and 2000, much lower compared to the reduction of more than 35 percent in 1998. The main reason for this improvement came from the improvement in the overall liquidity since the second half of 1998, which allowed interest rates to lower. However, financial institutes were still very cautious about extending credits. Also, problem of non-performing loans was still persisted. By 2001, the growth rate of the GDP had finally

bounced back to the positive region. The liquidity in the financial system remained high in 2001, interest rates had lowered further, the problem of non-performing loans had also been solved, and financial institutions began to compete in the extension of housing credits.

Figure 4.4: Annual Gross Domestic Product at Current Price
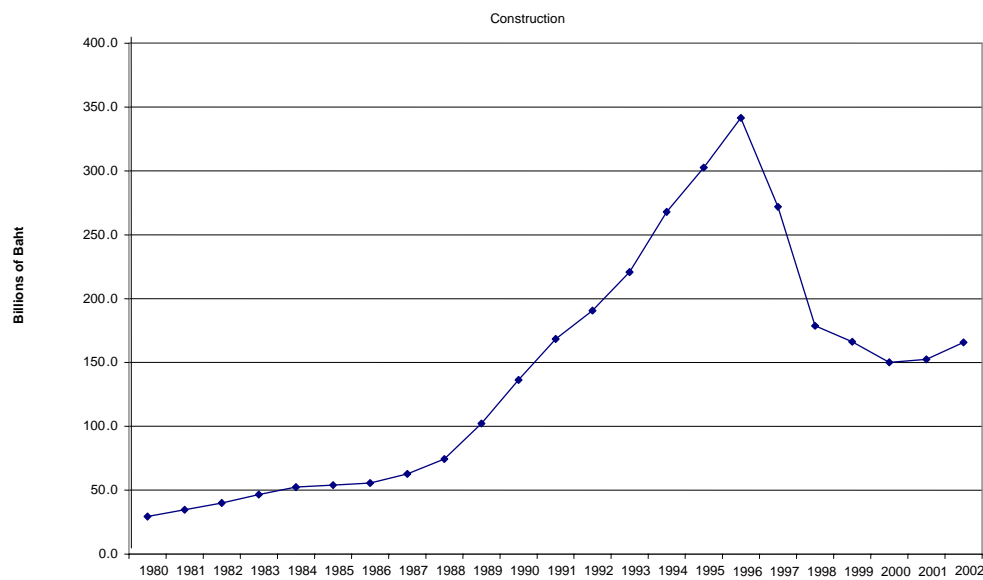
Source: Bank of Thailand

From the market supply side, the successful progressed in debt restructuring since 1999, combined with the improvement in the overall liquidity since late 1998 had enable the revival of many companies, which had once ceased operation due to debt problems. However, the recovery was not yet come in full until 2001, when household incomes started to experience full recovery in tandem with the overall economic recovery. Therefore, home-owning become much more affordable from the consumers' point of view.

4.3.1.3 Manufacturing Sector

In 1998, the Thai manufacturing sector experienced a negative impact from the 1997 economic crisis. The overall manufacturing production fell by 10.8 percent, a sharp contrast

to an increase of 7.8 in 1996, and an increase of 0.2 percent in 1997. Such a negative growth could be observed across most production segments, except for textiles which continued to expand. Major factors contributing to this downturn were[36]: 1) the contraction in domestic demand, both on consumption and investment due to the crisis; 2) the liquidity shortage faced by producers and exporters; and 3) the ongoing financial crisis in the East Asian region. The effects of this crisis also spred across the rest of the world, creating recessions in many other economies, which causing only marginal improvement in Thailand's export performance, despite substantial depreciation of the Baht.

Domestic Oriented industries

Sectors that experienced the most severe downturn were the domestic oriented sectors (export less than 30% of the total production), such as construction materials, vehicles and transport equipments, and iron and steel products (figure 4.5, 4.6, and 4.7). The production of construction materials exhibited a slight decline of 3.25 percent in 1997; followed by a great contraction of 38.2 percent in 1998, in accordance with the sluggish construction sector. Factor contributing to this decline were 1) the excess supply in the real estates, 2) decline in government construction projects following the moderation of budgetary disbursement since the end of 1997, and 3) the liquidity shortage that caused some producers in this sector to gradually stop their production lines in order to lower costs of merchandise stock accumulation[37].

The vehicles and transport equipments sector experienced sharp declined in both 1997 and 1998, the production fell by 26.51 percent in 1997, and further reduced by 54.03 percent in 1998. Although the decline in Baht had improved the competitiveness of this sector in the world market, and thus increased the export volume, they only account for

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[36] Bank of Thailand, (1999)
[37] Bank of Thailand, (1999)

about 20 percent of the total production, and were not sufficient to offset the impact of domestic demand contraction.

Figure 4.5: Manufacturing Production Index

Construction Materials
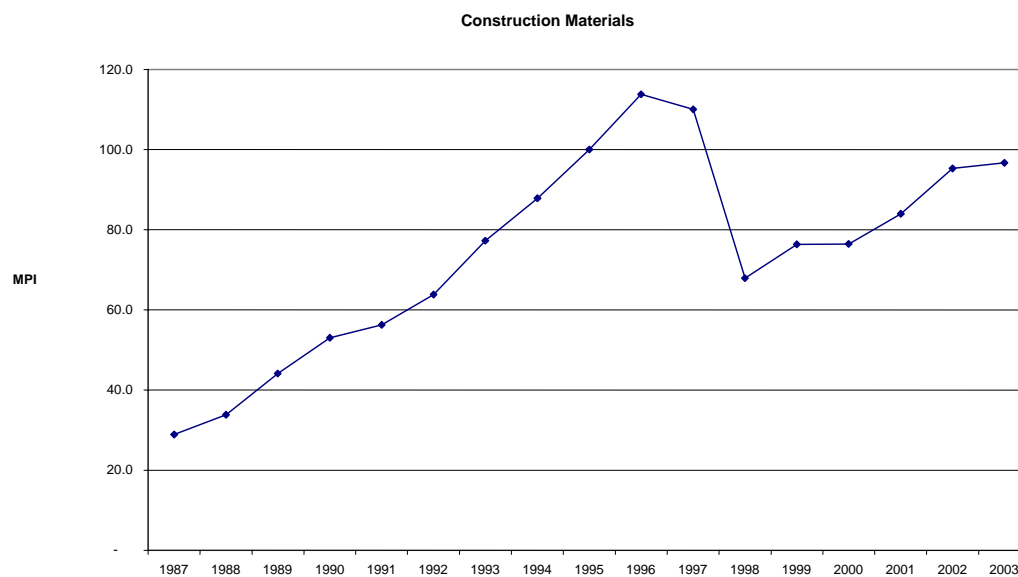
Source: Bank of Thailand

Figure 4.6: Manufacturing Production Index

Vehicles and Equipments
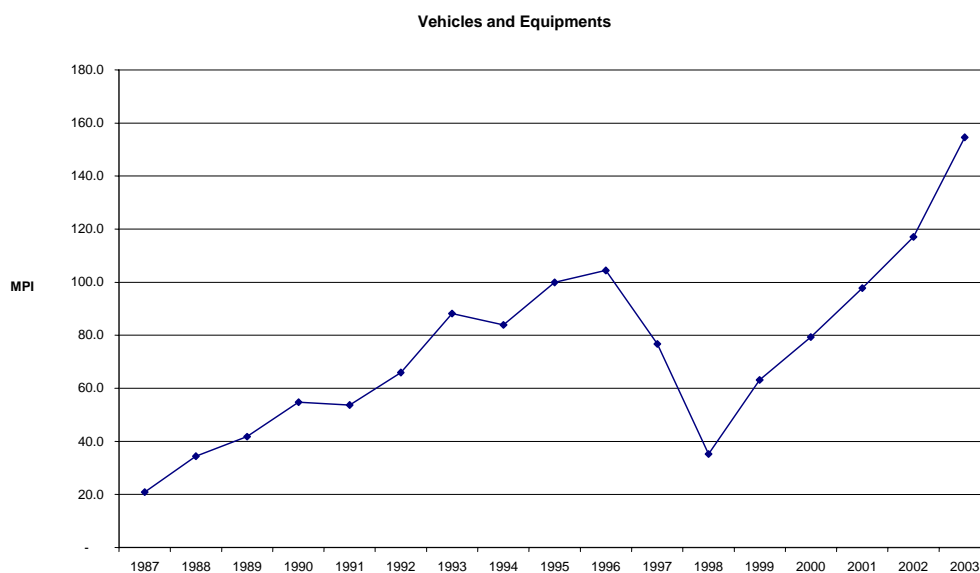
Source: Bank of Thailand

Figure 4.7: Manufacturing Production Index

Iron & Steel Products
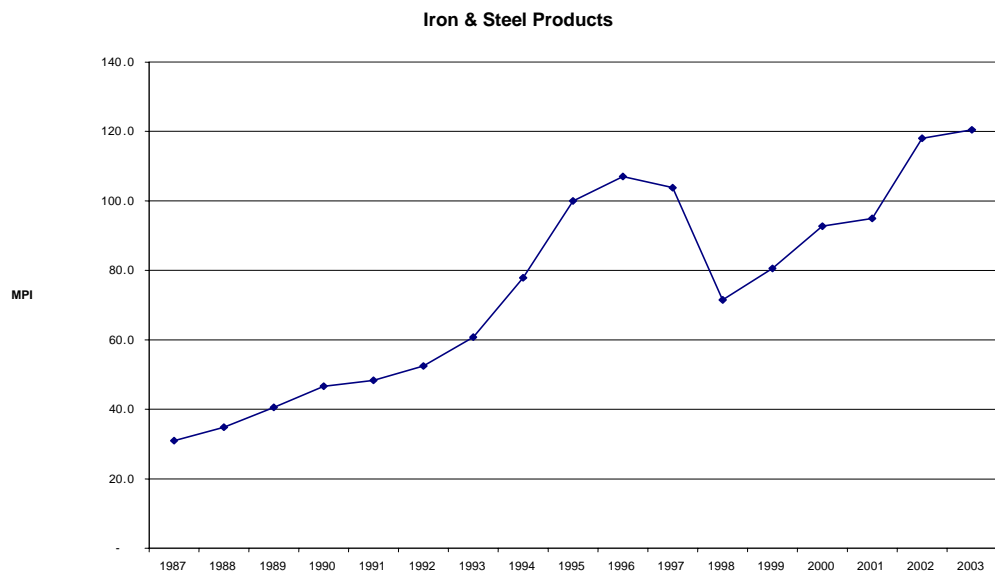
Source: Bank of Thailand

Iron and steel products sector, being the intermediate products for the declining industries (such as vehicles and transport equipments) and the declining sector (such as constructions) had inevitably experienced a decline in their production. The industry production contracted by 3.08 percent in 1997, and worsened to 31.02 in 1998. Traditionally, Thai steel producers relied heavily on loans to support their expensive investments. With the severe liquidity problem in 1997 and early 1998, many steel producers found themselves in a situation that is much more difficult to service their higher cost of loan repayments, hence resulting them to have no other option but to either cease their operation or to enter the debt restructuring process.

Export Oriented Industries

The export oriented industries (with more than 60 percent of productions being exported) were affected by the economic crisis in a much lesser extent. Although majority of the

producers in these industries had also experienced difficulties resulting from the crisis (i.e. very tight liquidity situation, severe shortage of funds, and decreased in inter-firm domestic trade credits), the depreciation in Baht had improved their competitiveness in the export markets, and hence had, to some extent, been able to weaken the negative effect of the crisis. Compared to the domestic oriented industries, industries in the export oriented sector experienced a much smaller declined in their productions. Also, many of these industries' productions returned at least to (but mostly significantly exceeded) their long-term trend in just one year after 1998, when the problems of liquidity and non-performing loans were solved. Nevertheless, one common trend most of these industries shared was the rather sharp decline, except the jewellery productions, in the growth in production between 2000 and 2001, as the result of world sluggish economic following the September 11th terrorist attacked[38].

Figure 4.8: Manufacturing Production Index
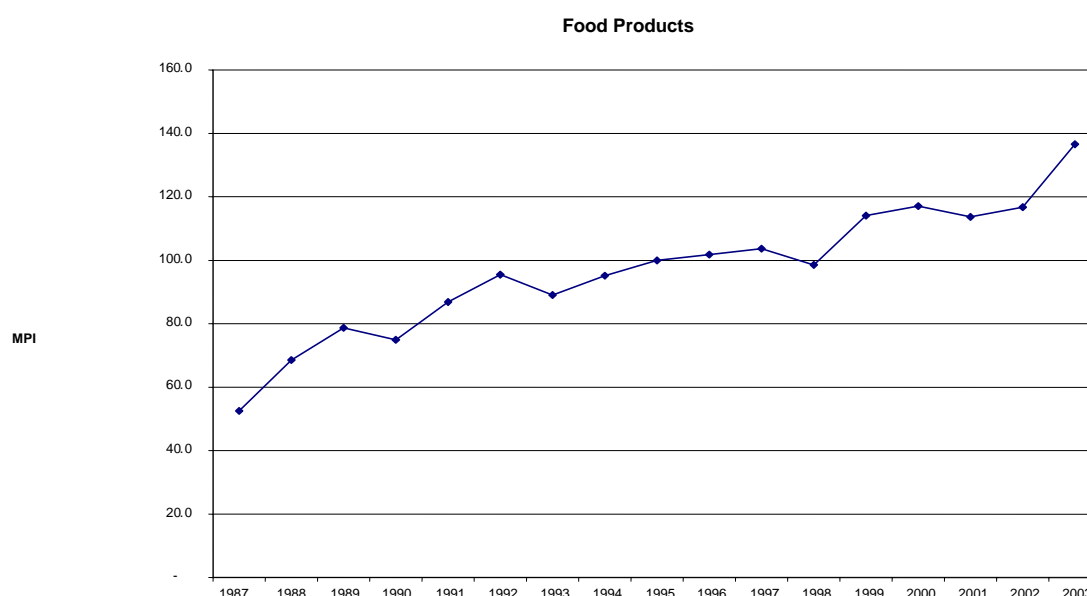
Food Products

Source: Bank of Thailand

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[38] Bank of Thailand, (2003)

Food productions (Figure 4.8) had experienced a slight growth of 1.77 percent in 1997, before a moderate declined of 4.92 percent in 1998. However, this slump might be owing to the shortage and low quality of raw materials, following the unfavourable climate condition in the country during that period, particularly, in the canned fruit and sugar industries, which are the major export products of Thailand. For 1999, the production reverted back to its long-term growth trend, before facing another slowdown in 2001 following the September 11th event.

The electronic sector (Figure 4.9) had experienced two consecutive years of moderate decline growth. The productions contract by 5.78 and 13.77 percent in 1997 and 1998, respectively. Although the devaluation of the Baht had improved Thailand's competitiveness, however the problems of non-performing loans were still severe among the producers in this sector. During the early 1990s, Thailand had become an important exporter of the electronic products in the world market, due to the cheaper labour costs. In addition, the liberalization of the capital account in the early 1990s had encourage many investors to borrow from aboard and invested in the fast growing electronic sector. Thus, resulting in a huge number of producers in this sector engaged in foreign currency debts. During the financial crisis in 1997 and 1998, these producers found it more difficult to service their loans, and were forced to cease their productions until the debt restructuring program had been negotiated. Therefore, resulting in the contraction of production stated earlier. By the last quarter of 1998, many businesses were able to resume their operation, thus a significant improvement in the production could be seen. The manufacturing production index grew by a respectable level of 12.04 percent in 1999 and a remarkable level of 31.54 percent in 2000, placing the production level back to the level envisaged by long-term trend. Unfortunately, this growth was greatly disrupted again by the effect of the terrorist attacked in September 2001.

Figure 4.9: Manufacturing Production Index

Electronic and Electrical Products
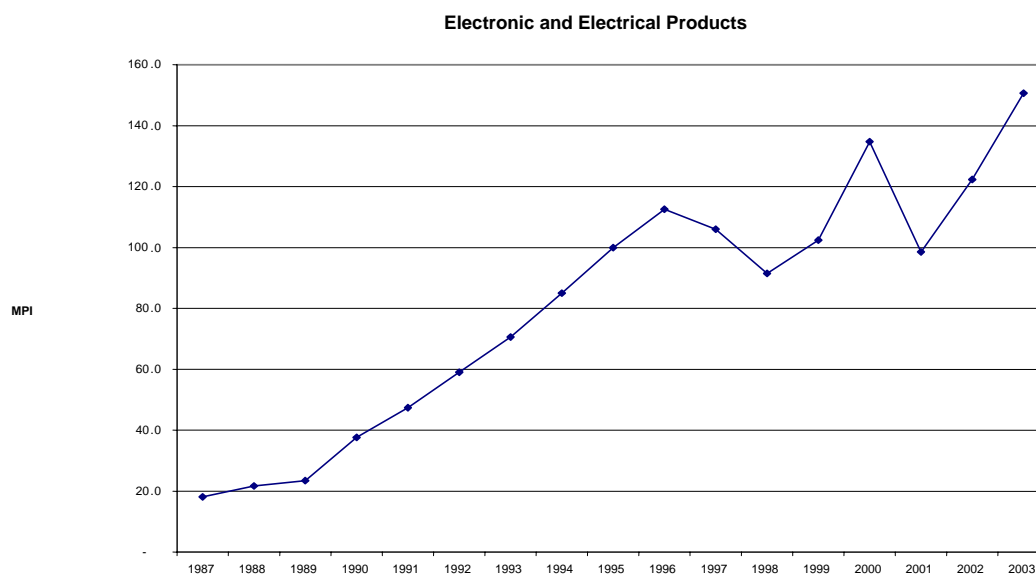
Source: Bank of Thailand

Figure 4.10: Manufacturing Production Index

Integrated Circuit
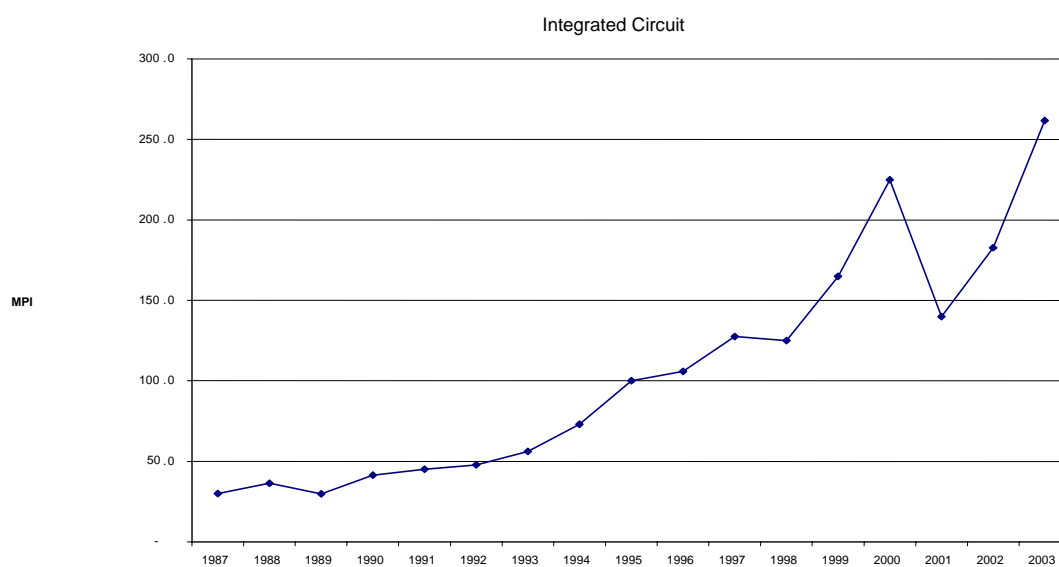
Source: Bank of Thailand

The integrated circuits industry (figure 4.10) had been hit briefly by the economic crisis in 1998, where the production shrivelled slightly by 2.04 percent. Similar to the electronic sector, this industry had benefited from the devaluation of the Baht, but at the same time suffered from the credit crunch problems. After the non-performing loan issues had been solved in the last quarter of 1998, the industry experienced the full benefit of devaluation, and thus enjoyed the impressive growth of 31.92 percent in 1999 and 36.39 percent in 2000, before being affected by the world economic recession in 2001 as a result of the terrorist attacked.

Figure 4.11: Manufacturing Production Index

Jewellery

Source: Bank of Thailand

Despite a small declined in production in 1997, the jewellery industry (Figure 4.11) had enjoyed an immense growth during the most difficult years of the economic crisis. In 1997, this industry faced with a slight contraction of 3.13 percent, but then enjoyed a notable growth of 33.60 percent in 1998, followed with a slower growth of 14.41 percent and 28.53 percent in 1999 and 2000. Like most of the export oriented industries, this growth was interrupted by the sluggish economic conditions caused by the terrorist

attacked in the United States, Thailand's biggest export market. However, exports to other important markets such as the United Kingdom, the European Union, and Japan were still expanded favourably, as a result of the government export promotion package in exemption of import duty on 11 items of jewellery and ornament raw materials.

Industry that export between 30 to 60 percent of total production

Industries in this group experienced similar growth pattern during the 1990s. The majority of them enjoyed production expansion during 1990 to 1993, then a significant boom during 1994 and 1995, with the exception of textile industry that enjoyed the boom earlier in 1992 and 1993. These industries experienced less severe impacts from the economic crisis in 1997, when compared to the domestic oriented industries, as the devaluation of the Baht increase Thailand's competitiveness. Also, when compared to the export oriented industries, these industries experienced less negative impact during the world economic slowdown in 2001.

Figure 4.12: Manufacturing Production Index

Textiles and Textiles Products

Source: Bank of Thailand

Textiles and textile products sector (Figure 4.12) were fortunate enough not to experience the declined in their productions during the two most difficult years following the economic crisis. The productions in this sector continued to expand, following its long-term trend, by 1.79 and 2.83 percent in 1997 and 1998, respectively. The important of the increase in Thai competitiveness could be seen very clearly in this sector. Since 1993, Thai Textiles producers had started to lose their competitiveness of the low-end products to newly developing countries such as Vietnam, and China, which had much cheaper labour costs. The devaluation of the Baht in 1997 had resulted in the improvement of the competitiveness in this low-end market, thus improved the overall performance of the industry which could be much worsen attributed to the significantly lower domestic demand in line with the economic contraction. However, by 1999, the effects of Baht devaluation had started to fade away as many countries in the East Asian region had also devalued their currencies. As a result, Thailand, once more, faced eroded competitiveness in mid- and low-end textile products. The productions declined by 1.14 percent in 1999, and stay rather stagnant at that level until 2003. Therefore, improvements in design and production, as well as the shift of productions toward the mid- to high-end products are necessary if Thailand wishes to maintain its share in the world market.

The production of glass sheets (Figure 4.13) and electric motors (Figure 4.14), like most of the industries, experienced negative effects from the tight liquidity problem in 1998. The production of the glass sheet industry contracted by 21.39 percent in 1998, while the production of the electric motor industry contracted by 27.47 percent, in the same year. Both industries started to experience recovery in 1999, and continued to grow until the world economic slowdown in 2001, when the glass sheet industry faced zero growth and the electric motor industry contracted by 5.45 percent.

Figure 4.13: Manufacturing Production Index

Glass Sheet
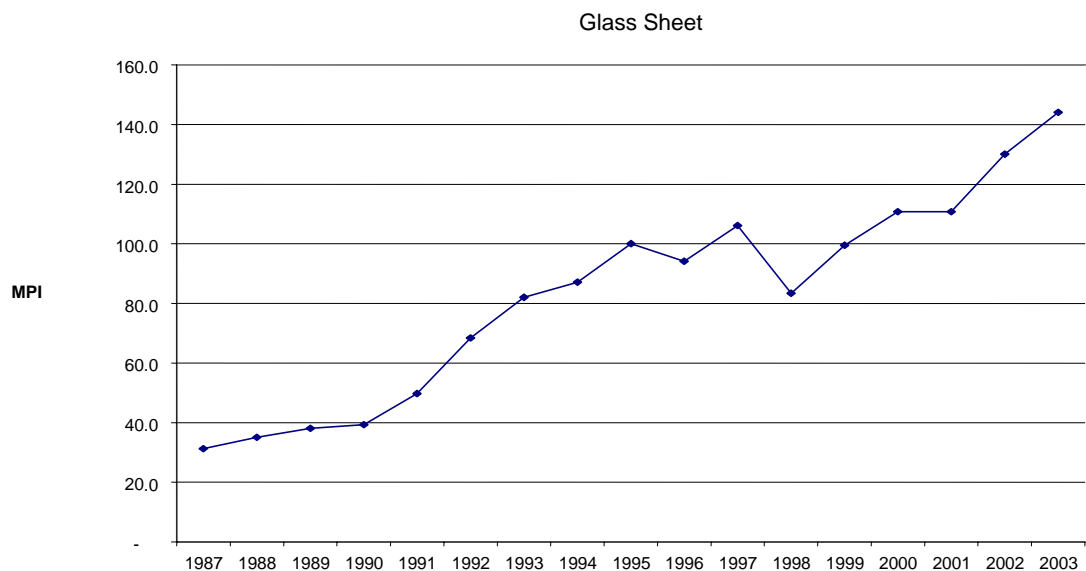
Source: Bank of Thailand

Figure 4.14: Manufacturing Production Index

Electric Motor
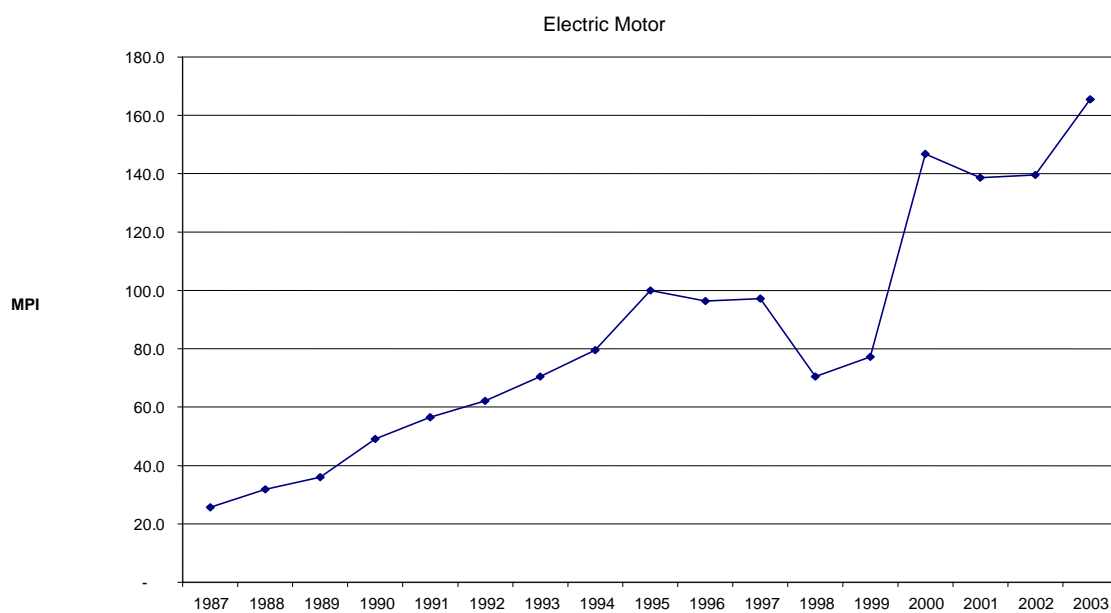
Source: Bank of Thailand

4.3.2 Employment

The population of Thailand was a little over 62 million in 2000[39]. The labour force, estimated at approximately 34 million (54.4% of the population) in the same year, was growing at declining rates of an annual average of 3.0 percent during 1980-1985, 2.9 percent during 1986-1990, 1.5 percent during 1991-1995, and about 1 percent during 1995-2000[40]. It should also be emphasized here that employment in Thailand is highly seasonal. The size and pattern of employment and unemployment vary from season to season, and thus a single set of labour force data from one particular season would not necessarily represent the employment pattern in another season. In order to capture the seasonal variations, the labour force surveys (LFSs) carried out by the National Statistic Office (NSO) are conducted on a quarterly basis, which in February and May correspond to the dry or slack agricultural season, and in August and December are the wet (planting) and harvesting months, respectively. In most studies, for simplicity, two major seasons are used, the February round represents the dry or slack season, and the August round to represent the wet or the peak agricultural season.

Paitoonpong (2002) alleged that in general, the severity of the impact of a financial crisis on labour markets depends on three major factors. First is the flexibility of quantity adjustment by the groups and/or industries directly affected by the crisis. The flexibility of employment can cooperatively happen between employers and workers. Firms can adjust their production process to maintain the level of employment, while the workers can reduce their working hours to minimise the cost of production. The second is the flexibility of wage adjustment, which provides firms the option of reducing their operating costs, and consequently, minimising the impact of the crisis on employment. The final factor is the structure of the economy. Thai economy has relatively large agricultural and informal

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[39] National Statistical Office Thailand, (2002), *Thai Labour Force Survey, 2001*
[40] Data from Paitoonpong, (2002)

sectors, which are more likely to be able to absorb workers from other sectors that are directly affected by the crisis. In addition, government policies, such as the unemployment benefits, can also reduce the impact of the crisis on labour.

In this study, the impact of the 1997 economic crisis on labour can be categorized into 4 parts. These are the impact of the crisis on employment, unemployment, underemployment, and real wages. The analysis will proceed by comparing the above four indicators in the years prior to and follow the crisis.

4.3.2.1 Employment

The majority of Thai labour force is engaged in the agricultural sector. In 2000, during the peak season, 48.5 percent of the total employment was engaged in this sector, while 15.2 percent was in services sector, 14.8 percent in commerce, 13.7 percent in manufacturing, and 4 percent in construction. During the dry or slack season, the proportion of employment in agriculture decreased to 41.8 percent, while employment in the non-agricultural sector mostly increased, with the share of services at 16.3 percent, commerce at 16.1 percent, manufacturing at 16.2 percent, and construction at 5.2 percent. Since 1995, in spite of the economic crisis, employment in manufacturing was relatively stable, accounting for about 16 to 17 percent of total employment during the slack season and around 13 percent during the peak season. Employment in services and construction was less stable during this period. In the slack season, employment in services increased from 14.3 percent in 1995 to 16.3 percent in 1999, while in the peak season it increased from 12.7 percent in 1995 to 15.2 percent in 1999. This phenomenon reflects the capacity of the service sector to absorb labour during economic hardships[41]. However, a totally different picture could be seen in the construction sector, the employment proportion declined from 10.4 percent and 6.7

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[41] Paitoonpong, (2002)

percent in 1996, during the slack season and the peak agricultural season, respectively, to 5.2 and 4.0 percent in 1999.

The long-term employment trends of Thailand reflected the nature of the changes in economic activity during the past 2 decades, which were to be expected in the course of economic development, namely, a shift away from agricultural toward industrial and service sector. The share of agricultural employment significantly decreased from 74.4 percent in 1977 to 48.5 percent in 1999, while industrial employment increased from 8.3 percent to 18.4 percent, and service employment from 17.2 percent to 33.1 percent. During this period, before the crisis, employment in industry showed a slowly-increasing trend, with an annual growth rate of 6.2 percent, and with an annual growth rate of GDP per worker of 3.8 percent. There was a small decline in the growth of manufacturing employment during the time of the economic crisis. Employment in services showed a consistently increasing trend both before and after crisis, with an average rate of 4.6 percent, but with a lower annual growth rate of GDP per worker of only 0.8 percent.[42]

Table 4.6: Employment, Percentage Change between 1996 and 1999

Industry	% Changes in Round 2	% Changes in Round 3	% Changes in Round 4
Agriculture	0.17	1.13	-1.60
Mining	-5.54	5.12	6.91
Manufacturing	-2.34	-2.29	-1.66
Construction	-35.57	-41.04	-39.10
Electricity, Gas, Water	16.51	12.33	7.56
Wholesale and Retail Trade	2.92	4.69	7.26
Transportation	-2.70	-0.18	-0.07
Services and Others	9.44	12.30	13.92
Total	-1.52	-1.10	-1.21

Source: Labour Force Surveys (Various Years)

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[42] Paitoonpong and Thanapura (1998)

Impact of the crisis on employment had a similar pattern to the impact on the GDP. On the GDP side, the construction sector, which was a major part of the real-estate-driven "bubble" economy, was the most severely hit sector. The percentage change of average sectoral GDP in eight quarters before and during the crisis indicates that GDP in the construction, commerce and service sectors declined by 53.1 percent, 12.4 percent, and 10.1 percent, respectively. The industries that were less involved during the "bubble" period prior to the crisis (such as the agriculture, mining, and electricity, gas and water supply) had an increasing percentage of average sectoral GDP. Similarly, workers in the construction sector were the most seriously affected. The negative results of the bubble economy also affected employment in the manufacturing and transportation sectors, but not in the electric, gas and water, commerce and service sectors. As Table 4.6 indicates, the percentage changes of average employment in the construction sector between 1995 and 1999 had decreased by 35.6 percent, 41 percent, and 39 percent, according to data from rounds two, three, and four, respectively. For the agricultural sector, even though it's sectoral GDP increased by 1.3 percent, the crisis had an ambiguous impact on employment in this sector which normally employs around 40 to 50 percent of the total workforce.

4.3.2.2 Unemployment

Unemployment measurement in Thailand is based on Labour Force Survey (LFS), partly because there are no unemployment insurance and unemployment registration schemes, which would normally give a fair estimate of unemployment in a country. The LFS defines the unemployed as "persons, 13 years of age and over who, during the survey week did not work even for one hour, had no jobs, business enterprises or farms of their own from which they were temporarily absent, but were available for work". The unemployed also consist of those who were waiting to take up a new job or for the agricultural season to begin, as well

Table 4.7: Labour Force Survey

(Average (Round 1) and (Round 3))	1993	1994	1995	1996	1997	1998*	1999*	2000*
	(Thousand Persons)							
Population	58,442.0	59,239.5	59,281.9	59,897.9	60,499.8	61,173.8	61,778.7	62,404.7
Age Under 13	15,466.0	15,300.0	14,216.0	14,141.6	13,932.8	13,966.8	13,866.4	13,759.9
Age 13 Up	42,976.0	43,939.5	45,065.9	45,756.3	46,567.0	47,207.1	47,912.4	48,644.8
Labour Force	**32,240.0**	**31,816.1**	**32,174.9**	**32,324.2**	**32,780.5**	**32,595.5**	**32,910.8**	**33,393.9**
1. Employment	**30,679.0**	**30,164.3**	**30,815.1**	**31,166.0**	**31,714.3**	**30,270.2**	**30,835.4**	**31,446.7**
of which underemployment	**844.0**	**630.0**	**568.0**	**642.0**	**760.5**	**1,035.3**	**1,216.0**	**1,057.1**
- Agriculture	16,269.0	15,180.0	14,389.1	14,136.7	14,314.6	13,571.3	13,997.3	13,999.9
- Non-Agriculture	14,410.4	14,983.8	16,426.0	17,029.0	17,399.7	16,698.9	16,838.1	17,446.7
Mining and quarrying	58.0	57.8	55.0	53.6	52.5	44.7	64.3	44.8
Manufacturing	4,179.0	4,190.8	4,608.2	4,650.8	4,644.2	4,577.3	4,611.3	5,004.8
Construction, repair and demolition	1,615.2	1,996.7	2,247.6	2,648.6	2,502.1	1,632.5	1,401.8	1,506.5
Electricity,gas,water&sanitary services	146.0	184.0	184.0	151.7	176.4	195.7	157.1	165.9
Commerce	3,806.7	3,766.0	4,184.5	4,396.6	4,601.9	4,632.8	4,784.2	4,911.2
Transport storage & communication	909.1	894.9	1,006.2	995.2	1,039.4	989.5	1,008.5	969.4
Services	3,676.5	3,882.0	4,132.3	4,097.1	4,371.0	4,612.9	4,793.5	4,833.6
Activities not adequately described	19.5	12.0	11.1	35.2	12.0	13.3	17.1	10.4
2. Unemployed Persons	**843.8**	**833.0**	**550.0**	**497.6**	**495.2**	**1,423.3**	**1,382.6**	**1,204.3**
(rate of unemployment)	2.6	2.6	1.7	1.5	1.5	4.4	4.2	3.6
- Looking for Work	139.2	169.3	134.2	114.9	138.0	457.6	389.5	318.7
- Not Looking for Work	704.5	664.3	415.1	382.7	357.2	965.6	993.0	885.5
3. Seasonal Inactive Labour Force	717.2	818.8	809.8	660.6	571.0	902.0	692.9	742.9
(share of total labour force)	2.2	2.6	2.5	2.0	1.7	2.8	2.1	2.2

Source: The Labour Force Survey by the National Statistical Office

Remark: * Average of 4 rounds of the survey.

as those who had been looking for work, and those who had not been looking for work due to illness or because they believe there was no suitable work available.

Prior to the economic crisis in 1997, unemployment in Thailand had been generally low, with an average of 2.36 percent of total labour force during 1990 to 1996 (Table 4.7). However, there are several reasons that could be related to this low 'open' unemployment rate. Firstly, Thailand did not yet have an unemployment insurance system, which results in the lack of incentive for workers to report their unemployment. Secondly, similar to many developing countries, the informal sector played an important role in providing employment opportunities for Thai labour force. And finally, the definition of the 'unemployed' was in itself problematic in many ways[43]. Firstly, a person works for more than one hour during the survey week would be automatically considered employed. Secondly, the definition does not include the "seasonally inactive labour force" which is defined as persons, 13 years of age and over who were neither employed nor unemployed, but were waiting for the appropriate season. Thirdly, the definition also does not include "unpaid family workers" - persons who usually worked without pay on farms or in business enterprises engaged in seasonal activities owned or operated by the head of the household or any other member of the household.   In Thailand, a large proportion of the labour force comprises of this category, mainly in agriculture. According to the LFSs, this group accounted for 58.7 percent of the total employment in 1999.

The 1997 crisis caused unemployment to increase significantly. As can be seen from Table 4.7, the rate of unemployment, as the percentage of the total labour force, jumped from 1.7 percent in 1995 to 4.4 percent in 1998. Similar to the case of GDP growth, the negative consequence of the crisis on unemployment was unevenly spread across sectors. Despite its sectoral GDP growth, in the short and medium periods, the mining sector was hit hardest by the crisis in terms of unemployment. Average unemployment in this industry increased by 546.4 percent and 323.7 percent in rounds two and three, respectively, from

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[43] Paitoonpong, (2002)

1996 to 1999. In average, unemployment in the agriculture sector increased the least, but was still as high as about 90-100 percent (Table 4.8).

Table 4.8: Unemployment, Percentage Change between 1996 and 1999

Industry	% Changes in Round 2	% Changes in Round 3	% Changes in Round 4
Agriculture	90.31	99.54	98.33
Mining	546.38	323.71	137.51
Manufacturing	260.49	239.66	242.84
Construction	266.69	265.33	257.23
Electricity, Gas, Water	294.38	64.82	90.52
Wholesale and Retail Trade	276.74	274.62	268.68
Transportation	295.55	306.51	214.41
Services and Others	166.20	160.73	191.11
Total	**148.83**	**155.92**	**157.16**

Source: Labour Force Surveys (Various Years)

4.3.2.3 Underemployment

As mentioned above, unemployment in Thailand has been generally low except after the 1997 crisis. One of the major reasons is that a substantial number of those considered employed were underemployed, or in order word, worked less than they could or wished. Officially, underemployment is defined by the National Statistical Office (NSO) as those who work less than 35 hours per week during the week of the survey. However, in many studies, underemployment is arbitrarily defined as those persons who work less than 20 hours per week in order to include only those who were really in need of more work[44]. Under this definition of 20 hours per week, the number of the underemployed (Round 3) had significantly increased after the economic crisis, from 580,700 persons (1.77% of the labour

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[44] Siamwalla (1998), for example, used this definition and classified this group as being "severely underemployed" and persons who work less than 35 hours per week as being "moderately underemployed".

Table 4.9: Underemployment by Industry 1995-1998: Industry Working less than 20 hours per week

(thousands of people)	1995		1996		1997		1998		1999	
	Round 1	Round 3	Round 1	Round 3	Round 1	Round 3	Round 1	Round 3	Round 1	Round 3
Total	**490.0**	**644.4**	**638.8**	**580.7**	**543.9**	**721.4**	**1477.2**	**938.4**	**862.7**	**953.9**
Agriculture	299.2	473.0	437.4	436.3	353.7	531.4	585.6	713.3	580.4	750.1
Mining and Quarrying	0.6	0.4	0.0	0.9	0.0	0.4	2.9	0.2	4.3	0.0
Manufacturing	35.9	44.2	51.2	32.9	44.1	40.5	489.2	30.5	49.3	30.4
Construction and Repair	8.3	3.6	20.7	8.5	13.7	7.7	31.0	12.4	13.0	18.8
Electricity, Gas, Water, etc.	0.4	0.1	0.1	0.1	2.3	1.3	1.4	0.0	1.0	0.1
Commerce	68.4	61.4	70.8	57.0	67.5	80.9	220.1	100.1	105.5	79.1
Transport, Communications	10.7	10.8	12.9	3.8	11.3	12.7	31.3	10.1	11.3	11.9
Service and Others	66.4	51.0	45.7	41.2	51.2	46.4	115.8	71.9	97.7	63.5

Source: Report of the Labour Force Survey, National Statistics Office (various years)

force) in 1996 to 938,400 persons (2.81%) in 1998, 953,900 persons (2.87%) in 1999, and 982,700 persons (2.89%) in 2000 (Table 4.9).

Generally, underemployment did not show seasonality. There was no trend or direction of underemployment between 1995 and 1999. In 1995, 1997 and 1999 it was greater in the slack season than in the peak season, while in 1996 and 1998 it was the other way around. The underemployment figures of 1998, in both dry and slack seasons, were significantly higher than those in 1996. It increased from 638.8 and 580.7 in round 1 and round 3, respectively, to 1,477.2 and 938.4 in 1998.

During the crisis, underemployment increased in every industry except the electric, gas and water supply sector. Underemployment in the electric, gas and water supply sector declined by 43.1 percent, 6.1 percent, and 2.6 percent during the crisis, for all rounds. Underemployment in the mining and manufacturing sector had the largest increment during the crisis, with the manufacturing sector increased by 574.62 percent, 343.78 percent, and 247.65 percent, in round 2, round 3 and round 4 respectively. Underemployment grew the least in the agriculture sector, where the percentage changes of underemployment during the crisis period were 64.4 percent, 53.1 percent, and 54.6 percent (Table 4.10).

Table 4.10: Underemployment, Percentage Change between 1996 and 1999

Industry	% Changes in Round 2	% Changes in Round 3	% Changes in Round 4
Agriculture	64.42	53.11	54.64
Mining	230.75	695.72	440.46
Manufacturing	574.62	343.78	247.65
Construction	94.53	31.13	61.32
Electricity, Gas, Water	-43.10	-6.10	-2.56
Wholesale and Retail Trade	157.12	118.00	96.69
Transportation	174.35	88.04	66.44
Services and Others	103.18	106.76	84.61
Total	114.79	85.90	75.77

Source: Labour Force Surveys (Various Years)

It should be noted here that the increase in the underemployment level implied the reduction in the number of working hours, as a result of the economic crisis. Hence, it suggested that Thai labour markets were able to absorb the negative impacts of the economic crisis through the adjustment of quantity of working hours, as well as the quantity of head-count. Also, the increase in underemployment also partly explained the reason the level of employment in Thailand was steadier than one would have expected in the period following the crisis, as a large proportion of the labour quantity adjustment was in the form of reduction in working hours rather than reduction in the number of workers. Thus, when attempting to evaluate the impact of a crisis, it is important to examine a number of possible quantity adjustment channels. Examination only on the figures of employment and unemployment might miss important quantitative adjustments in hours worked, and thus leaded to the misleading conclusion.

4.3.2.4 <u>Labour Wage</u>

As suggested in the previous section, when one attempted to examine the impact of an economic crisis, a number of possible labour market quantity, price and earnings outcomes were all needed to be considered. Wage adjustment is one of the most common adjustment mechanisms seen in many countries, especially in developing countries, where there is the absence of government policies or labour unions to impose much wage rigidity.

However, the study of Thai labour market adjustment after the 1997 economic crisis indicated that the impact of the crisis occurred less in terms of price adjustment than in terms of quantity adjustment. Real wage rates, as estimated from the LFSs, did not decline significantly in the immediate post-crisis period in relation to the immediate pre-crisis period. One factor contributing to this outcome was due to a combination of reduced hours worked for workers paid hourly or daily, and the selective movements from wage to non-wage employment.

The real monthly wage for all types of worker declined only by 0.8 percent, 0.2 percent, and 1.6 percent during the crisis, for round 1, 2, and 3, respectively (Table 4.11). Real monthly wages in the electric, gas and water supply sector increased by 24.2 percent, 25.2 percent, and 22.5 percent, and real monthly wages in the transportation industry rose by 12.9 percent, 13.1 percent, and 7.9 percent during the crisis. The largest reduction of real monthly wages occurred in the mining industry, where the real wages decreased by 11.5 percent, 13.3 percent, and 18.9 percent in all rounds. Interestingly, the sector with the smallest reduction in real monthly wages was the construction industry, whose real wages declined by only 1.7 percent and 1.8 percent in the second and third round, respectively, given it had been the industry that faced the most severe negative impact in term of GDP growth rate. One suggestion was that prior to the crisis, the construction sector was the sector with average wage very close to the minimum rate, thus the flexibility of price adjustment was somewhat limited.

Table 4.11: Real Monthly Wage Rate, Percentage Change between 1996 and 1999

Industry	% Changes in Round 2	% Changes in Round 3	% Changes in Round 4
Agriculture	-5.49	-4.40	-3.08
Mining	-11.49	-13.29	-18.86
Manufacturing	-5.96	-5.46	-6.47
Construction	-1.73	-1.75	-5.68
Electricity, Gas, Water	24.20	25.21	22.51
Wholesale and Retail Trade	-4.80	-6.99	-7.06
Transportation	12.92	13.13	7.92
Services and Others	-4.22	-4.63	-4.26
Total	-0.82	-0.19	-1.64

Source: Labour Force Surveys (Various Years)

4.4 Conclusion

The 1997 economic crisis had affected Thailand in a very profound and extensive scale. The majority of the sectors in the economy were affected by the crisis, although the effects might not be even. The economic growth recorded severe contraction, financial market collapsed, domestic demand slumped, industrial sectors were in severe excess capacity, employment deteriorated, personal and corporate income diminished, inflation and cost of living mounted, and finally, poverty surged. The crisis culminated from a complex set of causes. Radelet and Sachs (1998) expressed their opinions on such issue as:

> *"To be sure, there were significant underlying problems besetting the Asian economies, at both a macroeconomic and microeconomic level (especially within the financial sector). But these imbalances were not severe enough to warrant a financial crisis of the magnitude that took place in the second half of 1997….. A combination of panic on the part of the international investment community, policy mistakes at the outset of the crisis, and poorly designed international rescue programs have led to a much deeper fall in (otherwise viable) output than was either necessary or inevitable."*

The Thai economy, as Krugman (1994) has pointed out, had deep-rooted problems in the structure of the economy. The rapid growth in the early 1990s had built up on higher use of inputs from resource mobilization rather than technology progress and efficiency. However, such growth based on utilizing inputs and mobilizing resources was impossible to be sustained in the long-run. Nevertheless, these problems were, yet, concealed at the time. The relative stable growth of more than two decades had convinced everyone into complacency regarding the risks they might be running. Mistakes in investments had almost always been rescued by high growth. But it was this high growth that led to the accumulation of structural problems. Institutions were inadequately prepared to deal with the consequences of mistakes, and no arrangement had ever been properly set up. One

obvious example was the financial market liberalization when the supervision and the regulation of financial institutions were not yet overhauled to take into account of the new environment that would be opened up by such liberalization. The result of it was devastated. The massive capital inflow had led firms to over-reliance on external debt as a mean of financing new investments, which made them, as well as the financial institutions, became extremely vulnerable to external factors. The attack of the currency, which later led to the devaluation of the Baht, had put many firms and financial institutes in the ravaged situation, hence, intensifying the impacts of the crisis even further. More unfortunate, the mistake in the recovering programs by the IMF had pushed the situation even further down. The suspension of financial institutions had created panic across the economy. The stringent fiscal and monetary policies left no prospect for business to recover. As a result, the impacts of the crisis were far greater than what it should have been.

However, the worst of the crisis had already passed, and Thailand is on its route to moving forward, therefore, it is time to look back and address the root of the fundamental problems. Firstly, the economic growth has to be built based on 'efficiency-led sustainable growth' instead of the mobilizing of inputs and resources. Secondly, the country's long-run productivity and competitiveness has to be well planed. And finally, institutions and arrangements to deal with mistakes and external shocks have to be established, so that Thailand will be better equipped in dealing with future difficulties.

Chapter 5 – Measuring Productivity

"Productivity is never an accident. It is always the result of a commitment to excellence, intelligent planning, and focused effort."

Paul J. Meyer

5.1 Introduction

The principal objective of this chapter is to provide a general overview of the concept of productivity and its measurement. The concept of productivity has long been examined, and while there is neither a unique purpose for, nor a single measure of productivity, there is no argument that productivity is commonly defined as the economy's ability to convert inputs into outputs. At the simplest level, the productivity concept can be expressed as a ratio of a volume measure of output to a volume measure of input use[1], with the simple equation:

$$\mathrm{P}roductivity = \frac{Output}{Input}$$

The productivity concept is distinct from the simple production notion (which concerns only the total volume of goods and services produced), by its relating output to the quantity of resources or inputs used to produce them[2]. Its concern is with how efficiently a certain output of goods and services is produced[3], or generally speaking, it aims at maximizing outputs produced, for a given set of inputs, or, for a given output, minimizing inputs used. The measurement of productivity can be made at various levels – economy, industry, company and operational; and comparisons can be made either across time or between different production units[4]. The term productivity is closely related to 'efficiency', and very often used interchangeably. However, they are different in that the term *productivity* refers

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[1] *Measuring Productivity*, OECD Manual, 2001, pp.11
[2] Lipsey and Carlaw, (2003)
[3] *Productivity in the New Millennium*, APO Video Text
[4] Green, (1993b)

to the ratio that evaluates relationship between inputs and outputs. It is a measurement of the level of production in an absolute term (e.g. how many units of outputs can be produced by a certain set of inputs). On the other hand, the term *efficiency* is a relative concept. It evaluates the degree of acheivement of productivity at a certain level (in the case for this thesis, technical efficiency refers to an index that relates the level of productivity to a maximum attainable production level defined by a frontier production function).

It is commonly believed (Griliches (1987), Green (1993b), Barro (1998), Harberger (1998), Diewert and Lawrence (1999), Hulten (2000), Carlaw and Lipsey (2003a, 2003b)) that along with increases in factor endowments and changes in the terms of trade, productivity improvement is a major determinant of economic growth and national welfare. Despite this belief, there is much less agreement on the area of the purpose of productivity measurement. The most frequently stated objective of measuring productivity growth is to trace technological change. Griliches (1987) described technology as 'the currently known ways of converting resources into outputs desired by the economy', which could appear either in embodied or disembodied form. Although many economists (Basu and Fernald (1997), Hulten (2000), Lipsey and Carlaw (2002), Carlaw and Lipsey (2003a)) argued that productivity measurement is an imperfect measure of technological change, it is still somehow related to the productivity, at least by measuring the supernormal gain associated with growth creating technological change. The next objective for measuring productivity is to locate efficiency adjustment, which conceptually is different from technological changes. Full efficiency implies that a production process has achieved the maximum amount of output that is physically achievable with current technology, given a certain amount of inputs[5]. Therefore, technical efficiency gain is the advance towards the 'best possible practice', or the elimination of technical and organizational inefficiency.

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[5] Diewert and Lawrence, (1999)

The third objective for measuring productivity is to identify real cost savings in production. Productivity, in general, is measured residually, which captures not only the effect of efficiency changes, technical change and economies of scale, but also changes in capital utilization, learning-by-doing and measurement errors. Harberger (1998) referred to this as real cost savings. Productivity, in practice, could be used as a way to identify them in the production process. Moreover, productivity could also be used in benchmarking the production processes, where in many cases, comparisons of productivity measures for specific production processes can help to identify production inefficiencies among producers. And finally, productivity measurement is the key element in assessing the standard of living[6]. Labour productivity, using value added per hour of work, is a good measure of per capita income, while the long term trend in multifactor productivity (MFP) is a good indicator of the economy's underlying productive capacity[7], which is an important measure of inflationary pressure.

This chapter is organised as follows: Section 5.2 discusses the different types of productivity measures. It compares and contrasts the single and the multi/total factor productivity measures. Also, the differences between the gross output and value-added productivity measures are considered. Section 5.3 then examines the four main approaches to measuring productivity, including the growth accounting approach, the index number approach, the conventional econometric approach, and the distance function based approach. However, an important point to be mentioned here is that, due to the extensive literatures in each approach, it is unrealistic to include very detailed discussion of every one of them. Therefore, only those approaches that fall within the scope of this thesis will be discussed in detail, both in their technical aspects and in the literature development, and these discussions will be made later in the relevant chapters. However, this chapter is only aimed at giving a broad overview of the subject of productivity, and no rigorous theoretical

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[6] Griliches, (1987)
[7] Carlaw and Lipsey, (2003a)

advancement or breakthrough is intended. Also, readers should be warned that there are some slight repetitions of key ideas in this chapter, to make the material more accessible, and to make sections more self-contained.

5.2 Types of Productivity

There are several approaches to measuring productivity. The choice between them depends on the purpose of the study and, in many cases, on the availability of data[8]. At the broadest level, productivity measurement can be classified as 1) single factor productivity measures (i.e. relating a measure of output to a single measure of input such as output per worker, output per hour worked, or output per unit of capital used). It can also take the form of 2) total factor productivity (TFP), where all the production inputs such as land, natural resources, and inventories are included in the calculation. Other methods of classifying productivity (of particular relevance at the industry or firm level) include productivity measures that relate gross output to one or several inputs (i.e. gross output based productivity), and those that use value-added concept to capture output movements (i.e. value-added based productivity).

5.2.1 Single Factor Productivity

Historically, productivity is often expressed as the ratio of output to the most limited or critical input, with all the other inputs held constant[9]. In industries that require skilled labour (which is often in relative shortage), output per worker is considered as the most appropriate measure of productivity. However, such partial productivity measures, that only relate to one class of input, suffer from many obvious limitations. Firstly, as output is,

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[8] Green, (1993)

mostly, a product resulting from a bundle of inputs, there may be several factors of production that are of almost equal importance. Deciding on a single input as the measurement could be very difficult, and could be rather subjective. Secondly, the relative importance of inputs may change over time, and thus, the chosen input at one particular period might no longer be appropriate in the following period. For instance, the relative importance of labour may be low in the initial stages of development when unemployment is high, but may become critical as the country becomes more developed, because of declining birth rates and aging labour force.

Finally, as the partial productivity measure reflects the combined effects of a number of factors (including the changes of other inputs, intermediate inputs, as well as, technical, organizational and efficiency change), relying on only a single factor input can often be misleading[10]. A simple substitution of capital for labour within the input mix of a firm or industry can raise labour productivity without, or with a much less, improvement in actual productivity. This implies that movements in the partial productivity statistics do not always represent true changes in the underlying productivity of the economy. Caution, thus, needs to be applied when examining this type of productivity measurement.

However, despite the above shortcomings, partial productivity measures, such as the labour productivity index, are still used commonly by the statistics institutes around the world as a key indicator for the productivity level. This is due to the reason that single productivity measures offer ease of comprehension and interpretation, thus, is suitable for a wide range of clients[11]. Also, the single productivity measures require much less extensive use of data, making it suitable for economies, in which the data are not profusely recorded.

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[9] Hulten, (2000)
[10] OECD Manual, (2001)
[11] OECD Manual, (2001)

5.2.2 Total Factor Productivity

In order to avoid the problems faced by measures based on one input factor, as described above, the total factor productivity had been suggested as an alternative (Hulten (2000)). Total factor productivity (TFP) refers to the weighted average productivity of all inputs, where the weights to these inputs are their shares in the total cost of production[12]. Since every input in the production process is included, TFP provides a much more accurate measure of efficiency and the effectiveness of the production in question[13]. Also, as each input proportion is allowed to vary, TFP takes into account the possibility that the relative importance of factors may change over time.

However, TFP is also subject to some drawbacks[14]. First, the formation of it requires a significant amount of data, which is often lacked in developing economies. Hence, the use of TFP is currently limited, mostly, to only a number of developed countries. Second, the level of TFP is normally measured by dividing a measure of total output by a measure of total inputs; however, the total inputs are often an aggregation of only physical capital and labour, and may overlook many less obvious inputs. Consequently, many analysts (Ahmed and Patricia (2001), Duke and Torres (2005), Meyer and Harper (2005)) recognize the incompleteness of their input coverage, and thus prefer to refer to the resulting measures as multifactor productivity (MFP), rather than total factor productivity measures. However, the distinction between MFP and TFP is usually made only by those concerned greatly with the exact accuracy of terminology, and the term TFP continues to be used more widely. Hence, in this thesis, the term total factor productivity will be referred to in this looser sense.

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[12] Carlaw and Lipsey, (2003a)
[13] OECD Manual, (2001)
[14] Hulten, (2000)

5.2.3 Gross Output and Value-Added Based Productivity

The measurement of productivity can also be classified by the nature of the output data being used. Goods and services that are produced by a production unit, and become available for use outside that unit are called *gross output*[15]. This is considered as a gross measure in the sense that it represents the value of sales and net additions to inventories, without allowing for purchases of intermediate inputs. The *value-added* measure is considered a net measure, as purchases of intermediate inputs are deducted from gross output[16]. The argument over which one of these measures should be preferred over the other has been the focus of considerable debate.

Theoretically, when technical progress affects all factors of production proportionally (i.e. under Hick-neutral technical progress) gross output total factor productivity would be a better measure of technical change. This is due to the fact that it is less sensitive to changes in the degree of outsourcing; therefore, it becomes a valid representation of disembodied technical change. However, this is not the case for the value-added based total productivity measure, which varies with the degree of outsourcing and, instead, provides an indication of the importance of productivity improvement for the economy as a whole. Rather than technical change itself, the value-added based measure reflects an industry's capacity to translate technical change into income and into a contribution to final demand. Nevertheless, the opposite is true for the labour productivity measures. The gross output based productivity measures are more sensitive to the degree of vertical integration and outsourcing than the value-added based labour productivity measure. A process of outsourcing, for example, implies substitution of primary inputs for intermediate inputs, thus, gross output based labour productivity may rise as a consequence of outsourcing rather than a shift in technology or efficiency. Value-added based labour

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[15] Economic A-Z, The Economist
[16] Economic A-Z, The Economist

productivity measures, on the other hand, are much less dependent on the processes of substitution between primary and intermediate inputs. When outsourcing takes place, primary inputs are replaced by intermediate inputs, which leads to a fall in value-added, as well as a fall in primary inputs.

However, practical aspects should, also, be considered when choosing the productivity measures to be used. At the industry level, measures of value-added are generally easier to use than measures of gross output, because of intra-industries transactions, such as the deliveries of intermediate inputs[17]. With gross output based productivity measures, when the output from one industry becomes the intermediate input for the other, the problem of double counting arises[18]. Therefore, an adjustment has to be made, and one way of doing so is by the exclusion of intra-industries deliveries, in a measure referred to as *sectoral output*. Conceptually, this refers to the adoption of a process of integration of different units or industries, in which as one moves up the hierarchy of the activity classification, more and more different units are formed and treated as a single larger unit. At each level of aggregation, only products that flow out of (or into) the sector will be accounted for. However, this method has one disadvantage: that the growth rates of components cannot be compared to their aggregate. The productivity measures for aggregates are built up as weighted sums, not single averagea, from their components; therefore, a one percent growth of total factor productivity in all individual industries may lead to a 1.5 percent growth in the integrated economy. Value-added based productivity measurement is a good way to avoid this difficulty in dealing with intermediate inputs in the process of aggregation. Current price values of value-added can simply be summed up across different units, without regard to any inter-industry flows of inputs. Quantity indices of value added can be aggregated by forming weighted average, with weights adding to unity. Therefore, the value-added based productivity measures of

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[17] OECD Manual, (2001)
[18] Lipsey and Carlaw, (2000)

aggregates are also weighted averages of their components, and can be compared across levels of aggregation.

Overall, the gross output and the value-added based productivity measures should be seen as useful complements, in which each of the two have their own advantages and drawbacks, depending on the nature of the research. Nevertheless, in many cases, the availability of data would become the ultimate determinant of the choice of measures used.

5.3 Approaches in Measuring Productivity

Productivity measurement has long been of interest to economists. Productivity analysts (Griliches (1987), Green (1993b), Barro (1998), Harberger (1998), Diewert and Lawrence (1999), Hulten (2000), Carlaw and Lipsey (2003a, 2003b)) claimed that along with increases in factor endowments and changes in the terms of trade, productivity improvement is a major determinant of economic growth, and therefore, of the national welfare. This, hence, has made productivity measurement a key concern for many policy makers around the world. Many approaches to productivity measurement have been developed over the years. At the most basic level, productivity change is often approximated by changes in labour productivity, as the required information is usually readily available and easy to access. However, as mentioned in the previous section, labour productivity is a single factor measure, which could easily produce misleading results, when other inputs (such as capital) are substituted for labour. Therefore, a more complex measure (namely, the total/multi-factor productivity measure) should generally be calculated and used collectively. There are several approaches that could be used in calculating the total/multi-factor productivity. The following section summarizes four prominent approaches to these measurements; including the growth accounting approach, the index number approach, the conventional econometric approach, and the distance function based approach. It should be called here again that

because of the scope of this thesis, the survey of these four measures is only aimed at providing a general overview, but not an in-depth discussion of either the literature development, or the technical elements of these approaches. However, a detailed development, of the parametric distance function based approach specially, will be found later in Chapter 7 of this thesis.

5.3.1 Growth Accounting Approach

The relationship between the aggregate production function and the productivity has long ago been explored by Jan Tinbergen (1942)[19]; however, it was the seminal contribution by Solow (1957) that provides a useful frame of reference for the main empirical approach to measuring productivity. Solow established a significant theoretical link between the production function and the index number approach. Where as earlier index number studies had interpreted their results in the light of a production function, Solow started with the production function, and deduced the consequences for (and restrictions on) the productivity index.[20] Such estimates of productivity are computed using a method called the *growth accounting approach*, which examines how much of an observed rate of change of an industry's output can be explained by the rate of change of combined inputs. This can be done by measuring a residual resulting from separately evaluated contributions of the specified input factors to output growth, and then subtracting these measured contributions from the total growth of output[21]. Thus, the growth accounting approach evaluates productivity growth residually, and is sometimes referred to as the *residual approach*.

5.3.1.1 The Solow Residual

Solow began his calculation by specifying a production function that defined what level of

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[19] Griliches (1996)
[20] Hulten (2000), pp.8

output can be produced at a particular time, given the availability of a certain level of inputs. Specifically, he began with an aggregate production function with a Hicks-neutral shift parameter. Here, the technical change which occurred was neutral in the sense that any shifts in production left all marginal rates of substitution of inputs unchanged. Thus, the production function could be written as:

$$Y_t = Q = A(t)f(K,L:t) \tag{5.1}$$

where Y_t is output at time t, $A(t)$ represents total factor productivity at time t, K_t is the capital stock at time t, and L_t is a measure of the labour available at time t. The time variable is included in order to allow for technical change. The growth accounting approach is based on several important assumptions: 1) the technology or the total factor productivity term, $A(t)$, has to be separable, 2) the production function exhibits constant return to scale, 3) the producers in the industries behave in a profit maximizing manners, and 4) the markets are perfectly competitive, with all participants being price-takers, who can only adjust quantities but have no impact on prices.

Solow then addressed the key question of measuring $A(t)$ using a non-parametric index number approach, by differentiating (5.1) with respect to t, which gave:

$$\dot{Y} = \dot{Q} = \dot{A} f(K,L) + \frac{\partial f}{\partial K} \dot{K} A + \frac{\partial f}{\partial L} \dot{L} A \tag{5.2}$$

where the dots indicated a first partial derivative with respect to time. Thus, dividing (5.2) by Y gives

$$\frac{\dot{Y}}{Y} = \frac{\dot{Q}}{Q} = \frac{\dot{A}}{A} + A \frac{\partial f}{\partial K} \frac{\dot{K}}{Y} + A \frac{\partial f}{\partial L} \frac{\dot{L}}{Y} \tag{5.3}$$

Equation (5.3) can be rewritten as

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[21] Diewert and Lawrence, (1999)

$$\frac{\dot{Y}}{Y} = \frac{\dot{Q}}{Q} = \frac{\dot{A}}{A} + w_K \frac{\dot{K}}{K} + w_L \frac{\dot{L}}{L} \tag{5.4}$$

where the elasticity of output with respect to labour (w_L) and the elasticity of output with respect to capital (w_K) are

$$w_L = \frac{\partial Y}{\partial L}\frac{L}{Y} = A\frac{\partial f}{\partial L}\frac{L}{Y}$$

$$w_K = \frac{\partial Y}{\partial K}\frac{K}{Y} = A\frac{\partial f}{\partial K}\frac{K}{Y} \tag{5.5}$$

Solving (5.4) for $\left(\dot{A}/A\right)$ gives

$$\frac{\dot{A}}{A} = \frac{\dot{Y}}{Y} - w_K \frac{\dot{K}}{K} - w_L \frac{\dot{L}}{L} \tag{5.6}$$

which indicates that productivity change is equal to the rate of output growth less the rates of growth in capital and labour inputs weighted by their output elasticities, for small movements along the production function. In another word, $\left(\dot{A}/A\right)$ represents what we called the *Solow residual growth*, which is the shift in the production function, reflecting that part of the total growth of real output that cannot be explained by the growth in inputs.

In order to disentangle $\left(\dot{A}/A\right)$, we will need data on the growth rate of real output $\left(\dot{Y}/Y\right)$, the growth rate of the capital stock $\left(\dot{K}/K\right)$, the growth rate of labour input $\left(\dot{L}/L\right)$ and capital and labour's share of income, which correspond to (w_L) and (w_K). However, the estimates of (w_L) and (w_K) are not directly observable. Therefore, some assumptions about the production function, the returns to scale, and the marginal cost of inputs have to be made. If each input is assumed to be paid the value of its marginal product, then

$$\frac{\partial Y}{\partial L} = \frac{w_t}{p_t} \qquad and \qquad \frac{\partial Y}{\partial K} = \frac{r_t}{p_t} \tag{5.7}$$

Hence, these relative prices can be substituted for the corresponding marginal products. This, in turn, converts the unobservable output elasticities into observable income shares,

S_K and S_L.

$$\frac{\dot{A}}{A} = \frac{\dot{Y}}{Y} - S_K \frac{\dot{K}}{K} - S_L \frac{\dot{L}}{L} \qquad\qquad (5.8)$$

These data can then be easily acquired from the national accounts, making growth accounting a very vital approach in productivity measurement, despite the fact that the choice of the set of data sometimes depends on making *ad hoc* assumptions.

5.3.1.2 <u>Criticisms of the Solow Residual</u>

The growth accounting approach proposed by Solow was a very influential development in the productivity measurement sphere. Nevertheless, it is still subject to several flaws. In theory, the Solow residual $\left(\dot{A}/A\right)$ is equal to the growth rate of the Hicksian efficiency parameter. However, in practice, it reflects not only technical change, but also the effects of our ignorance of many components, such as measurement errors, omitted variables, aggregation bias, and model misspecification. Solow, in his own words, defines this residual as follows: *"I am using the phrase 'technical change' as a short hand expression for* any kind of shift *in the production function*[22]*."* Hence, everything that shifts the production function (such as recessions, natural disasters, and improvements in the education of labour force) will appear in the model as technical change. Thus, caution should be exercised when employing this residual.

Second, the Solow model is inextricably linked to the assumption of constant returns to scale[23], where it is needed in order to estimate the return to capital as a residual. This has its foundation in Euler's Theorem, which implies that the value of output will equal to the sum of the input values, if the production function exhibits constant returns to scale,

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[22]Solow (1957), pp.312
[23] Hulten, (2000)

and the inputs are paid the values of their marginal products. Therefore, the accounting

equation $PQ = wL + rK$ will hold, and substitutions as stated earlier could then be made.

Similarly, the third criticism against the Solow model is that the model is, in practise,

wedded to the assumption of marginal cost pricing (i.e. to the marginal productivity

conditions, shown earlier in equation (5.7)). The Solow method is by nature non-parametric,

in that it uses prices in estimating the slopes of the production function at the observed

input-output configurations, without having to estimate the shape of the function at all

points. The estimate of the residual (A) is produced directly from prices and quantities, and

could be seen as a parsimonious method for getting at the shift in the production function.

However, this parsimony comes at the cost of needing to use prices as substitutes for

marginal products[24]. When markets display the imperfect competition that categorize real-

world industrial structure (such as the mixture of monopoly, oligopoly, and monopolistic

competition), this leads to price being greater than marginal cost, and the residual will yield

a biased estimate of the Hicksian shift parameter[25], and there is unfortunately no way

around this.

Moreover, the Solow residual is based on another strong assumption of Hicksian

technical change, where the innovation is assumed to improve the marginal productivity of

all inputs equally, and thus, shifts the production function by the same proportion at all

combinations of labour and capital. However, in reality, Hicks-biased technical change, in

which productivity growth depends on the input shares, as well as on the parameters of

innovation, is a rather common occurrence, especially when the general purpose of

technology is evolving through its many new uses[26]. Therefore, it is highly possible that this

assumption would be violated, and thus leading to a bias of the Solow residual.

Finally, another line of criticism has been based on the fact that the Solow residual

approach, although a non-parametric approach, still needs a specific functional form of the

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[24] Hulten, (2000
[25] Hall, (1988)

technology to be assumed, in order to obtain an exact estimate of the efficiency parameter. Therefore, since the assumption on the production function has to be made inevitably, why should it not be estimated with the econometric techniques, instead of with the non-parametric techniques, so that the assumption about the marginal productivity conditions could be avoided? The additional advantages of the econometric techniques are that they can also accommodate a full representation of the technology, non-competitive pricing behaviour, non-constant returns, and non-Hicksian technical change.

5.3.1.3 <u>Further Development on Growth Accounting</u>

Hulten (2000) praised the 1967 paper by Jorgensen and Griliches as a major milestone in the evolution of productivity theory and measurement. It advanced the hypothesis that careful measurement of the relevant variables and correct model specification should cause the Solow measure of total factor productivity to disappear, given this residual involved 'measurement of our ignorance'. They introduced a number of measurement innovations, based on a strict application of the neoclassical theory of production, into the Solow framework. They began by estimating the rate of growth of output, input, and total factor productivity, in which these initial estimates contain many of the errors made in attempts to measure total factor productivity without fully exploiting the economic theory underlying the social accounting concepts of real product and real factor input. Then, they started eliminating errors of aggregation, measurement, and assumptions. When all these processes were completed, they found that the residual had all but disappeared. Their result was in stark contrast to the prevailing results, in which the residual is believed to be the main reason behind economic growth.

However, Denison (1972) utilized the simpler concepts and statistical procedures that he considered appropriate for input measurement, and compared his results with those

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[26] Lipsey and Carlaw (2003)

of Jorgenson and Griliches (1967). He found a striking contrast between the results of the two studies, partly because of the difference in the time periods covered, and another part coming from the capacity utilization adjustment based on electricity used. After the appropriate adjustment had been done, Denison still found that the Jorgenson-Griliches residual was far from zero. According to Denison, a substantial part of the post-war growth of national output was due to an increase in productivity, while according to Jorgenson-Griliches almost all of the increase had been due to an increase in factor inputs. This set off a major debate on the 'bottom line' of empirical growth analysis, concerning how much output growth can be explained by total factor productivity (the 'Manna from Heaven') and how much by long term capital formation.

The 1980s were the prime years in which the prestige of the residual approach was high, and indeed that of non-parametric productivity analysis as a whole was high. The United States Bureau of Labour Statistics began publishing their multi-factor productivity estimates in 1983. Outside of the government statistics field, articles by Denison (1979), Griliches (1980), Diewert (1980), Hulten (1981, 1986), and many other authors were published. Also, many books were printed including Jorgenson, Gollop, and Fraumeni (1987), and Baumol, Blackman, and Wolff (1989). Interest had become extended from the simple measurement of growth and productivity, to the applying of growth accounting to explain international growth dispersion (e.g. Dowrick and Nguyen (1989)). However, by the 1990s, interest in the non-parametric approaches to measuring productivity had started to decline. The arrival of the 'New Growth Theory' challenged the underlying assumptions of the growth accounting residual, namely constant returns and perfect competition. The New Growth theory offered a new view in which markets were non-perfectly competitive, the production function exhibited increasing returns to scale, externalities among micro-units were important, and finally, the innovation was an endogenous part of the economic

system[27]. Therefore, there was a growing preference for econometric modelling in which these characteristics could be accommodated. Also, with the great improvement in computing technology, and the resulting development of high-powered personal computers, researchers were able to assemble and analyze large sets of data, thus, enhanced their ability to estimate a complex set of models.

Nevertheless, despite the shift in interest among productivity economists, the non-parametric growth accounting residual, together with the index number approach, were still widely used techniques, employed by the statistical agencies around the world, who published regular periodic productivity statistics reports (including the US Bureau of Labor Statistics, the OECD Productivity Database, the New Zealand Treasury, the Australian Bureau of Statistics, and the Thailand Productivity Institute). Moreover, many recent works on productivity have still been conducted based on the growth accounting approach, with some of these works being as follows.

Sarel (1997) examined the nature of the growth process in the ASEAN countries in order to discover whether it had been generated primarily by the additional inputs used or by productivity gains. He used internationally comparable data and explored an alternative method, including the growth accounting method, for estimating the capital and labour factor shares. The results contradicted to some previous studies. They indicated that Singapore, Thailand, and Malaysia had very impressive productivity growth rates, as well as identifying a relatively strong growth rate for Indonesia, but a negative one for the Philippines.

Jones (2002) developed a model, based on the growth accounting approach, to estimate the recent growth of the U.S. economy. The rising educational attainment and research intensity were suggested to be the main forces behind U.S. economic growth. The results from the model revealed that these factors explained 80 percent of recent U.S. growth, while less than 20 percent came from world population growth.

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[27] Hulten , (2000) and Reid, (1989)

Feinberg and Keane (2003) used confidential Bureau of Economic Analysis data on the activities of U.S. multinational corporations (MNCs) to examine the rapid growth of the U.S. MNC-based trade. They estimated a simple structural model of the production and trade decisions of U.S. MNCs with affiliates in Canada (which was the largest trading partner of the U.S.) using data from 1983-1996. They then used that model as a framework for decomposing the growth in intra-firm and arms-length trade flows into components due to tariff reductions, technological change, wages adjustments, and many other factors. They found that, although tariff reductions could account for a substantial part of the increase in arms-length MNC-based trade, most of the growth was attributed to technical change, with tariff reductions playing only a secondary role.

Kohli (2003) provided a decomposition of GDP growth of the United States for the period of 1948 to 1998, based on the translog national income function and the Törnqvist index of real GDP. The contributions of changes in output quantities, factor prices, and total factor productivity were identified, with special consideration were given to foreign trade, in which imports were treated as a negative output.

Crafts (2004) examined reasons for the slow productivity growth of the British industrial sector during the Industrial Revolution, despite the arrival of famous inventions. He used a growth accounting method based on an embodied innovation model. His results highlighted the relatively small (and long-delayed) impact of steam on productivity growth even when capital deepening was taken into account. Technological change (including embodied effects) accounted entirely for the acceleration in labour productivity growth that allowed the economy to achieve 'modern' economic growth.

Oulton (2004) argued that apart from using growth accounting to analyse the aggregate growth of a country, it was also possible to analyse the consequences of the changing economic structure of a country. In his paper, he analysed the changing of the economic structure of the UK, utilizing disaggregated industrial data from the national accounts. He suggested that for such a case, the theory of growth accounting provided an

important empirical framework, from which the contribution of each industry to the national economy could be measured and assessed. Also, it revealed how these contributions were evolving over time. He also identified several obstacles currently faced by analysts attempting to implement the growth accounting approach. These include: long runs of data series; variety of data sources; and inconsistencies between the levels of aggregation at which different data series are published.

Some works on measuring productivity utilizing the growth accounting approach have also been conducted using data on the Thai economy. Tinakorn and Sussangkarn (1996) analyzed the sources of output growth in Thailand using the Solow-Denison growth accounting framework. The total factor productivity of Thailand was found to be (on average) 2.6 percent per year during 1972 to 1990, without adjusting for improved quality of the factor inputs. From 1978 to 1990, the average adjusted total factor productivity growth for Thailand was 1.2 percent per annum, which translates into a 15.8 percent contribution to growth. The remaining part of growth was explained by changes in the factor inputs, with 37.2 percent coming from capital, 1.2 percent from land, and 45.8 percent from labour.

Tinakorn and Sussangkarn (1998) provided further estimates of Thai productivity growth. They examined the sources of Thailand's growth from 1980, when the new series of GDP and its components were available based on 1988 prices, up to 1995. They found that the average total factor productivity growth for the whole economy was about 2.7 percent, while the average growth of GDP was about 8.1 percent. The contribution of total factor productivity growth to the growth of the economy was around 33.6 percent. With the improved quality of labour being adjusted, the total factor productivity growth became 1.65 percent, which implied a contribution of about 20 percent to the overall GDP growth rate. Therefore, another 80 percent of GDP growth came from the increased use of factor inputs.

5.3.2 The Index Number Approach

Today, a significant number of statistic agencies that produce regular productivity statistics use the index number approach as the measure of productivity changes. A *productivity index* is generally defined as the ratio of an index of output growth divided by an index of input growth, where the outputs refer to the total quantities of all outputs produced by the production sector and the inputs are the total quantities of all inputs utilized by the same production sector over two accounting periods.[28] Therefore

$$A(t) = \frac{Y_t}{I_t} \tag{5.9}$$

where $A(t)$ is the productivity, Y_t is an index of output quantities, I_t is an index of input quantities, and the subscript t indicates the time period.

5.3.2.1 The Index Number Approach and Growth Accounting Approach

The index number approach and the Solow growth accounting approach are very closely related. The link between these two methods can be seen by rearranging equation (5.6) from the previous section as follow

$$\frac{\dot{A}}{A} = \frac{(\dot{Y} - \dot{I})}{(Y/I)} \qquad \text{where} \qquad \frac{\dot{I}}{I} = w_K \frac{\dot{K}}{K} - w_L \frac{\dot{L}}{L} \tag{5.10}$$

The index number approach can be viewed as an extension of, and complement to, growth accounting.[29] The two approaches are very similar. Both use indexes in computing productivity, and both suffer from similar problems. In the growth accounting approach, the estimation process starts by selecting a suitable production function, while in the index number approach, the process starts with the selection of the appropriate index. In theory,

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[28] Diewert and Lawrence, (1999)
[29] Carlaw and Lipsey , (2003)

the main difference between these two approaches is that the index number approach does not necessary require an aggregate production function to be specified, meaning that no assumptions about the underlying economic structure have to be made. Therefore, the productivity level measured by $A(t)$ and the subsequent growth rates may not be the same as would result from using the growth accounting approach.

However, in reality, in order to be able to select an appropriate index to be used for a set of data, some properties of the production function would have to be assumed. Each index is related to different underlying assumptions about the aggregate production function and therefore, calculation varies with the different indexes. For example, the Cobb-Douglas production function is explicitly related to the Divisia index when the model is specified in continuous time, and to the Törnqvist index when the model is in discrete time. Therefore, each one of these two approaches in measuring productivity implies the other, in the sense that in order to measure productivity from an aggregate production function, an appropriate index number would be needed, while if the index number approach is used and the estimation process is started with a specific index number, an aggregate production function is then implied[30]. Consequently, the difference between the index number approach and the growth accounting approach is, in reality, obscured.

5.3.2.2 <u>Selecting an Index Number Formula</u>

The calculation of equation (5.9) is straightforward, but the difficulty lies in the determination of the type of index to be used. In order to construct an output (as well as input) quantity index, it is necessary to determine an appropriate way to aggregate the different outputs and inputs. Most economies have a diverse range of outputs and inputs to which consideration must be given in determining how to add up the various outputs into single scalars, while avoiding the 'adding apples to oranges' problem of output

heterogeneity. Therefore, calculating the indexes requires a means of adding together these diverse quantities. There are a number of different index number formulations that attempt to overcome this problem. The most common way is by using prices or output shares to weight the various types of outputs. The most commonly used indexes include the Laspeyres, Paasche, Fisher, and Törnqvist index, which can be defined, respectively, as follows:

The Laspeyres index is the index, which uses the value of period 1 output measured in period 0 prices, divided by the value of period 0 output measured by period 0 prices. Therefore,

$$Y_L\left(p^0, p^1, y^0, y^1\right) = \frac{\sum_{i-1}^{m} p_i^0 y_i^1}{\sum_{i=1}^{m} p_i^0 y_i^0} = \sum_{i=1}^{m} s_i^0 \frac{y_i^1}{y_i^0} \qquad (5.11)$$

where $\quad s_i^t = \dfrac{p_i^t y_i^t}{\sum_{i=1}^{m} p_i^t y_i^t}$ (5.12)

The Paasche index measures the value of output in the two period using period 1 prices,

$$Y_P\left(p^0, p^1, y^0, y^1\right) = \frac{\sum_{i=1}^{m} p_i^1 y_i^1}{\sum_{i=1}^{m} p_i^1 y_i^0} = \left[\sum_{i=1}^{m} s_i^1 \left(\frac{y_i^1}{y_i^0}\right)^{-1}\right]^{-1} \qquad (5.13)$$

The Fisher index is the geometric average of the Laspeyres and Paasche indexes.

$$Y_F\left(p^0, p^1, y^0, y^1\right) = \left[Y_L\left(p^0, p^1, y^0, y^1\right) \cdot Y_P\left(p^0, p^1, y^0, y^1\right)\right]^{\frac{1}{2}} \qquad (5.14)$$

And finally, the Törnqvist index is the geometric weights of the output of the two periods using an average of the two period share weights.

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[30] Hulten, (2000)

$$Y_T\left(p^0, p^1, y^0, y^1\right) = \prod_{i=1}^{m} \left(\frac{y_i^1}{y_i^0}\right)^{0.5\left(s_i^0 + s_i^1\right)} \tag{5.15}$$

As stated earlier, one most critical issue for the index number approach is selecting the appropriate index for use in calculation. Two approaches are commonly used for making the decision regarding the 'best' type of index formulation to be used, namely, the economic and the axiomatic approaches[31]. The *economic approach* selects index number formulations on the basis of an assumed underlying production technology, which involves the production, cost, revenue, and profit functions. This approach, generally [32], assumes competitive optimising behaviour by producers in which producers are assumed to maximise profit, or minimise costs, for a given production technology[33]. The *axiomatic (test) approach* involves comparing the properties of the different index number formulations with a number of desirable properties they should possess. Potential indexes are then evaluated against those specified properties, and the one that passes the most tests would become the 'preferred' index formulation. Diewert and Lawrence (1999) defined these properties to include the following attributes:

- The constant quantities test states that if quantities are identical in two periods, then the output index should be the same irrespective of the price of the goods in both periods.

- The constant basket test indicates that if prices are constant over two periods, then the ratio of the quantity indexes between the two periods should be equal to the ratio of the values between the two periods.

- The proportional increase in output test requires that if all quantities increase or decrease by a fixed proportion between two periods, then the index should increase or decrease by the same fixed proportion.

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[31] McLellan, (2004)

[32] A recent research by Diewert and Fox (2004) shows that an index of multifactor productivity can be derived using the economic approach without the need for the optimising behaviour assumption.

[33] McLellan, (2004)

- The time reversal test specifies if the prices and quantities in period 0 and *t* are interchanged, then the resulting output index should be the reciprocal of the original index.

Diewert and Lawrence note that of the four index formulations mentioned above, only the Fisher index had all four desirable properties. Both the Laspeyres and Paasche indexes were inconsistent with time reversal test, while the Törnqvist fails the constant basket test. Thus, Diewert and Lawrence chose a chained Fisher index as the preferred index for constructing output and input quantity indices. These results are summarized in Table 5.1.

Table 5.1: Index Axioms

	Constant quantities	**Constant basket**	**Proportionality**	**Time reversal**
Laspeyres	Yes	Yes	Yes	No
Paasche	Yes	Yes	Yes	No
Törnqvist	Yes	No	Yes	Yes
Fisher	Yes	Yes	Yes	Yes

Source: McLellan (2004)

Nonetheless, in practice, it is rather common that both the economic and the axiomatic approaches will be used alongside one another when choosing an index number formula. Also, in reality, data availability will be another important factor that often influences the decision.

5.3.2.3 Exact and Superlative Index Numbers

Although it is widely accepted that the Solow growth residual provides a simple, yet elegant, framework for productivity measurement, in reality, the calculation of the Solow residual has one main difficulty. Solow's derivative of the residual is based on a continuous-time formulation, but unfortunately, data do not normally come in this form. One solution to this difficulty is to find a reasonable discrete-time approximation to the continuous-time model. In this approach, the choice among competing approximation methods is based largely on

computational expediency, with the implication being that the discrete-time approximation is not derived as an organic part of the theory, thereby weakening the link between theory and measurement.[34]

Jorgenson and Griliches were the first to recognize the use of a discrete-time approximation to the Divisia index. In their 1967 work (in which they attempted to prove that careful measurement of the relevant variables would cause the Solow residual to disappear), the Divisia index[35] framework was applied to their disaggregated capital and labour components in order to avoid the aggregation bias associated with internal shifts in the composition of the inputs. However, because the data available are not continuous over time, they, instead, introduced a discrete-time approximation to the Divisia index that was derived from the Törnqvist index, where the continuous-time income share were replaced by the average between-period shares.

Diewert (1976) later showed that the Törnqvist approximation to the Divisia index used by Jorgenson and Griliches was not an approximation, but an 'exact' index number under the right conditions about the production function. He defined the exact index as a particular index that corresponded directly to the theoretic index derived from the production technology. He claimed that since the Törnqvist index is the corresponding index for the translog functional form, therefore, the Törnqvist index is the exact index for the translog production technology. The degree of the exactness would then depend on how close the assumed translog production function was to the true production function. He also proceeded further to define the term 'superlative' index as an exact index that corresponded to a production technology that has a flexible functional form in which it is able to approximate to a range of other functional forms. Therefore, the Törnqvist index is a

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[34] Hulten , (2000)

[35] The Divisia index is a weighted sum of growth rates, where the weights are the components' shares in total value. The continuous time Divisia index is $D(\Gamma) = \exp\left\{ \int \left(\sum_{i=1}^{n} \frac{p_{it} X_{it}}{\sum p_{jt} X_{jt}} \cdot \frac{\dot{X}_{it}}{X_{it}} \right) \right\}$

superlative index because the translog functional form could approximate a range of other functional forms[36], e.g. the Cobb-Douglas production function.

Hulten (2000) mentioned that what Diewert showed, in effect, was that the translog specification of the production function served as a potential function for the discrete Törnqvist index, in the same way that the continuous production function served as a potential function for the continuous Divisia index. One important by-product of this finding is that the index number approach of the Solow residual is not entirely non-parametric. There is a parametric production function underlying the method of approximation if the discrete-time index is to be an exact measure of Hicksian efficiency

5.3.2.4 Other Issues on Index Number

Many other complex issues also need to be considered when dealing with the index number approach in measuring productivity. However, it is not with in the scope of this thesis to go further into the details of these issues. Therefore, a general overview of these issues will be provided in this section, and some literatures to be noted for further detailed study.

In addition to choosing an index number formula, a choice also needs to be made on whether it is more appropriate to construct a fixed-weight or a chained index. A fixed-weight quantity index is an index that compares quantities in period t relative to some fixed base period. Information on price movements as well as on the weighting changes in the intervening periods are ignored. By contrast, a chained index compares quantities between two periods by taking into account the information on weighting changes in the intervening periods. McLellan (2004) has claimed that a chained index uses price information that is more representative of that faced by economic agents in each period than is a fixed-weight index. In general, when relative prices of goods change, relative quantities would change as well. Using a fixed-weight index in measuring quantity changes in such cases would,

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[36] McLellan N., 2004

undoubtedly, introduce substitution bias into the quantity index, since the information on relative price changes is not taken into account. Moreover, the fixed-weight index usually becomes less representative over time. Therefore, the substitution bias becomes larger, hence the need for the use of the chained index becomes more evident.

The chained output quantity index can be formed by linking the fixed weight quantity indices as follows

$$C_{0,t} = 1 \times D_{0,1} \times D_{0,2} \times ..... \times D_{t-1,t} \tag{5.16}$$

where $C_{0,t}$ denotes the chained index between period *0* and *t*, and $D_{t-1,t}$ denoted the direct index between period *t-1* and *t*.

One other issue that needs careful consideration when measuring productivity is the measuring of physical capital inputs. Information on capital flow is needed when the measuring of productivity growth is the prime concern. However, as the flow of physical capital services is not directly observable, the flow of capital is usually assumed to be proportional to the capital stock. Moreover, the capital stock is also subjected to an age-efficiency schedule in which the productive capacity of capital assets is discounted over time in order to take into account of the loss in its productive capacity. Three commonly used age-efficiency patterns are the linear, the 'one-hoss-shay', and the geometric age-efficiency schedules. The linear age-efficiency schedule assumes that the productive capacity of an asset depreciates linearly over the entire asset's economic life. The one-hoss-shay efficiency schedule (sometimes refered to as the light bulb efficiency pattern) assumes that the productive capacity remains constant over its economic life, but then falls to zero when the asset's economic life ends. The geometric age-efficiency pattern assumes that the productive capacity of an asset declines at a constant rate. Further details on this literature concerned with measuring physical capital stocks are Hulten (1990), Hulten and Wykoff (1995), Diewert and Lawrence (2000), the OECD Manual (2001), and McLellan (2004).

The selection of labour inputs is another complex issue in measuring productivity. In general, the number of hours worked is usually the preferred labour input, as compared to the number of people employed. This is because the number of people employed could not reflect the changes in the number of hours worked by each worker or changes in the composition of part-time versus full-time workers. However, the labour input using the number of hours worked is still unable to capture differences in human capital. The hours worked by different types of workers are, essentially, treated as if they are identical. Therefore, the differences in human capital and the quality of workers are subsumed within the productivity measure. In order to separate the contribution to the changes in output that comes from the changes in human capital that coming from changes in the quality of labour inputs, adjustments for differences in the quality of hours worked by different types of workers arre needed. This could be done through the separate accounting of different types of labour inputs when forming productivity measures. From equation (5.1), in which the aggregate production function was presented, an alternative specification can be developed as follows

$$Y_t = Q = B(t)g(K^1,...,K^M,L^1,...,L^N : t) \tag{5.17}$$

With this specification, each group of the capital inputs $\left(K^1,...,K^M\right)$ and each class of the labour inputs $\left(L^1,...,L^M\right)$ are accounted for separately. McLellan (2004) has shown that

$$B(t) = A(t)\left(\frac{\prod\limits_{n=1}^{N}\left(L_t^n / L_0^n\right)^{\frac{1}{2}\left(w_0^n + w_t^n\right)}}{\sum\limits_{n=1}^{N} L_t^n \Big/ \sum\limits_{n=1}^{N} L_0^n}\right)^{\frac{1}{2}\left(w_0^L + w_t^L\right)} \tag{5.18}$$

Equation (5.18) shows that the alternative productivity index $B(t)$ is simply the original productivity index $A(t)$ adjusted by the quality composition of the labour input. Literature that adopt a similar type of index includes Jorgenson, Gallop and Fraumeni (1987), and Jorgenson and Fraumeni (1989, 1992).

5.3.2.5 <u>Statistical Realities of the East Asian Growth Experience</u>

Of the extensive literature on measuring productivity growth utilizing the index number approach, the most cited is undoubtedly the work of Young (1995). He provided a careful analysis of the historical patterns of output growth, factor accumulation, and productivity growth in the newly industrializing countries (NICS) of East Asia, i.e. Hong Kong, Singapore, South Korea, and Taiwan, between 1966 to early 1990s. He argued that the common premise stating that productivity growth in these economies, particularly in their manufacturing sectors, had been extraordinarily high, was largely incorrect. Once one has taken into account an equally remarkable record of factor accumulation in these countries during that period, one finds a much less impressive growth in productivity.

He pointed out that, during that period, the East Asian NICs had experienced remarkable growth in factor accumulation in terms of labour inputs, capital inputs, and human capital. The rapid post-war decline in population birth rates (hence changing dependency ratios), the rising rates of female labour force participation, as well as the intersectoral transfer of labour (Notably from the agricultural sector to the manufacturing sector) have all led to a substantial growth in labour inputs. The expanding investment rates over time have led to growth in capital inputs. And finally, the improving levels of education have led to improvements in human capital.

He then estimated the growth in productivity of these four countries using the translogarithmic value added production function

$$Y = \exp[\beta_0 + \beta_K \ln K + \beta_L \ln L + \beta_t t + \tfrac{1}{2}B_{KK}(\ln K)^2 + B_{KL}(\ln K)(\ln L)$$

$$+ B_{Kt} \ln K \cdot t + \tfrac{1}{2}B_{LL}(\ln L)^2 + B_{Lt} \ln L \cdot t + \tfrac{1}{2}B_{tt} t^2] \qquad (5.19)$$

where K, L, and t denote capital input, labour input, and time, under the assumption of constant returns to scale. The parameters β_i and B_{jk} satisfy the restriction:

$$\beta_K + \beta_L = 1, \qquad B_{KK} + B_{KL} = B_{LL} + B_{KL} = B_{Kt} + B_{Lt} = 0 \quad (5.20)$$

He then differencing the logarithm of the production function, which provide a measure of the causes of growth across discrete time periods:

$$\ln\left(\frac{Q(t)}{Q(t-1)}\right) = \Theta_K \ln\left(\frac{K(t)}{K(t-1)}\right) + \Theta_L \ln\left(\frac{L(t)}{L(t-1)}\right) + TFP_{t-1,t} \quad (5.21)$$

where $\Theta_i = [\Theta_i(t) + \Theta_i(t-1)]/2$ and Θ_i denotes the elasticity of output with respect to each input or, equivalently, assuming perfect competition, the share of each input in total factor payments. The translog index of TFP growth $(TFP_{t-1,t})$ provides a measure of the increase in output attributable to the time-related shift in the production function.

In order to allow for more accuracy of measurement, Young subdivided capital and labour inputs into finer sub-input categories. He divided the capital input into five categories consisting of residential buildings, non-residential buildings, other durable structures, transport equipment, and machinery. (This method had also been applied in this thesis in Chapter 9 where capital input was separated into 3 categories including land, machinery, and office appliances.) Labour was distinguished on the basis of sex, age, and education.

His results showed that over the period of concern, productivity growth in the aggregate non-agricultural economy of the NICs was 0.2 percent in Singapore, 1.7 percent in South Korea, 2.1 percent in Taiwan, and 2.3 percent in Hong Kong, while in the manufacturing sector, productivity growth was -1.0 percent in Singapore, 1.7 percent in Taiwan, and 3.0 percent in South Korea. When compared to productivity growth in the manufacturing sector of other countries (e.g. 1.6 percent in Germany, 2.0 percent in Japan, 1.3 percent in United Kingdom, 0.4 percent in United States, 1.2 percent in Mexico, and 2.6 percent in Venezuela), it can be seen that productivity growth in the NICs is not particularly low, but at the same time, neither is it not extraordinarily high.

Young concluded that the remarkable post-war growth of East Asian economies was primarily the result of a one-shot increase in output, brought about by the rise in

participation rates, investment to GDP ratios, educational standards, as well as the intersectoral transfer of labour from agriculture to other sectors (e.g. manufacturing) with higher value added per worker, but not the growth in productivity.

5.3.2.6 Recent Empirical Researches

Many further developments have been accomplished within the scope of the index number approach, both theoretically and empirically. In this section, some of the most recent literature is considered in order to provide a guideline on the direction of current research. It should also be noted here that this section is not aimed at showing knowledge of the rigorous literature n this particular topic of index number, which is not the primary objective of this thesis.

Carlaw and Lipsey (2003a) briefly surveyed the literature on total factor productivity calculations, including the various techniques and problems associated with it. They argued that TFP was not a measure of technological change and only under ideal conditions did it measure the supernormal profits associated with technological change. The critical driving force of economic growth was not the super-normal profits that technological improvement generated, but the continuous creation of opportunities for further technological development. Six illustrations of cases in which TFP failed to correctly measure these super-normal profits were provided. A version of the Carlaw and Lipsey (2003b) model of endogenous general purpose technology-driven growth is then utilized to make some progress towards answering Prescott's (1998) call for a theory of TFP. The model was then used to simulate artificial data and connect theoretical assumptions of returns to scale and resource costs to the conditions under which TFP miss-measured the actual growth of technological knowledge.

Färe and Primont (2003) examined two ways of aggregating Luenberger productivity indicators across firms, in order to show that this is only possible under assumptions of allocative efficiency. The first approach imposed a rather implausible allocative efficiency assumption that employed every observed input-output vector with respect to the technologies in every time period. The second approach relied on more palatable assumptions, and only imposed allocative efficiency on the observed input-output vectors, with respect to their contemporaneous technologies. It utilized the superlative index number approach, which was then applied to a directional distance function approach by Balk (1998). The results indicated that for the first approach, aggregation is possible only if both observed quantities vectors are allocatively efficient with respect to both of the time-adjacent technologies. For the second approach, aggregation is only possible if each observed quantity vector is allocatively efficient with respect to the current technology, and if the directional distance function has a quadratic functional form, with time-independent second order coefficients. They concluded that the superlative index number approach was the more promising approach of the two.

Diewert and Fox (2004) examined the sources of profit change for Australia's largest telecommunications firm, Telstra. A new method allowed for changes in firm's profits to be broken down into separate effects. Productivity change, price changes and growth in the firm's size were the suggested effects. This method, therefore, allowed them to calculate the distribution of the benefits of productivity improvements between consumers, labour, and shareholders. The results showed that about half the benefits from Telstra's productivity improvements from 1984 to 1994 were passes on to consumers in the form of real price reductions.

Griffith, Redding, and van Reenen (2004) argued that research and development (R&D), apart from its conventional role of stimulating innovation, had an additional role in enhancing technology transfer, or the so-called absorptive capacity. They examined this issue using a panel data of industries across twelve OECD countries. Their results showed

that R&D was both statistically and economically important in the process of catching up as well as stimulating innovation. They also found that human capital played a major role in productivity growth, while trade only had a minor effect. They claimed that the existing U.S.-based empirical studies might have underestimated the return to R&D, as they had failed to take account of the R&D-based absorptive capacity in their studies.

Färe, Grosskopf, Forsund, Hayes, and Heshmati (2006) attempted to model and compute the productivity of public education. This was in the service sector and did not have marketable outputs. They used data on the Swedish primary and secondary school system over the period from 1992 to 1995. They utilized a Malmquist productivity index in which multiple outputs such as test results were allowed, without the need of requiring price data with which to aggregate these outputs. Also, this index allowed inputs, such as teachers and facilities, and proxies for quality of inputs, such as experience of teachers, as well as outputs to be accounted for. The results indicated that productivity growth did change when the quality of inputs and outputs were taken into account.

5.3.3 Econometric Approach

The empirical estimation of production functions began as early as 1928, with the paper by Cobb and Douglas (1928). However, until the 1950s, production functions were still largely used only as devices for studying the functional distribution of income between capital and labour at the macroeconomic level. The origins of empirical analysis of microeconomic production structures can be more recently identified with the work of Johnston (1960), and Nerlove (1963). However, these papers focused mainly on costs rather than production per se, though Nerlove (following Samuelson (1938) and Shephard (1953)) has highlighted the relationship between the cost and the production[37]. The methodology employed in most of the recent studies has been developed from the seminal paper on the translog production

function by Bernt and Christensen (1973). The conventional econometric approach of productivity measurement involves estimating the parameters of a specified production function (or in some case, cost or profit function) in order to yield an estimate of the parameter that reflect the growth in technological progress. This is typically interpreted as a measure of productivity growth. This approach of productivity measurement is only based on observations of the volume outputs and inputs. Thus it avoids postulating a relationship between production elasticities and income shares, and therefore, leaves room for the possibility of testing these relationship.

A single output production function can be written as

$$Y = Q = f(x_i; \beta) + \varepsilon \tag{5.22}$$

where ε is a random statistical error term with zero mean. Producers are assumed to be price takers in their input markets, so input prices may be treated as exogenous. This function could be expressed in the log linear form as

$$\ln Y = \ln Q = \alpha + \beta x_i + \varepsilon \tag{5.23}$$

where this functional form does not restrict the model only to the Cobb-Douglas, as a number of other functions are also linear in the parameters (i.e. translog production function). The least squares method, or some variant of it, was routinely used to lit a function to a 'cloud' of data points.

5.3.3.1 Econometric VS Non-Parametric Approach

The conventional econometric approach has several major advantages when compared to the non-parametric approaches, i.e. index number and growth accounting approaches. Firstly, it allows other parameters of the production technology to be explored, in addition to merely estimating the efficiency term, as in the growth accounting and index number

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[37] Greene, (1993)

approach. Embellishments like the cost-of-adjustment parameters can also be incorporated into the analysis to help explain the residual. Moreover, greater flexibility in specifying the production technology can also be accommodated. The econometric approach allows the investigation of technical change other than the Hicks-neutral formulation implied by the growth accounting and the index number approach. Furthermore, non-competitive pricing behaviour, non-constant returns, and factor-augmenting technical change can all be examined.

However, this increased flexibility, and the ability to test the validity of different assumptions of the econometric approach, do not come without costs. The fully-fledged models (i.e. the estimation of the translog and other flexible function) can raise complex econometric issues such as parameter estimates that imply oddly shaped isoquants. This requires practitioners to place *priori* restrictions on the values of these parameters. Therefore, the problem of robustness of the resulting parameter estimates against alternative ways of imposing restrictions could arise. Additionally, with these complex functions, when data samples are not large enough, the profusion of parameters can press on the number of data observations, requiring further re-imposing *a priori* the restrictions in order to increase the degrees of freedom. Furthermore, the use of more flexible, but highly complicated, production function usually requires non-linear estimation techniques, which are valid only under special assumptions, and therefore, again, brings about further questions on the statistical properties of the resulting estimates.

Moreover, the use of the econometric approach is generally limited in the academically oriented, single studies of productivity growth, but not in the publication of regular productivity statistics, because of several reasons. Firstly, the updating of the econometric approach involves a full re-estimation of the complicated model and the hypothesis testing following it, therefore, such an approach could be very inconvenient and time-consuming. Secondly, the methodology of such an approach is often too complicated to communicate to a broad spectrum of users. And finally, the significant amount of data

required by complicated models tends to reduce the timeliness of the results. Therefore, the econometric approach undermines the main purposes of the regular publication of productivity statistics in delivering timely and easy-to-understand statistics to the broadest group of recipients. Hence it presents little attraction from the point of view of statistical agencies[38]. However, the potential richness, and the testable set-up of this approach make it a valuable complement to non-parametric, index number, approaches which are currently used as the standard tool for productivity statistics. Hulten (2000) pointed out that there is no reason why the econometric and the index number approach should be viewed as competitors. Both approaches should be implemented simultaneously, thereby exploiting the relative simplicity and transparency of non-parametric estimates to serve as a benchmark for interpreting the more complicated results of the econometric approach. At the same time, the econometric approach could further explain the productivity residual, thereby reducing our ignorance about the 'measure of our ignorance'.

5.3.3.2 <u>Measuring Average Behaviour</u>

One fundamental problem with the conventional econometric approach lies in the fact that it is very often estimated utilizing an 'averaging' estimators, such as the least squares estimators, which involves estimating the average rather than the 'best practise' technology upon which the production function concept is based on. This practise causes two major problems for the estimates of the conventional econometric approach. First, in the standard models of production function analysis, producers are assumed to be maximizing the quantity of their outputs given the available quantities of a set of inputs. However, when these production functions are estimated by the standard statistical techniques (i.e. regression of output on inputs), which is generally estimated based on the method that simply estimate a function that passes through the middle of a scatter of data points, and

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[38] OECD Manual, (2001)

therefore the mean output rather than the maximal output is estimated. Thus, this results in estimates that are inconsistent, with the above definitions.

Moreover, these analyses, which often employ simple least squares technique, will have error terms that are assumed to be symmetrically distributed, with zero means. This assumption, in turn, indicates that the only source of departure from the estimated function is due to the statistical error, e.g. measurement error, or random shocks beyond the control of producers, such as bad weather. Therefore, these models are subjected by a common, but rather untenable, assumption that producers are always operating on their production functions, and that technical inefficiencies in the production process do notr exist.

5.3.3.3 <u>Recent Developments</u>

Despite the above inconsistency of the *average* measurement technique, the conventional econometric approach is still a very useful method for decomposing growth because of its flexibility. The recent developments in this approach have concentrated on this issue and have been used greatly to complement the index and growth accounting approaches. Key such works are consider below.

Szeto (2001) used the capital stock series published by Statistics New Zealand (SNZ) in estimating the production function, and the elasticity of substitution. The primary purposes of this paper were to, firstly, test the validity of the Cobb-Douglas specification with New Zealand data. He argued that many researchers had used the Cobb-Douglas function for its linear property; however, the use of such a function implied that the elasticity of substitution between capital and labour was constant and always equal to one. He argued that in the long-run endogenous growth model with possibly multiple steady states, there was a possibility that the elasticity of factor substitution might not be equal to one. Secondly, he attempted to test the validity of the use of the value-added form in the production function, which implied that the marginal product of the intermediate-good

inputs was constant and equal to unity. He argued that the use of the value-added form was justifiable only under very restricted conditions such as functional seperability between intermediate-good inputs and capital/labour inputs. Therefore, he employed two approaches in estimating the production function.

In the first method, he employed the methodology proposed by Grimes (1983) in which the constant elasticity of substitution (CES) production function was estimated using value-added data. Since the CES technology had an elasticity of substitution that was constant and took values other than unity, he argued that it was possible to test the suitability of the Cobb-Douglas specification. Then, by allowing for gross output as the measure of output, he proceeded further by estimating a nested CES structure. The two approaches were then compared and tested to identify whether the use of the value-added form is justified or would cause the estimates of parameters to be biased.

He reported that the results from both approaches rejected the Cobb-Douglas specification, indicating that the elasticity of capital and labour substitution was not equal to one. Also, he found strong evidence that there was some substitutability between value-added and imports, and therefore, that this could lead to a downward bias in labour productivity estimates. This paper by Szeto has raised an important issue concerning the importance of including imports as inputs in the production function in New Zealand. In particular, from the 1990s onward, the New Zealand economy had been marked by higher import penetration ratios and a changing composition of imports. Therefore, the gross output approach was more suitable in constructing models of growth for New Zealand for the post-1990 period.

Chun and Nadiri (2002) examined the sources of productivity growth in the U.S. computer industry from 1978 to 1999. They separated technical change in total factor productivity growth into two components: *product innovation*, associated with better quality and *process innovation* associated with added quantity. They argued that the traditional TFP approach focused mainly on the latter component, in which they concentrated on how much

productivity growth was commensurate to improvements in the technological efficiency of teh production process. However, productivity growth could also take place in the improvement of output quality. Therefore, the identification of both process and product innovations were crucial to exploring the sources of productivity growth. They constructed the variables of output quantity and quality utilizing both the hedonic (quality-adjusted) prices and the list (quality-unadjusted) prices. They then formulated a joint production model of output quantity and quality, and estimated the joint optimization conditions of quantity and quality together with a general cost structure that accounted for scale economies and mark-ups. Based on the estimation results, they decomposed TFP growth into three effects consisting of process innovation, product innovation, and economies of scale.

They found that, firstly, the technical change associated with process innovation was a major factor contributing to TFP growth in the computer industry. It accounted for almost half of the total TFP growth, while product-oriented technical change also explained about 30 percent of the total TFP, and the effect of economies of scale explained about 20 percent. Hence, the technical changes contributed for almost 80 percent of the total TFP growth. Secondly, the found a substantial size of mark-ups in pricing of both output quantity and quality, while was larger for the quality compared to the quantity mark-up. This suggested that the computer market was more competitive in quantity rather than in quality. Thirdly, they found that the TFP contribution from product innovation rose rapidly in the late 1990s, while the contribution from process innovation and economies of scale changed very little. They claimed that this increasing trend in product innovation challenged the predictions of the industry life-cycle theory, which stated that new industries should experienced product innovation in the earlier period, and then face process innovation later on.

Crafts and Mills (2005) considered traditional TFP growth estimates and thier accuracy in revealing the underlying 'pure' technological change, by taking into account of

scale economies, fixed factors of production, and adjustment costs. They claimed that in a pure Solow model with perfect competition and constant returns to scale, the TFP growth was equal to the contribution of technological progress. However, this is not always the case. The TFP growth would understate the impact of technological progress when endogenous innovation is embodied in the new types of capital, in which case these better technologies would transmit their impact indirectly through the capital contribution. Also, even when technological change was exogenous and disembodied, the TFP growth would only measure its contribution to growth correctly when there were constant return to scale, when factor shares reflect marginal products, and when there were no fixed factors of production.

They argued that, following the Morrison (1992, 1993) methodology, these problems could be solved by the use of econometric techniques to filter out other effects in order to obtain the pure TFP growth. Therefore, they proposed using the Morrison methodology to reconsider the contribution of innovation to productivity growth in West Germany and the UK during the period of 1950 to 1996. Their finding suggest that the biases in the traditional estimates of TFP were not very substantial, and were on average 2 percent per year in the early post-war period, and declining over time. Also, the size of bias was fairly similar in each period for both countries, but varied over time. They also claimed that in both countries, the early post-war years were marked by a larger bias, as the adjustment costs from a rising supply price of capital goods held down the TFP growth below the level which should have arisen from pure technological progress. However, as might be expected, this problem has largely disappeared in the later globalisation period.

5.3.4 Distance Function Based Approach

The issue of technical inefficiency was first introduced in the pioneer work by Koopmans (1951) in which he implied that not all producers are technically efficient, and an increase in

output is sometime possible without the need to increase inputs. Since this introduction of the technical inefficiency concept by Koopmans, there has been an immense increase in the number of studies concerning the issue. Economists had since then have used the term productive efficiency to describe how well an organizational unit is performing in utilizing resources to generate outputs or outcomes. Farrell (1957) further demonstrated that overall efficiency can be decomposed into two components, allocative efficiency and technical efficiency. Allocative efficiency is the market condition in which resources are allocated in a way that maximises the net benefit attainable throughout their use. It could be measured by the reduction in cost that could potentially be achieved when firms use their optimal combinations of inputs. On the other hand, technical efficiency is the condition arising when the maximum amount of an output is produced, for a given set of inputs (output-oriented technical efficiency) or when the minimum amount of inputs are required to produced a given output level (input-oriented technical efficiency). A firm is considered to be technically efficient if it is producing the maximum quantity of output that is technologically feasible, given the quantities of the factor inputs it employs. Therefore, it could be measured by the amount of outputs that would be potentially increased by producing on the possible production frontier.

However, the traditional production functions estimate by the standard statistical techniques will have error terms that is assumed to be symmetrically distributed with zero means, which implies that the only source of departure from the estimated function is due to the statistical noise, hence, leaving no room for the inefficiency component. For this reason, production function estimates by the least squares estimations are no longer the appropriate choice for estimating models based on the Koopmans' and Farrell's concepts. An alternative estimation method for the production function and productive efficiency, based on the distance function was then suggested by many analysts such as Aigner and Chu (1968), Aigner, Lovell and Schmidt (1977), Stevenson (1980), Pitt and Lee (1981), Schmidt and Sickles (1984), Battese and Coelli (1988), Cornwell, Schmidt and Sickles (1990), and

Kumbhakar (1990). These approaches aimed to separate productivity into two components, namely the changes resulting from a movement towards the production frontier, and the shifts in the frontier as such. Simply speaking, the distance function approach estimates the productivity level by utilizing an output distance function that measures how close production of a particular output is, when compared to the maximum attainable level of output, given the current level of input, if production is technically efficient. In other word, it represents how close a particular output vector is to the production frontier, given a particular input vector. At the aggregate level, this simply involves measurement of the distance of an economy from its production function.

5.3.4.1 Parametric VS Non-Parametric Distance Function

Among the many suggested measures of efficiency, based on the concepts of technical and allocative efficiency, two main approaches could be classified. The first, favoured by the majority of economists, is the parametric approach. Here, the form of the production function is either assumed to be known or is estimated statistically. The advantages of this approach are that any hypotheses can be tested with statistical rigour, and that relationships between inputs and outputs follow know functional forms. However, in many cases, there is no known functional form for the production function and, indeed, it may be inappropriate to talk in terms of such a 'production' function. This is most clearly the case in public sector organizations such as health and education, but is also evident in certain private sector organizational units that are not, for example, concerned with taking unfinished goods or raw materials, processing them and producing finished goods or sale or transfer. (However, a more detailed development and discussions of the parametric distance function approach will be presented later in chapter 7 of this thesis.)

Second, the non-parametric approach (which shall be examined in more details in the next section) is an approach that makes no assumptions about the form of the

production function. Instead, a best practice function is built empirically from observed inputs and outputs. Charnes, Cooper and Rhodes (1978), the pioneers of this approach, had attempted to estimate production efficiency by utilizing the technique they called Data Envelopment Analysis (DEA), in which a non-parametric technique is used in assessing the efficiency of a unit, in relation to the other units in its grouping[39]. They also introduced the generic term 'decision making units (DMUs)' to describe the collection of firms, departments, divisions, or administrative units which have common inputs and outputs and which are being assessed for efficiency. Finally, they described the technique used in the DEA as follows: 'The efficiency measure of a DMU is defined by its position relative to the frontier of best performance, established mathematically by the ratio of a weighted sum of outputs to a weighted sum of inputs'.

However, the original model introduced by Charnes, Cooper and Rhodes (1978) was applicable only to technologies characterized by constant returns to scale. Banker, Charnes, and Cooper (1984) later extended this model to accommodate technologies that exhibited variable returns to scale. In subsequent years, methodological contributions from a large number of researchers have accumulated into a significant volume of literature concerning these models, and the generic approach of DEA has merged as a valid alternative to regression analysis for efficiency measurement. However, unlike in management science, where DEA became virtually an instant success, in economics, its welcome has been far less enthusiastic[40]. This scepticism about DEA on the part of economists was due to three principal reasons:

- First, DEA is a non-parametric method, and therefore, there is no production, cost, or profit function that could be estimated from the data. This, thus, precludes the possibility of evaluating the marginal products, partial elasticities, marginal costs, or elasticities of substitution from a fitted model. As a result, the usual conclusions

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[39] Norman and Stoker (1991)

[40] Ray , (2004)

about the technology, which are usually possible from a parametric functional form, could not be derived.

- Second, and more importantly, DEA utilizes the linear programming techniques to estimate efficiency components. However, being non-statistical in nature, the linear programming solution of a DEA produces no standard errors, and therefore leaves no room for hypothesis testing.

- Third, in DEA, with no standard errors, any deviation from the frontier will be treated as inefficiency, leaving no provision for random shocks of any types. This is in contrast to the more popular stochastic frontier model, which explicitly allows the frontier to shift as a result of random shocks.

The above problem of the DEA efficiency measures lacking standard errors was explained in Ray (2004), in that it stemmed from the fact that the stochastic properties of inequality-constrained estimators were not well established in the econometrics literature. Although there was new research underway to address this problem, a simple solution was still unlikely to be found in the near future. This research can be classified into several different lines including, first, the convex and monotonic non-parametric frontier with one-sided disturbance term, suggested by Banker (1993). He showed that the DEA estimator of such a frontier would converge in distribution to the maximum likelihood estimators; hence, he was also able to specify F tests to be used for hypothesis testing. Subsequently, Banker and Maindiratta (1992) introduced an additional two-sided component in the composite error term, and proposed a new estimation procedure for the non-parametric frontier by DEA. Second, Park and Simar (1994) employed parametric and non-parametric estimation techniques in order to derive the statistical distribution of the efficiency estimates.

Third, a line of research was initiated by Simar (1992) and Simar and Wilson (1998, 2000) in which a bootstrapping technique was combined with DEA to generate empirical distributions of the efficiency measures of individual firms. Simar and Wilson (1998, 2000) proposed an alternative ways to make estimates of technical efficiency employing the

method of DEA more robust. The DEA approach is estimated non-parametrically from a set of n observed production units; therefore the efficiency is measured relative to an estimate of the true, but unobserved, production frontier. Since statistical estimators of the frontier are obtained from finite samples, the corresponding measures of efficiency are sensitive to the sampling variations of the obtained frontier. DEA estimators show consistency under very weak general conditions, but the obtained rates of convergence are, as with many nonparametric estimators, very slow. Simar and Wilson solved this problem by adopting a smoothed bootstrap method to obtain more reliable efficiency rankings.

Bootstrapping is based on the idea of repeatedly simulating the data-generating process (DGP), usually through resampling, and applying the original estimator to each simulated sample, so that resulting estimates mimic the sampling distribution of the original estimator. The primary difficulty in applying bootstrap methods in complex situations, such as the case of non-parametric frontier estimation, lies in simulating the DGP. In the case of nonparametric frontier estimation, a model of the DGP must be defined clearly, a priori, otherwise we cannot know whether the bootstrap mimics the sampling distribution of the estimates of interest, or some other distribution.

Simar and Wilson demonstrated that although nonparametric efficiency measures were often criticized for lacking a statistical basis, in fact, nonparametric efficiency measures do have a statistical basis. One of their chief differences from stochastic, parametric models is the implicit nature of the DGP. By focusing on the underlying nature of the DGP, they were able to use bootstrap methods to analyze the sensitivity of nonparametric efficiency scores to sampling variation.

The bootstrap estimates offered by their methodology offer several possible enhancements to typical DEA applications. Firstly, one can test for statistical significance among differences in firms' efficiency scores, similar to the way in which t ratios are used in classical regression studies. Secondly, the bootstrap estimates can also be used to test hypotheses about the structure of the underlying technology. Thirdly, their approach

requires only minimal assumptions on the DGP, hence allowing one to avoid more restrictive assumptions usually imposed. Finally, their approach can be used with cross-sectional data, unlike other non-parametric approaches that require panel data.

Currently, this line of research has generated quite a lot of interest, and attempts are being made to developing the standard DEA software to incorporate the bootstrapping option.

5.3.4.2 Data Envelopment Analysis

Followed the work by Charnes, Cooper and Rhodes (1978) and Banker, Charnes, and Cooper (1984), Färe, Grosskopf, Norries and Zhang (1994) have defined an output distance function at time t as

$$D_0^t(x^t, y^t) = \inf\{\theta : (x^t, y^t/\theta) \in S^t\} = (\sup\{\theta : (x^t, \theta y^t) \in S^t\}^{-1} \qquad (5.24)$$

where x^t is a vector of input quantities at time t and y^t is a vector of output quantities at time t. S^t describes a production technology, or production possibility set, that is feasible using the technology available at time t. The term $\inf\{\theta : (x^t, y^t/\theta) \in S^t\}$ indicated that given the set of real numbers θ, where θ is such that the input/output combination $(x^t, y^t/\theta)$ is part of the production possibility set that is technically feasible, given the technology at time t, the infimum or the greatest lowest bound of θ is needed. This infimum of θ is defined by the biggest real number that is less than or equal to every number in θ.

The term $D_0^t(x^t, y^t)$ is the output distance function based on the input and output vectors at time t. To calculate $D_0^t(x^t, y^t)$, it is necessary to find the largest factor by which all the outputs in the output vector could be increased when making production as technically efficient as possible, based on the input vector x^t. $D_0^t(x^t, y^t)$ is then the reciprocal of this value. The closer the economy is to the production frontier, the smaller the

factor increase will be, and the larger the value of $D_0^t(x^t, y^t)$. If the economy is operating

on the frontier, $D_0^t(x^t, y^t)$ will take a value of 1. In contrast, when the economy is

operating below the frontier, $D_0^t(x^t, y^t)$ will be less than 1.

Caves, Christensen, and Diewert (1982a, and b) developed Malmquist output and input productivity change indices for multiple-input and multiple-output technologies that are valid for any returns to scale. The output-oriented index is based on an output distance function and reflects changes in maximum output given a set of inputs. This index can be expressed as

$$M^t = \frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \qquad (5.25)$$

which is the ratio of two output distance functions which both utilize technology at time t as a reference technology. The numerator is the output distance function at time $t+1$ based on technology at period t. The denominator is the output distance function at time t based on technology at period t.

Färe, Grosskopf, Norries and Zhang (1994) extended this index by avoiding the need to choose an arbitrary benchmark technology for a particular period, hence, the constructed output distance function based on period $t+1$ is:

$$M^{t+1} = \frac{D_0^{t+1}(x^{t+1}, Y^{t+1})}{D_0^{t+1}(x^t, y^t)} \qquad (5.26)$$

They then computed the Malmquist index relative to a non-parametric specification of the production frontier by utilizing the non-parametric, linear programming techniques of data envelopment analysis to fit distance functions of data on input and output quantities. They directly calculated the productivity change as the geometric mean of the two Malmquist indices shown in equation (5.22) and (5.23), without price data and without specifying a functional form. This becomes

$$M_0(x^{t+1}, y^{t+1}, x^t, y^t) = \left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \right) \left(\frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)} \right) \right]^{\frac{1}{2}} \qquad (5.27)$$

which can be rewritten as

$$M_0(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \times \left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1}0)} \right) \left(\frac{D_0^t(x^t, y^t)}{D_0^{t+1}(x^t, y^t)} \right) \right]^{\frac{1}{2}} \quad (5.28)$$

Therefore, they decomposed this productivity index into technical change, (viz. the shift of frontiers) and efficiency change (viz. the movement toward the frontier). The two terms on the right hand side of equation (5.25) can be interpreted as

$$\text{Efficiency change} = \frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \qquad (5.29)$$

$$\text{Technical change} = \left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1})} \right) \left(\frac{D_0^t(x^t, y^t)}{D_0^{t+1}(x^t, y^t)} \right) \right]^{\frac{1}{2}} \qquad (5.30)$$

Hence the Malmquist productivity index they derived was simply the product of the change in relative efficiency that occurred between periods *t* and *t+1*, and the change in technology that occurred between periods *t* and *t+1*.

However, since this approach is non-parametric, it is still imposing a constant returns to scale restriction on the frontier technology.

5.3.4.3 Further Development on DEA

Färe, Grosskopf, Norries and Zhang, in their 1994 paper, examined the productivity growth of seventeen OECD countries over the period from 1979 to 1988 and produced a world production frontier following their Malmquist productivity index that was derived from the non-parametric data envelopment analysis. They then compared the performance of these seventeen OECD countries to the computed world production frontier. Their results showed

that the United States has slightly higher than average productivity growth, which is due to the highest technical efficiency they had relative to the world frontier. However, Japan has the highest productivity growth among the total of seventeen countries in the sample. But, unlike the case of the United States, this growth was mainly the result of efficiency change.

Färe, Grosskopf, and Margaritis (1996) followed the approach by Färe, Grosskopf, Norries and Zhang (1994) in estimating the productivity growth, but used sectoral level input and output data for New Zealand to produce an aggregate production frontier for the New Zealand market sector. Individual sectors are then compared to this frontier in the assessment of their productiveness.

Atkinson, Cornwell, and Honerkamp (2003) proposed an alternative method of estimating productivity growth that combined the approach by Färe, Grosskopf, Norries and Zhang (1994) with the econometric approach. They first estimated a flexible, parametric, stochastic distance function accounting for the technical inefficiency in which this flexible nature of the stochastic distance function allowed them to compute productivity change without arbitrarily restricting returns to scale. Then, within this new framework, they obtained a decomposition for productivity change equivalent to that of Färe, Grosskopf, Norries and Zhang (1994). They used a panel data of US electric utilities comprised of forty three privately-owned US electric utilities operating during the period from 1961 to 1992. They then compared the results of the simple DEA approach with their new approach. They result of DEA, when compared to the new approach, exhibited a much higher average annual rate of productivity growth. Moreover, there was also significant difference between the relative importance assigned to the efficiency change and the technical change in the two methodologies. The new approach attributed all of the average productivity gain to technical change, whereas the DEA yielded more balance in the measured sources of productivity growth. Besides, the DEA results exhibited much higher volatility over time. Atkinson, Cornwell, and Honerkamp then argued that these disagreements were most likely

caused by the failure of DEA to account for noise, as well as the DEA's assumption of constant returns to scale.

5.4 Comparison between Alternative Approaches to Measuring Productivities

As seen from the previous sections, each approach to productivity measurement has its own advantages and drawbacks. Therefore, it is not easy to reach a conclusion as to which approach is superior to the other. One approach might be more suitable for some particular purpose, but not the other. This section aims to consider and summarize the differences, including the advantages and drawbacks, between these approaches. The contents of this section involve some necessary overlap with other sections, in order to emphasise differences between these alternative approaches.

The Growth Accounting Approach is a *non-parametric approach* that measures the residual resulting from separately evaluating the contribution of the specified input factors to output growth, and then subtracting these measured contributions from the total growth of output[41]. The major drawbacks of this approach are that 1) it is inextricably linked to the assumption of constant returns to scale, 2) it is, in practise, wedded to the assumption of marginal cost pricing, 3) it is based on the strong assumption of Hicksian technical change (see the more detailed discussions on p.113-114). Moreover, although the growth accounting approach is a non-parametric approach, it still needs a specific functional form of the technology to be assumed, in order to obtain an exact estimate of the efficiency parameter.

The Index Number Approach employs the same conceptual background as the growth accounting approach. They both measure the residual in output growth that could not be explained by the growth of factor inputs. It is noted that the index number approach suffers from the same drawbacks as in the growth accounting approach : more specifically, the strong assumptions of constant returns to scale, marginal cost pricing and Hicksian

technical change. However, in the growth accounting approach, the estimation process starts by selecting a production function, while in the index number approach, it starts with the selection of an index. In theory, the index number approach is superior to the growth accounting approach, in that it does not necessarily require an aggregate production function to be specified, meaning that no assumptions about the underlying economic structure have to be made. However, in reality, in order to select an appropriate index, some properties of the production function would have to be assumed. Hence, the distinction between the two approaches is somewhat obscured (more detailed discussion on this is elsewhere, see p.121).

Table 5.2: Comparing the different approaches to measuring productivity

Assumption	Growth Accounting	Index Number	Conventional Econometric	Data Envelopment	Stochastic Frontier
Constant Returns to Scale	Yes	Yes	No	Yes*	No
Marginal Cost Pricing	Yes	Yes	No	Yes	No
Hicksian Technical Change	Yes	Yes	No	Yes	No
Pre-Specific Functional Form of Technology	Yes	No	Yes	No	Yes
Parametric vs Non-Parametric	Non-Parametric	Non-Parametric	Parametric	Non-Parametric	Parametric
Measuring Average Behaviour	N/A	N/A	Yes	N/A	No
Allows for Inefficiencies in Production Process	N/A	N/A	No	Yes	Yes
Provision for Random Shocks	No	No	Yes	No	Yes

Note: * Recent developments have extended this approach to accommodate technologies that exhibited variable returns to scale.

The conventional econometric approach involves estimating the parameters of a specified production function to yield an estimate of the parameter that reflects the growth in technological progress. The advantage of this approach is that it is only based on observations of the volume of outputs and inputs, and thus avoids postulating a relationship between production elasticities and income shares. Hence, it leaves room for the possibility of testing these relationships. It is superior to

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[41] Diewert and Lawrence (1999)

the non-parametric approach (i.e. growth accounting and index approaches) in that it allows other parameters of the production technology to be explored, in addition to merely estimating the efficiency term. It can also accommodate greater flexibility in specifying the production technology, in contrast to the growth accounting and index number approaches. Furthermore, non-competitive pricing behaviour and non-constant returns to scale can also be examined. However, this increase in flexibility comes with costs, both theoretically and practically. In practice, the use of the econometric approach is generally limited to the academically oriented, one-off studies of productivity growth, but it is not relevant to the publication of regular productivity statistics, because the updating of the econometric approach involves a full re-estimation of the complicated model and the hypothesis testing following it. Also, the methodology of such an approach is often too complicated to communicate to a broad spectrum of users. In theory, the fully-fledged models can raise complex econometric issues and, hence, requires practitioners to place *priori* restrictions on the values of these parameters. Therefore, the problem of robustness of the resulting parameter estimates against alternative ways of imposing restrictions could arise. For more detailed discussion in these issues, see p.133-139.

The distance function based approaches (i.e. Data Envelopment Analysis, Stochastic Frontier Estimation) is superior to other approached previously discussed in that they recognize that not all producers are technically efficient. These approaches estimate the productivity level by utilizing an output distance function that measures how close production of a particular output is, when compared to the maximum attainable level of output, given the current level of input if production is technically efficient. The *Data Envelopment Analysis* is a non-parametric approach that makes no assumption about the form of the production function, Instead, a best practice function is built empirically from observed inputs and outputs. However, because DEA is a non-parametric method, it precludes the possibility of evaluating the marginal products and elasticities of substitution of the production technology. Moreover, the DEA produces no standard errors and, therefore, any deviation from the frontier is treated as inefficiency, leaving no provision for random shocks of any types.

This is in contrast to the parametric *Stochastic Production Frontier*, for which the form of the production function is either assumed to be known, or is estimated statistically. The advantages of this approach are that any hypotheses can be tested with statistical rigour, and that relationships between

inputs and outputs follow known functional forms. When compared to the conventional econometric approach, the stochastic production frontier is superior in that it estimates the 'best practice' technology upon which the production function concept is based on, while in the former case it is based on 'averaging' estimators. Therefore, the conventional econometric model may generate results that are fundamentally inconsistent with the definition of the production function. Moreover, the conventional econometric models often employ simple least squares techniques, and hence, will have error terms that are assumed to be symmetrically distributed with zero means. This assumption, effectively, indicates that the only source of departure from the estimated function is due to statistical noise. Therefore, these models are predicated on a common, but rather untenable, assumption that producers are always operating on their production functions, and technical inefficiencies in the production process do not exist.

5.5 Conclusion

This chapter provided an overview of the conceptual and methodological issues in the theory and measurement of productivity. Attention was focused on the concept of productivity, the different types of it, and its measurement approaches. Productivity was defined at the simplest level as being the ratio concerning how efficiency a certain output of goods and services is produced given a set of inputs. Although there is no argument in the general definition of the productivity concept, but the unique consent on the measurement of it had been reached, and it remains an intense topic of debate. The measurement of productivity could be classified in several forms – the single and multi/total factor productivity, or the gross output and the value-added productivity. Each of these has its own strength and weakness. Also, there are several approaches to the measurement of productivity, both parametric and non-parametric. They could be summarized into four main lines including the growth accounting, the index number, the conventional econometric, and the distance function based approaches. Unsurprisingly, each of them also has advantages

and drawbacks, with one approach being more suitable for some particular objectives, but not others. No conclusion can easily be reached on which approach or which type of productivity measurement is superior to the other. Therefore, the choices between the types of measurement, as well as between the different approaches in measuring the productivity are always dependent on the purpose of each particular case, and, in reality, are very often dependent on the availability of the data as well. Nevertheless, it should always be remembered that these options should not be viewed as rivals. There is no reason for an 'either-or' choice, when several approaches can be implemented simultaneously. If the availability of data allows it, one is thereby exploiting the advantages of all measures, while avoiding the drawbacks from each of them.

Chapter 6 – Exploratory Data Analysis

"Economists often like startling theorems, results which seem to run counter to conventional wisdom."

Joseph E. Stiglitz

6.1 Introduction

The aim of this chapter is to carry out a preliminary analysis that would help identify the underlying structure of the Thai manufacturing sector (in both pre- and post-crisis periods) in order to minimize the assumptions that need to be made when further, more detailed analyses are carried out. The effects of the 1997 economic crisis have already been examined earlier in Chapter 4. It is clear that the Thai economy has been hit in a very broad and profound scale. In the manufacturing sector, output of most industries declined immediately post-crisis, although the intensity was varied across industries. While a large number of studies have examined the effects of this crisis, however, almost none has attempted to compare the structural change between the pre- and post-crisis manufacturing sector. This thesis is aiming at examining the productivity of the Thai manufacturing sector, and the effects that the 1997 crisis have on it. However, in doing so, in particular when there is no reference to the structural change between the two periods, strong presumptions about the pattern of the shift would be inevitable. Unfortunately, such presumptions could be easily criticized for their lack of robustness, and therefore, the creditability of the findings is reduced. Hence, this chapter proposes the use of the exploratory data analysis techniques to reduce such problem.

According to the Engineering Statistics Handbook[1], data analysis is the systematic study of data that enable the analysts to understand the meaning, organization, structure, and relationships taken place within that particular set of data. In the classical approach of

data analysis, a model is imposed *a priori*, according to the conjecture one has made about that set of data. However, this approach has been criticized. The reasoning is that although the statistical significance of the variables in a model could be easily achieved, the robustness of it could be in question, as such significance would only hold if the underlying assumptions were correct. Moreover, in the process of classical data analysis, nothing is done to ensure that the assumptions made are the right ones. Therefore, the creditability of the estimates from such model could easily be queried. For this reason, an alternative approach was introduced, namely, Exploratory Data Analysis (EDA). The EDA method is not a simple matter of employing a different technique for data analysis, but is rather a different 'philosophy' in approaching the problems to be analyzed. In EDA, very few assumptions are made; instead, it is the analysis of the data that takes priority. The main goal of EDA is to gain insight into the process behind data, and this is achieved by utilizing methods that would let the data itself suggest the most appropriate model to be used.

Therefore, in this chapter, the EDA approach is adopted in order to examine the underlying structure of the Thai manufacturing sector. Very few presumptions would then need to be made, and thus, the findings could help avoid any criticisms regarding the assumptions that will be made later on in the more refined analyses. This chapter starts with section 6.2 that will explain the concept, as well as the objectives of the exploratory data analysis. Section 6.3 is concerned with the source of the data being used, as well as the methodology in conducting this exploratory data analysis (i.e. the models being used and the hypothesis being tested). Section 6.4 examines the structure of the manufacturing sector, utilizing the graphical EDA approach, based on an efficiency measuring approach suggested by Foo (1992, 1993). Section 6.5 further examines the issue raises by the findings in Section 6.4, utilizing the quantitative EDA approach, based on a two-factor inputs production function. And finally, section 6.6 concludes the chapter.

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[1] The US. Department of Commerce, *Engineering Statistics Handbook*

6.2 Exploratory Data Analysis

Exploratory Data Analysis (EDA) is an approach to data analysis that is concerned with reviewing, communicating, and using data in which there is a low level of knowledge about its causal system. It was first introduced by John Tukey in his seminal work in 1977, and had been developed over the years by many other authors such as Mosteller and Tukey (1977), Hoaglin (1977), and Velleman and Hoaglin (1981). Tukey (1977) alleged that too much emphasis in statistics had been placed on evaluating and testing given hypotheses (in what is called the confirmatory data analysis), but not enough attention had been given to the use of data in suggesting the hypotheses that should be tested. Therefore, he suggested a new approach to data analysis that postponed the usual assumptions about the kind of model the data followed with the more direct approach of allowing the data itself to reveal its underlying structure and model. The objectives of the EDA are to[2]

- Suggest hypotheses about the causes of observed phenomena

- Assess assumptions on which statistical inference will be based

- Support the selection of appropriate statistical tools and techniques

- Provide a basis for further data collection through surveys or experiments

The EDA approach is different from classical data analysis in its sequence of procedures and the focus of the intermediate steps. For the classical analysis, after the research problem is identified, the data collection process is carried out. There then follows the imposition of a model, which reflects the assumptions behind on hypothesis. Later, the analysis, the estimation, and the testing are performed with the focus being put on the parameters of that model. And finally, the conclusions are drawn from the features that the data exhibits. However, for EDA, after the research question is identified and the data needed are collected, the next step (unlike the classical approach) is not followed by a model imposition, but rather it is followed immediately by an experimented analysis with the goal of inferring

an appropriate model for representing the data, and then the conclusion is drawn from such analysis. Therefore, it is possible to describe EDA in a simpler term as 'EDA used the data as a 'window' to peer into the heart of the process that generated the data in the first place'[3].

6.3 Data and Methodology

The data being used in this thesis comes from the published Manufacturing Industrial Survey conducted by the National Statistical Office (NSO) of Thailand and cover the period between 1990 to 2002 (with some gap years, see below). There were 177 observations in total, 89 in the pre-crisis period and 88 in the post-crisis period. The establishments under the scope of this survey are those engaged primarily in manufacturing industry (category D International Standard Industrial Classification of All Economic Activities; ISIC: Rev.3) which have 10 or more persons engaged in the business. The coverage of this survey is nation-wide. All information collected refers to the operation period of establishment during January and December. The methodology uses in the survey is Stratified Systematic Sampling, in which a larger population is divided into sub-groups (strata) by using systematic sampling, and then a random sample is taken from each sub-group. In this case, provinces are constituted strata while types of industrial activities and groups of industrial establishment are constituted sub-strata. The sampling units are the establishments. Establishment in each stratum (province, for this case) is also divided into industrial activities (sub-strata). The interviewing method is employed in data collection. These interviews are carried out by the enumerators who are permanent staffs of the National Statistical Office. The target interviewees are the owners or the entrepreneurs of the

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[2] Hoaglin, Mosteller, and Tukey (1983)
[3] The US. Department of Commerce, *Engineering Statistics Handbook*

manufacturing establishments. The survey is carrying out between June and September of the subsequent year.

The Manufacturing Industrial Survey is published annually, with some gap years in which the NSO did not carried out the survey. The data set used by this thesis covers the period from 1990 to 2002. However, the data of 1992, 1994, 1995, 1997, and 2001 are not presented, as these were the years the NSO failed to publish the survey. The data selected are 24 major manufacturing industries of Thailand, with the list of these industries being presented in Appendix A at the end of this thesis. The data extracted were variables for value added (Y), headcount (L), book value of capital (K) and a decomposition of capital into three further variables, namely land (l), machinery (m), and office appliance (of).

Value added (Y) was measured as value of gross output minus intermediate consumption. Headcount (L) was measured by the number of persons who worked in or for the establishment, including working proprietors, active business partners, unpaid workers and workers permanently working outside the establishment. Book value of capital (K) was measured as the net value of capital after deducting the accumulated depreciation at the end of the year. Capital includes land, building, machinery and equipment, vehicles, and office appliances. Land (l) was defined as land and buildings that are used for the production of outputs. Machinery (m) was defined as machinery and equipments that are used for the production of outputs. And office appliances (of) were defined as appliances that are used in the office to facilitate the production of outputs.

As mentioned at the beginning of this section (6.3), all data are secondary source and based on statistic gathered by the official Thai government statistical agency, The National Statistical Office (NSO) of Thailand. They conduct an annual survey (with occasional gaps, as in the crisis year of 1997) of manufacturing firms which are larger than micro-firms (i.e. headcount greater than 10). Government enumerators from the NSO gather these data 'on-site' at the plant or business. Approximately 100,000 firms are visited

for this purpose every year. Because data collection is 'on-site', and also because it is not self-reported but gathered by independent government personnel with expertise in this area, the quality of data is considered to be high. That is, it is comprehensive, detailed and accurate. Especially output data (because they come under the tax net) and headcount (because they are so easily verified on-site) are likely to be precise. Land is also easily verified. Book value of capital (which will typically include a significant component of land) will also tend to be quite accurate. Likely sources of minor inaccuracy could possibly arise from the machinery and office appliances component.

The aggregated industry level data are used in this thesis, rather than the firm level, despite the criticisms that aggregate production functions do not have a sound theoretical foundation, and that aggregating micro production functions into a macro production function is problematic[4]. Nevertheless, the aggregate data is being used here for three reasons. Firstly, following Solow (1966)'s argument, that based on the methodological position known as instrumentalism, as long as aggregate production functions appear to give empirically reasonable results, there is no reason why should they not be employed. Solow, in his own word, stated that "I have never thought of the macroeconomic production function as a rigorously justifiable concept. In my mind it is either an illuminating parable, or else a mere device for handling data, to be used so long as it gives good empirical results, and to be abandoned as soon as it doesn't, or as soon as something better comes along."[5]

Secondly, following Samuelson (1961-1962), the aggregate production function is to be thought of as a parable. Temple (2006) argued that 'the argument misunderstands the nature and purpose of economic theory and empirical research, and that critics ask too much of theory'. He further argued that 'a useful paper may offer new insights or provide a new and more sophisticated way of thinking about a problem. Some of the assumptions will be questionable or false, but readers will come away with a modified view of the world.'

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[4] It is important to keep in mind that the aggregate production function is the result of two types of aggregation. One is aggregate over multiple inputs or outputs and the other is aggregation over firms.

Finally, as argued by Ferguson (1968), in some certain cases, the use of an aggregate production function is the only option. In the case of this thesis, the goal of the research is to study the overall improvement in efficiency of the manufacturing sector as a whole, therefore an aggregate production function that relates aggregate output to aggregate inputs is fundamental, and unavoidable.

Following the EDA technique, it is important that before any in-depth analysis on the productivity and efficiency of the Thai manufacturing sector is conducted, a preliminary analysis aiming at the revelation of the underlying structure of this data set is carried out. According to the EDA, it is vital to allow the data itself to reveal its underlying structure without making too many presumptions, which could prejudice the results coming from it. In the case of this thesis, one of the main objectives is to examine the structural shift in the manufacturing sector between the pre- and post-crisis period. It is hypothesized that the 1997 economic crisis had affected the structure of the sector and hence, the productivity level. Therefore, most of the analyses following are built according to that assumption. However, as this thesis is the first literature to tackle this issue. Therefore, in order to enhance the validity of this assumption and the analyses, it is very important that the EDA is carried out to verify that there is indeed a structural shift between the two periods, and that the structural shift does not exist merely because of the presumption made.

Data analysis procedures can broadly be classified into two parts: quantitative and graphical[6]. *Quantitative techniques* are the set of statistical procedures that yield numeric or tabular output. Examples of quantitative techniques include: least squares regression, hypothesis testing, analysis of variance, point estimates and confidence intervals. On the other hand, there is a large collection of statistical tools that are generally referred to as *graphical techniques*, such as scatter plots, histograms, probability plots, and residual plots.

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[5] Solow 1966, p.1259-1260
[6] The US. Department of Commerce, *Engineering Statistics Handbook*

The EDA approach relies heavily on these and similar graphical techniques. It is alleged[7] that such graphical tools are the shortest path to gaining insight into a data set, in terms of assumption testing, model selection, model validation, relationship identification, outlier detection, and many more.

This chapter is intended to carry out the exploratory analysis utilizing both graphical and quantitative techniques. Section 6.4 adopts a simple efficiency measuring model developed by Foo (1992, 1993) for the graphical analysis purpose. Section 6.5 employs a simple two-factor input Cobb-Douglas production function for the quantitative analysis purpose. It should, again, be noted here that both models being used in this chapter are only intended for the purpose of exploratory data analysis, and the more refined method of productivity measurements will be developed in the later chapters (Chapter 8 and 9).

6.4 Graphical Technique

Oulton (2004) claims that the theory of growth accounting (Solow (1957), Domar (1961), Hulten (1978), Jorgensen *et al* (1987), OECD (2001)) provides a framework for measuring and assessing the contribution of each industry to the national economy. Moreover, it also allows the evolution of these contributions to be seen over time. However, one problem in implementing the growth accounting framework using official data is that a long time series of data (e.g. 20-30 years) is needed. However, in reality (especially for the developing countries or newly developed countries) some basic official series do not go back very far, hence making it very hard to utilize the growth accounting framework in practice. Foo (1992, 1993), seeing this difficulty, suggests an efficiency measuring approach, based on the concept of growth accounting, but with the mathematical identity of the model being developed by taking into consideration the availability of the data in published sources, as

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[7] The US. Department of Commerce, *Engineering Statistics Handbook*

well as the structural components of the firm. The main purpose of such a model is to relate the contribution of each components of organization structure configuration to changes in productive efficiency.

According to Foo (1992, 1993), a manufacturing firm may be conceptualised as an 'organism' that absorbs inputs from the external environment. Then, through the process of production, value is added and inputs are transformed and then re-channelled into the external environment as outputs. Such a firm can be seen to be comprised of three main structural components – the operating core, physical and support elements, and the technostructure. The *operating core* takes into account factors that are involved directly in the production process of value-adding. It is, in another word, where the core value-adding activities take place. In the manufacturing organism, this includes raw materials, fuel, electricity, water, and other factors used in the production line. The *technostructure* relates to the more structural aspects of the production process. It includes things such as machineries, computer software, automation technology, and core human skills. Relative to operating core and technostructure, the *physical and support elements* have a less direct, integrative relationship with the production process. Instead, they embrace the operating core and technostructure, ensuring the production process runs favourably. In doing so, the physical elements form the framework in which a firm needs in order to manufacture outputs, such as buildings, plant, land, offices, and furniture. The support elements are physically less obvious, such as expenditure on administration.

Apart from relating the contribution of each structural component of the firm to the productive efficiency, this model also places great emphasis on the availability of the data needed, in which it is constrained by the published sources, such as the national accounts. Thus, it is modeled by the following relation (where symbols are defined below):

$$NVA = VA - OCP \qquad\qquad (6.1)$$

and $$\qquad VA = O - WGO - I \qquad\qquad (6.2)$$

Therefore,

$$\frac{NVA}{E} = \frac{NVA}{O} \times \frac{O}{E} = \frac{NVA}{O} \times \frac{O}{CE} \times \frac{CE}{E} \qquad (6.3)$$

$$= \frac{VA - OCP}{O} \times \frac{O}{CE} \times \frac{CE}{E}$$

$$= \frac{(O - WGO - I) - OCP}{O} \times \frac{O}{CE} \times \frac{CE}{E}$$

$$= \left(1 - \frac{WGO}{O} - \frac{I}{O} - \frac{OCP}{O}\right) \times \frac{O}{CE} \times \frac{CE}{E} \qquad (6.4)$$

with $I = RM + F + El + W$, $OCP = Ro + Rm + Rt + D + OE$, and NVA = net value added, VA = gross value added, OCP = other costs of production, O = output, WGO = work given out, E = employees, CE = capital expenditure, I = inputs to production, RM = raw material, F = fuel, El = electricity, W = water, Ro = rent for office/factory promises, Rm = rent for machinery, Rt = rent for transport equipment, D = depreciation, OE = other expenditure.

Therefore, the net value added per employee of a firm can be expressed with:

$$\frac{NVA}{E} = 1 - \left[\frac{WGO}{O} - \left(\frac{RM}{O} + \frac{F}{O} + \frac{El}{O} + \frac{W}{O}\right)\right] - \left[\frac{Ro}{O} + \frac{Rm}{O} + \frac{Rt}{O} + \frac{D}{O} + \frac{OE}{O}\right]$$
$$\times \left[\frac{O}{CE} \times \frac{CE}{E}\right] \qquad (6.5)$$

in which the component $\left(\dfrac{RM}{O} + \dfrac{F}{O} + \dfrac{El}{O} + \dfrac{W}{O}\right)$ reflects the operating cores,

$\left[\dfrac{Ro}{O} + \dfrac{Rm}{O} + \dfrac{Rt}{O} + \dfrac{D}{O} + \dfrac{OE}{O}\right]$ reflects the physical and support

elements, and $\left[\dfrac{O}{CE} \times \dfrac{CE}{E}\right]$ reflects the technostructure.

This model implies that the net value added per employee $\dfrac{NVA}{E}$ is the gain in the

value of output which cannot be justified by the inputs in the three main structural

components of the firms (i.e. operating cores, physical/support elements, and

technostructure). Therefore, $\dfrac{NVA}{E}$ can be seen as an estimator of the productivity gain

from a firm's production process. It is similar to the Solow's residual referred to commonly

in the growth accounting approach, but is different in the sense that this model is static,

with only one period of time being taken into consideration. Therefore, it avoids the

problem of long time series needed (which very often comprise of gap years) as mentioned

by Oulton (2004).

6.4.1 Model Specification

Following the work by Foo (1992, 1993), a similar model based on the published data of

Thai manufacturing sector is developed. The model is specified as the following:

$$NVA = VA - OCP = (GO - IC) - (OOE + D) \qquad (6.6)$$

$$NVA = GO - (MC + F + El + CC + RM + PGR - CVS) - (OOE + D) \qquad (6.7)$$

$$= GO - MC - F - El - CC - RM - PGR + CVS - OOE - D \qquad (6.8)$$

With GO = gross output, IC = intermediate costs, MC = materials and components, CC =

contract and commission works, RM = repair and maintenance works, PGR = purchase of

goods for resale, CVS = changes in value of stock of materials and components, OOE =

other expenses.

Therefore:

$$\frac{NVA}{E} = \frac{GO - MC - F - El - CC - RM - PGR + CVS - OOE - D}{E} \qquad (6.9)$$

$$= \frac{GO - MC - F - El - CC - RM - PGR + CVS - OOE - D}{GO} \times \frac{GO}{CE} \times \frac{CE}{E}$$

$$= \left[1 - \frac{MC}{GO} - \frac{F}{GO} - \frac{El}{GO} - \frac{CC}{GO} - \frac{RM}{GO} - \frac{PGR}{GO} + \frac{CVS}{GO} - \frac{OOE}{GO} - \frac{D}{GO} \right]$$

$$\times \left[\frac{GO}{CE} \times \frac{CE}{E} \right]$$

$$= \left[1 - \left(\frac{MC}{GO} + \frac{F}{GO} + \frac{El}{GO} \right) - \left(\frac{CC}{GO} + \frac{RM}{GO} + \frac{PGR}{GO} - \frac{CVS}{GO} + \frac{OOE}{GO} + \frac{D}{GO} \right) \right]$$

$$\times \left[\frac{GO}{CE} \times \frac{CE}{E} \right] \qquad\qquad (6.10)$$

The component $\left(\frac{MC}{GO} + \frac{F}{GO} + \frac{El}{GO} \right)$ reflects the operating cores,

$\left(\frac{CC}{GO} + \frac{RM}{GO} + \frac{PGR}{GO} - \frac{CVS}{GO} + \frac{OOE}{GO} + \frac{D}{GO} \right)$ reflects physical and support elements,

and $\left[\frac{GO}{CE} \times \frac{CE}{E} \right]$ reflects technostructure.

In this model, the net value added per employee $\frac{NVA}{E}$ is also measuring the gain in the value of output that could not be explained by the use of inputs through the three components of the firms.

6.4.2 Results and Implications

The results from equation (6.10) for year 1993, 1994, 1996, 1998, 1999, 2000 and 2002 are presented in the graphical format, shown in figure 6.1, 6.2, 6.3, 6.4 and 6.5. Figure 6.1 reveals that there is a slight upward trend on the use of operating cores as a ratio to the gross output in the post-crisis period when compares to the pre-crisis. This upward trend can also be seen, but with a much stronger effect, in the physical and support elements component, shown in Figure 6.2. The technostructure component also shows a general upward trend post-crisis, despite a slightly higher level in 1996 (see Figure 6.3).

Figure 6.1: Pre- and Post-Crisis Operating Cores Component

Operating Core
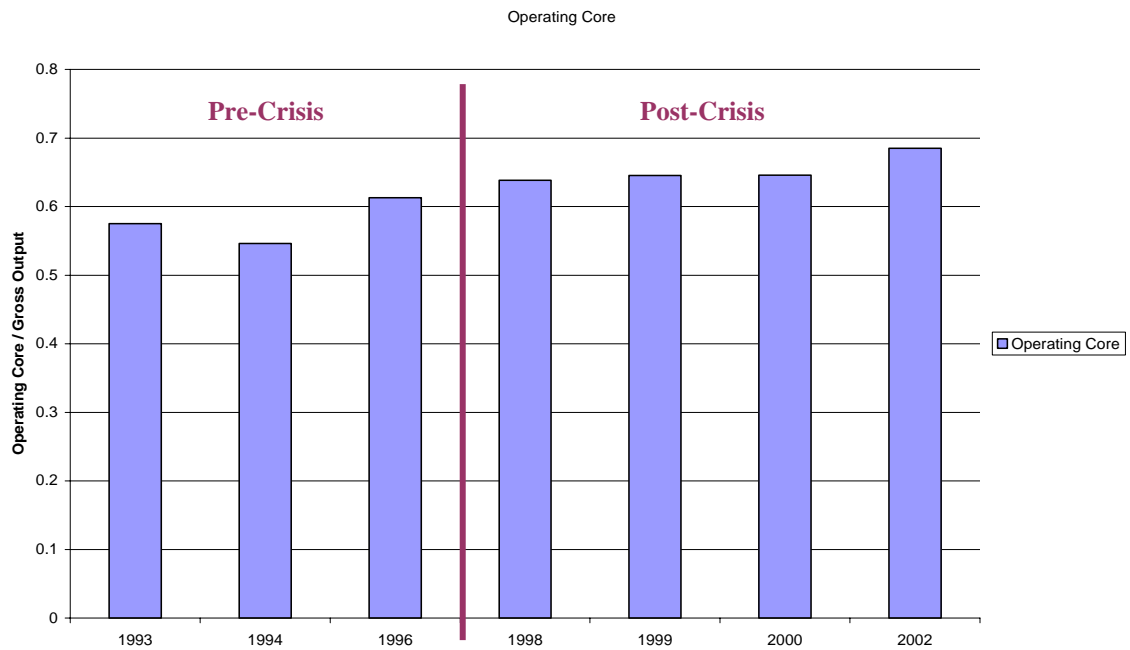
Figure 6.2: Pre- and Post-Crisis Physical and Support Elements Component

Physical & Support
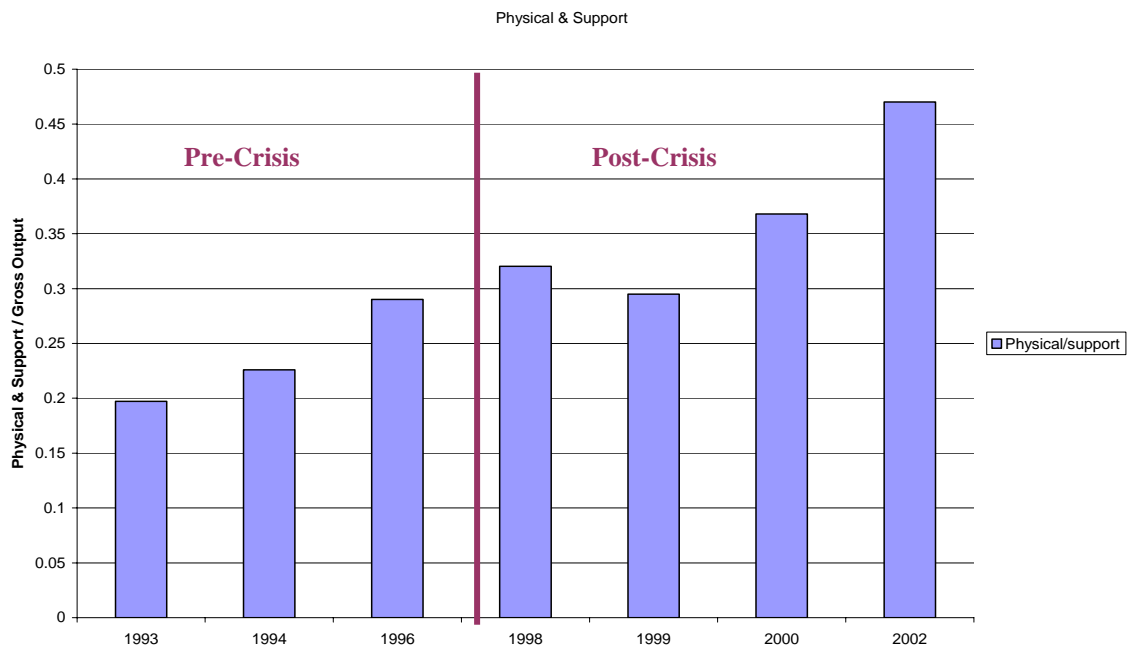
<u>Figure 6.3</u>: Pre- and Post-Crisis Technostructure Component
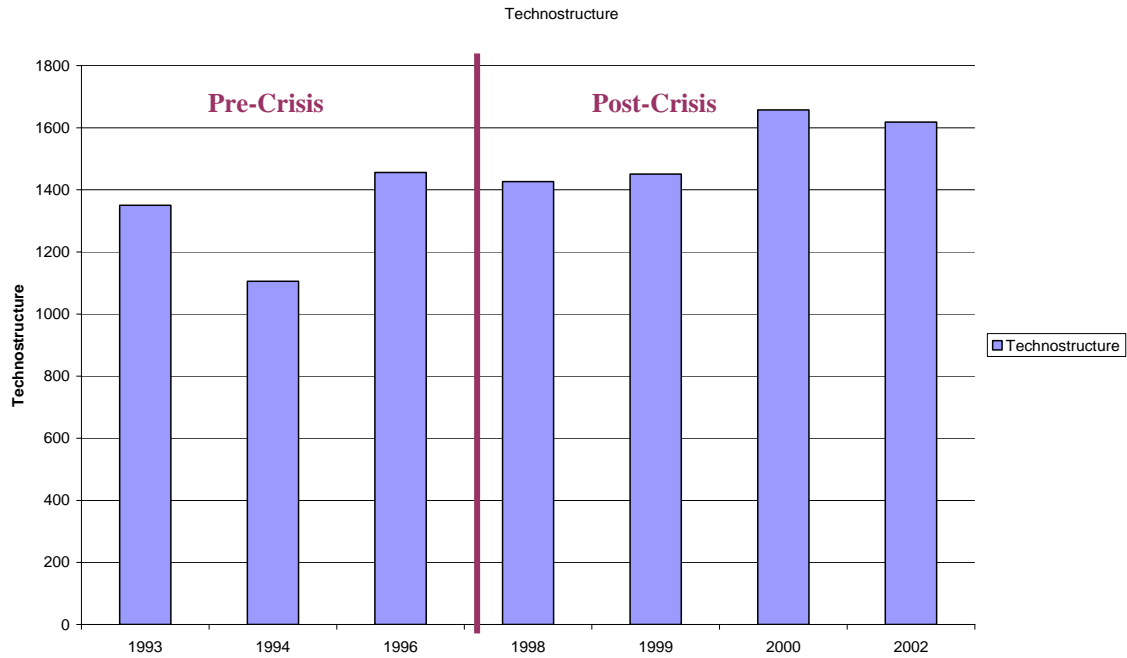
Results for the net value added per employee $\dfrac{NVA}{E}$ are shown by figure 6.4, where

it reveals that during the pre-crisis period, the net value added per employee in the

manufacturing sector of Thailand was declining, from 307.61 thousand Baht per employee

in 1993 to 141.27 thousand Baht in 1996. However, the trend in the post crisis period is

less clear. The net value added per employee exhibits and increasing trend between 1998

and 1999, however it demonstrates a declining trend again between 2000 and 2002. One

explanation for such declining trend between year 2000 and 2002 could have lied in the

statistical artefact resulting from a substantial increase in the rate of depreciation over gross

output in 2000 and 2002, increased two folds from 0.075 in 1999 to 0.151 in 2000, and

further increased to 0.356 in 2002. Such increase in the rate of depreciation came as a

result of a large number of firms were facing with severe debt problems as a consequence

of the devaluation of the Baht, and was forced to re-capitalize.

<u>Figure 6.4</u>: Pre- and Post-Crisis Net Value Added per Employee

NET Value Added / Employee
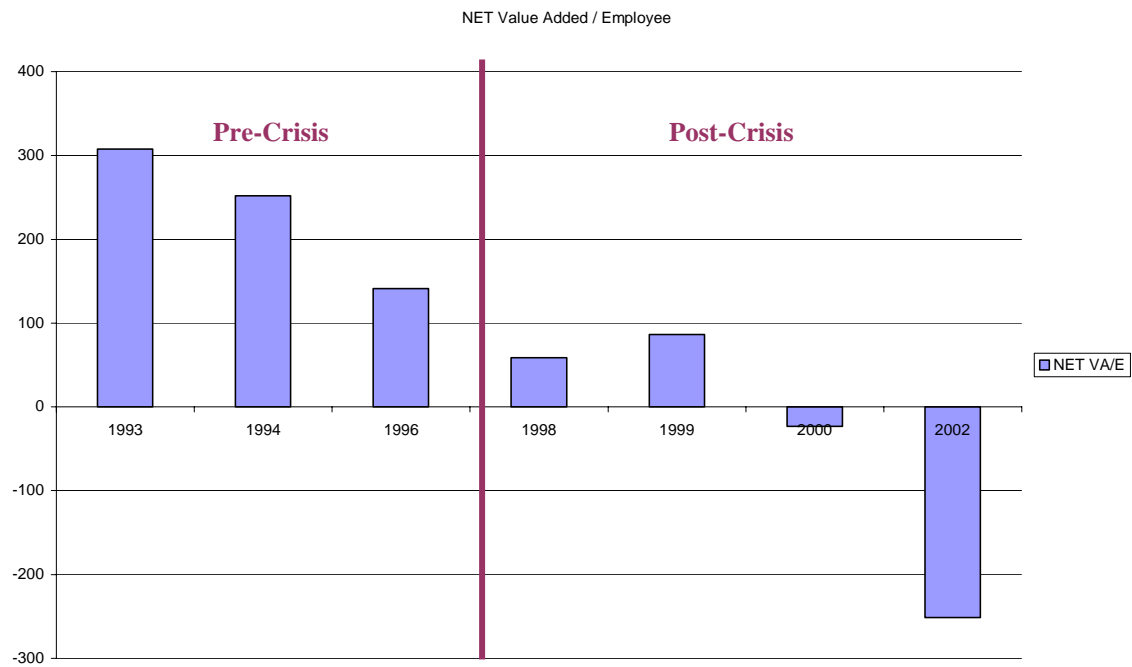
<u>Figure 6.5</u>: Pre- and Post-Crisis Depreciation

Depreciation
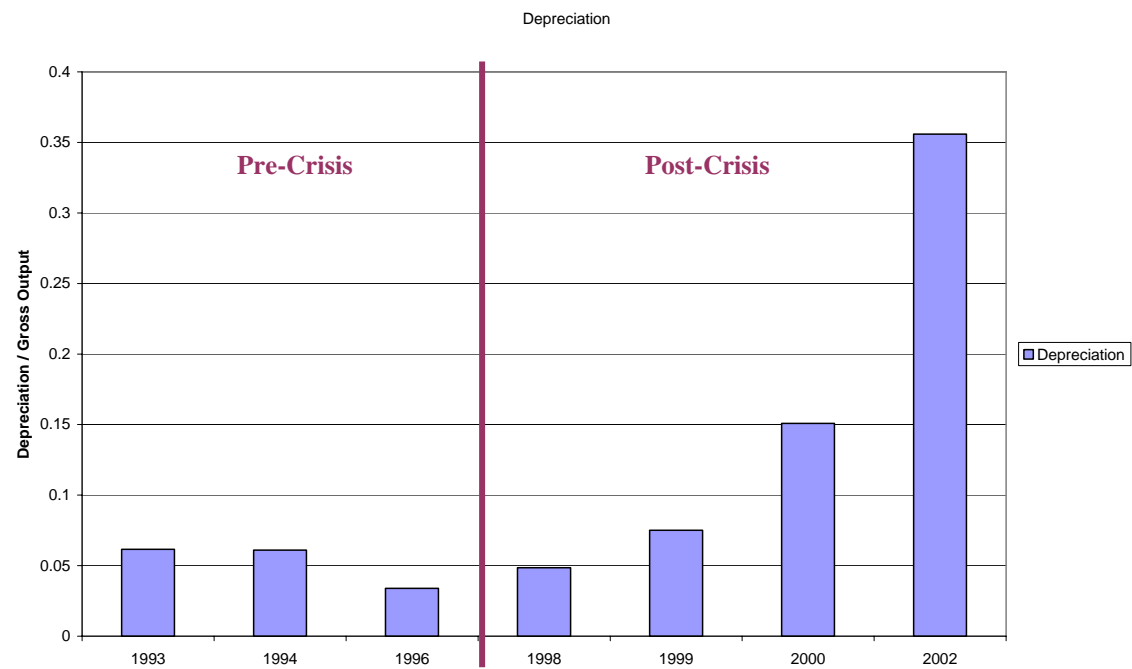
Despite the indefinite finding for the net value added per employee $\dfrac{NVA}{E}$, one

very important finding this model reveals is that there is an increasing trend in the

technostructure post-crisis. The technostructure component $\left[\dfrac{GO}{CE} \times \dfrac{CE}{E} \right]$ is the combined

effect between the ratio of gross output over capital expenditure $\left(GO/CE \right)$ and the ratio of

capital expenditure over employee $\left(CE/E \right)$. Therefore, the growth of the technostructure

component implies either an increase in the usage of more productive capitals (i.e. an

increase in the $\left(GO/CE \right)$ ratio), or an increase in the amount of capital usage per

employee (i.e. an increase in the $\left(CE/E \right)$ ratio), or both. Hence, a further exploratory data

analysis is proposed in the next section, employing the simple two-factor input (i.e. capital

and labour) production function in order to examine (with a more refined method) whether

or not the ratio between the amount of capital and labour used has changed pre- and post-

crisis.

6.5 Quantitative Technique

As suggested in the previous section, the growth of the technostructure component could

come partly from the increase in the usage of capital in comparison to the usage of labour.

Another way this finding could be verified is by the examination of the aggregate production

function of the manufacturing sector, and observes whether or not there is a different in the

elasticity of input factors used between the two time periods. This section proposes the use

of a simple two-factor inputs production function to examine the structural change that may

have occurred between the pre- and post-crisis periods. It should once again be mentioned

here that the use of a simple two-factor inputs production function is entirely due to the

specification of the EDA technique stating that a very simple model should be used in order to allow the data itself to reveal its underlying structure without making too many presumptions that may prejudice the outcomes.

6.5.1 Model Specification

This preliminary analysis starts with the choice of an appropriate production function that will provisionally represent the structure of the sector. The model being analyzed here is the simple two-factor input Cobb-Douglas production function and the generalized form of it, i.e. the translog production function. The reason for the choice among these two models was owing to the fact that they are simply the two most accepted and extensively used models for the analysis of production function. These models could be expressed as follow: The two-factor input Cobb-Douglas production function,

$$\ln Y_{it} = \beta_0 + \beta_1 \ln(K_{it}) + \beta_2 \ln(L_{it}) + V_{it} \qquad (6.11)$$

where Y represents the value-added, K denotes the net assets, L represents total employment in headcount, V is a disturbance term with zero mean. The subscription of i refers to industry, and t refers to year. β is a vector of unknown parameters, with β_0 representing the intercept term, β_1 representing the coefficient estimate of capital input parameter, and β_2 representing the coefficient estimate of labour input parameter to be estimated.

The two-factor input Translog production function takes the form as follow:

$$\ln Y_{it} = \beta_0 + \beta_1 \ln(K_{it}) + \beta_2 \ln(L_{it}) + \frac{1}{2}\beta_3 \ln^2(K_{it}) + \frac{1}{2}\beta_4 \ln^2(L_{it}) + \beta_5 \ln(K_{it})\ln(L_{it}) + V_{it}$$

$$(6.12)$$

This model in equation (6.12) differs from the Cobb-Douglas model in that it relaxes the Cobb-Douglas's assumption of a unitary elasticity of substitution. The Cobb-Douglas model could then be obtained by the restriction that $\beta_3 = \beta_4 = \beta_5 = 0$.

The data set mentioned earlier is then separated into the pre-and post-crisis period, and estimated according to these models for both periods, utilizing the ordinary least square method (OLS). The simple OLS estimation is being used here following the procedure of the EDA, which emphasizes that the simplest analysis should be conducted so as to obtain the basic knowledge of the data set, without too much data manipulation. Therefore, in this chapter, the OLS estimation is used for the purpose of achieving an overview picture of the structural change, if any, that has taken place in the manufacturing sector between the pre- and post-crisis period. And therefore, a further, more refined analysis could then be conducted with more confident.

Once the appropriate model is chosen among the two models mentioned above (for which, in this case, the Cobb-Douglas production function is proved to be more suitable, in which the details will be given in the next section), a hypothesis test of the structural change can then be conducted. The F test using the dummy variable technique is chosen, for this purpose, over the Chow test, as it has the benefit of being able to identify the sources of the structural shift, if any (on which more details will be given in the next section). By pooling all the observations both in the pre- and post-crisis period, the restricted multiple regression is analysed, based on the Cobb-Douglas production function, with the following expression,

$$\ln Y = \beta_0 + \delta_1 D + \beta_1 \ln(K) + \delta_2 (D \cdot \ln(K)) + \beta_2 \ln(L) + \delta_3 (D \cdot \ln(L)) + \varepsilon \quad (6.13)$$

where $D = 0$ for the pre-crisis data, and $D = 1$ for post-crisis. The hypothesis being tested is that

$$H_o : \delta_1 = 0, \delta_2 = 0, \delta_3 = 0 \qquad \text{against}$$

$$H_1 : \text{at least one } \delta_i \neq 0 \qquad\qquad (6.14)$$

The null hypothesis suggests that $\beta_0^{pre} = \beta_0^{post}$, $\beta_1^{pre} = \beta_1^{post}$, and $\beta_2^{pre} = \beta_2^{post}$. Therefore, if the null hypothesis could not be rejected, it could be concluded that there is no structural

shift taken place between the pre- and the post-crisis period, and equation (6.13) collapses into

$$\ln Y = \beta_0 + \beta_1 \ln(K) + \beta_2 \ln(L) + \varepsilon \qquad (6.15)$$

which is simply the Cobb-Douglas production function with pooled observations. Hence, there would be no need for the separation of the observations between these two periods, and further analysis of productivity measurement could be done assuming no structural shift.

6.5.2 Results and Implications

The results from the analysis of both Cobb-Douglas and Translog models indicated that the Cobb-Douglas production function is a better representation of this set of data in both pre- and post-crisis period. From the estimation of Translog equation (6.12), the coefficient estimates β_3, β_4, and β_5 are all *not* significantly different from zero in both periods, therefore, these findings suggest that equation (6.12) collapses into equation (6.11), and that the Cobb-Douglas model is a sufficient representative for the data of Thai manufacturing sector in both periods of studies. The estimates from the Cobb-Douglas production function are presented in Table 6.1 below.

Table 6.1: OLS Estimates of the Cobb-Douglas Production Function

Variable	Parameter	OLS estimates	
		Pre-Crisis	Post-Crisis
Constant	β_0	5.6532	4.5200
		(0.9189)	(0.8872)
In Asset	β_1	0.3430	0.5101
		(0.8156)	(0.0607)
In Employ	β_2	0.5098	0.3181
		(0.1171)	(0.0739)
	R^2	0.638	0.698
	Adjusted R^2	0.630	0.691
	n	89	88

Note: OLS estimates were computed using the exposition in equation (6.11) p.171, based on the Cobb-Douglas production function.
Standard errors are in brackets.

The coefficient estimate of the capital input parameter, β_1, is 0.3430 in the pre-crisis period, and increases to 0.5101 in the post-crisis period. On the other hand, the coefficient estimate of labour input parameter, β_2, is 0.5098 in the pre-crisis, and reduces to 0.3181 in the post-crisis period. These results (while confirming the previous finding of section 6.4 that there is indeed an increase in the capital use when compares to the number of employees) suggest that the manufacturing sector of Thailand exhibited a structural shift from labour intensive in the pre-crisis toward capital intensive in the post-crisis period. One possible explanation for such occurrence could have been the result of the post-crisis wage rigidity in the labour market as well as the sharp decline in the domestic interest rates, which therefore, causing a substantial adjustment in the relative price between labour and capital inputs. As a result, firms might have found it more efficient to substitute the use of labour with capital, and therefore, leading to this structural shift. However, this issue will be examined in more details later in Chapter 8.

Table 6.2: Test for Pre- and Post-Crisis Structural Shift

Variable	Parameter	OLS estimates	
		Unrestricted	**Restricted**
Constant	β_0	5.647	5.653
		(0.649)	(0.771)
D	δ_1	-	-1.134
		-	(0.608)
ln Asset	β_1	0.395	0.343
		(0.052)	(0.068)
D x ln Asset	δ_2	-	0.167
		-	(0.086)
ln Employ	β_2	0.413	0.510
		(0.071)	(0.098)
D x ln Employ	δ_2	-	-0.192
		-	(0.106)
	R^2	0.636	0.658
	Adjusted R^2	0.631	0.648
	SSE	113.609	120.921
	n	89	88

Note: The *unrestricted* OLS estimates were computed using the exposition in equation (6.15) p.173, based on the Cobb-Douglas production function.
The *restricted* OLS estimates were computed using the exposition in equation (6.13) p.172, based on the Cobb-Douglas production function.
Standard errors are in brackets.

The R^2 and *Adjusted* R^2 figures indicate an acceptable model fitting with the values having an approximate range from 0.63 to 0.70, implying that the two-factor input Cobb-Douglas production functions fits the data set being used in this analysis relatively well. However, before any conclusion could be made from these estimates, it is important to make sure that the structural shift suggested by the results is, in fact, statistically significance. Therefore, a hypothesis test following the null and alternative hypothesis indicated by equation (6.14) is conducted using the restricted, pooled-observation model specified in equation (6.13). The results are shown in Table 6.2.

The results from this analysis show that for all δ_i in the restricted model, at 95 percent significance level, their values are all significantly different from zero. Also, the null hypothesis $H_o : \delta_1 = 0, \delta_2 = 0, \delta_3 = 0$ is rejected as the calculated F value is equal to 3.6471[8], greater than the critical F, which is equals to 2.60, at 95 percent significance level. Moreover, since all δ_i are statistically different from zero, they imply that $\beta_0^{pre} \neq \beta_0^{post}$, $\beta_1^{pre} \neq \beta_1^{post}$ and $\beta_2^{pre} \neq \beta_2^{post}$. Therefore, it can be concluded that the structural shift between the pre and post crisis did indeed existed, and this shift was a combined result of the shifts in the intercept ($\beta_0^{pre} \neq \beta_0^{post}$), the capital coefficient ($\beta_1^{pre} \neq \beta_1^{post}$), as well as, the labour coefficient estimates ($\beta_2^{pre} \neq \beta_2^{post}$). Hence, for further analysis, this suggests that it is appropriated to divide the period of study from 1990 to 2002 into 2 time frames: the pre- and post-crisis, and thus, examines each period separately.

Although the finding of this analysis is valuable in that it does confirm the finding from Section 6.4 that there was, indeed, an increase in the usage of capital per employee, as well as suggests that there is a structural shift between the two time periods, the use of the OLS estimated Cobb-Douglas production function does not allow for any possibility that

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[8] $F_{cal} = \dfrac{\left((SSE_R - SSE_U)/J\right)}{SSE_U /(T - K)}$

inefficiency might exist in the production process of any industry. This analysis, which employs the least squares technique, has error terms that are assumed to be symmetrically distributed with zero means. Therefore, it assumes that the only source of departure from the estimated production function is coming from the statistic noises. Such assumption, nonetheless, is a very strong one, in particular for the pre-crisis period in which the Thai manufacturing sector was rather renowned for being unproductive. Therefore, a more refined method of estimation should be conducted, based upon the findings obtained from the analysis in this chapter. The stochastic production frontier approach, which allows for inefficiency as well as statistical noise to be the source of departure from the estimated production function, is suggested as the appropriated estimation for such data. The details of this approach in productivity estimation are presented in the next chapter, chapter 7.

6.6 Conclusion

In this chapter, the EDA approach to data analysis is used, in order to investigate the overall structure of the Thai manufacturing sector in both pre- and post-crisis period. The findings from the graphical approach provide the first glance into the underlying structure of the data set, and suggest that there is an increase in the technostructure component of the firms in this sector, This increase may have been a result of the increase in the usage of more productive capital, or the increase in the capital usage per employee, or both. Therefore, a further analysis employing a two-factor inputs production function is suggested. The findings from such analysis suggest that the Cobb-Douglas production function, with the assumption of a unitary elasticity of substitution, is an adequate, but incomplete model for representing the structure of the sector. It is also suggested that the 1997 economic crisis, indeed, had significant effects on this sector, more specifically, by causing a structural shift in the manufacturing sector, from being labour intensive to capital intensive.

Nevertheless, the simple OLS estimates Cobb-Douglas production function used in this analysis is subjected to a major drawback. The ordinary least squares techniques, due to its zero mean error component, does not permit any possibility of incorporating allowances for technical inefficiency into the model. Therefore, although it can verify that there is indeed an increase usage of capital compares to employee, it still cannot provide any answer to whether or not there is an increase in the usage of the more productive capital. However, according to the purpose of this chapter, this model had nevertheless served its intention sufficiently well. It had offered an overview picture of the effects that the crisis had on the Thai manufacturing sector, and therefore, provided an indicator of the further assumptions that would need to be made when more complex models are used in later analysis. Criticisms that the presumptions made could have affected the results of the analysis could largely be reduced. What is needed next is to include the inefficiency component into the model based on the findings in the chapter, so that in addition to the simple examination of structural change here, the changes in the technical efficiency could also be investigated. Chapter 7 utilizes the stochastic frontier estimation techniques in developing a stochastic production frontier, taking the two-factor input Cobb-Douglas model used here as its starting point.

Chapter 7 – The Stochastic Production Frontier

7.1 Introduction

This chapter, following the more general literature reviews presented in Chapter 5, is aimed at examining literature concerning the technical development of the stochastic production frontier on estimating productivity. In the standard models of production function analysis, producers are assumed to be maximizing the quantity of their outputs given the available quantities of a set of inputs (OECD Manual (2001)). However, these production functions, estimated by the standard statistical techniques (i.e. regression of output on inputs), are generally estimated based on the mean output, rather than the maximal output. Therefore, such estimation will generate results that are fundamentally inconsistent with the definition of the production function above. Moreover, these analyses (which employ least squares technique) will have error terms that are assumed to be symmetrically distributed with zero means[1]. This assumption, effectively, indicates that the only source of departure from the estimated function is due to statistical noise[2]. Therefore, these models are subjected by a common, but rather untenable, assumption that producers are always operated on their production functions, and technical inefficiencies in production process do not exist[3].

The issue of technical inefficiency was first introduced in the pioneer work by Koopmans (1951), who, in his own word, provided a definition of technical efficiency by indicating that '*a producer is technically efficient if, and only if, it is impossible to produce more of any output without producing less of some other output or using more of some input*'. This, thus, implies that not all producers are technically efficient, and an increase in output is sometime possible without the need for increasing inputs[4]. Since this introduction

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[1] Green, (1993)
[2] Hulten, (2000)
[3] Green, (1993)
[4] Kumbhakar and Lovell, (2000)

of the technical efficiency concept by Koopmans, there has been an immense increase in the number of studies (Farrell (1957), Aigner and Chu (1968), Schmidt (1976), Aigner *et al.* (1976), Stevenson (1980), Pitt and Lee (1981), Battese and Coelli (1992)) concerning the development of the analysis in which the production functions are modelled with the assumption that not all producers are operating efficiently. For this reason, the production function estimates by the least squares estimation is no longer the appropriate choice of estimate, as its key assumption of non-inefficiency is violated. An alternative estimation of the production function and productive efficiency, based on the distance function was suggested by a number of key works in the literatures since then.

This chapter is organized in the following way. Section 7.2 begins with the introduction of the pioneer work by Farrell (1957), in which the concept of technical and allocative efficiency was first introduced. Following this work, attempts have been made to develop a model in which the technical inefficiency component can be systematically included. Section 7.3 is concerned with the development of the deterministic production frontier. These models (Aigner and Chu (1968), Seitz (1971), Timmer (1971), Afriat (1972) and Richmond (1974)) can accommodate the technical inefficiency components, and all assumed that the deviations from the production frontier resulted from the inefficiency occurring in the production process. Section 7.4 examines the development from the deterministic frontier towards the 'stochastic' frontier (Meeusen and van de Broeck (1977), Aigner *et al.* (1977), Green (1980), Stevenson (1980), Jondrow *et al.* (1982)) in which the statistic error terms are introduced into the model, in order to allow for deviations that may have resulted from measurement errors and economic shocks. Section 7.5 studies the development from the cross sectional stochastic frontier to the panel data stochastic frontier. It also includes the development from the time-invariant panel data frontier (Pitt and Lee (1981), Sickles (1984)) to those with the time varying panel data (Cornwell, Schmidt and Sickles (1990), Kumbhakar (1990), Battese and Coelli (1992)). Section 7.6 concludes the chapter.

7.2 Early Development of Production Frontier

For the reasons mentioned above, the production function utilizing the frontier estimation is suggested as an alternative to the standard production function. The frontier production function is a production function that estimates the firms' *maximum* level of output as a function of a given input quantities[5]. The initial works by Debreu (1951) and Shephard (1953) introduced the distance function as a way of modelling multiple-output technology. The radial distance of a producer from the frontier is measured in an output-expanding direction in the paper by Debreu, but is measured in an input-conserving direction by Shephard. These three studies, including Koopmans (1951), which associated the distance functions with technical efficiency measures, were tremendously important to the development of the efficiency measurement literature that followed.

The modern literature on efficiency measurement, as well as on the estimation of production frontier, both began with the same article, namely, Farrell (1957). Following the works by Koopmans (1951) and Debreu (1951), Farrell defined cost efficiency and then decomposed cost efficiency into its technical and allocative components. Farrell's paper was the first work that attempted to measure productive efficiency empirically. However, in his paper, linear programming techniques, instead of econometric methods, were used. This has later influenced the development of the data envelopment analysis (DEA) technique by Charnes, Cooper and Rhodes (1978), which has later become a well-established non-parametric efficiency measurement technique, currently employed extensively in management science.

Farrell's analysis starts by assuming two inputs, x_1 and x_2, and one output Y, so that the production frontier is $Y = f(x_1, x_2)$. The further assumption of constant returns to scale is imposed, thus $1 = f(x_1/Y, x_2/Y)$, and the frontier is characterized by the efficient

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[5] OECD Manual (2001)

unit isoquant. This can be shown graphically by *II'* in Figure 7.1.

Figure 7.1: Technical and allocative efficiency
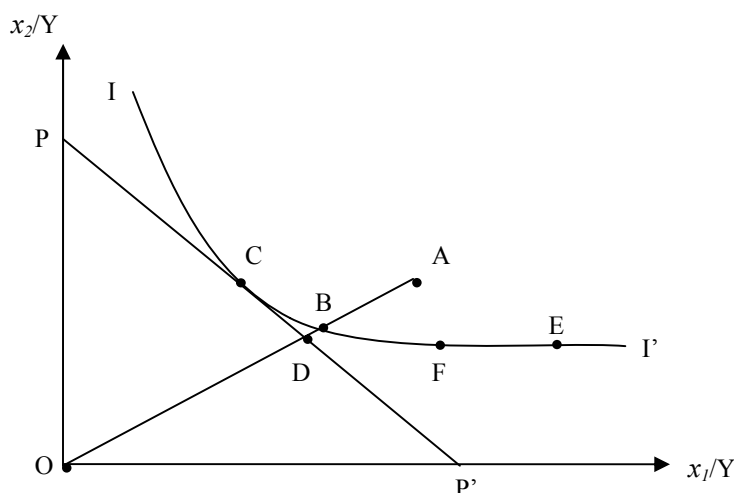
Suppose at an observed point *A*, a firm uses the combination of inputs (x_1^A, x_2^A) to produce output Y^A. Without reducing output, this firm can reduce the quantities of inputs used by moving to point *B*, holding the input ratio x_1/x_2 constant. This point *B*, as well as any point on the *II'* (e.g. *C* and *F*) is *technically efficient*, and is represented by the ratio of *OB/OA*, which measures the proportion of (x_1^A, x_2^A) that is truly necessary to produce Y^A. The ratio *1-OB/OA* represents the technical inefficiency of this firm, measuring the proportion by which inputs could be reduced. Suppose that *PP'* represents the ratio of input prices; thus, the cost minimizing point of producing the output is point *C*, where the *PP'* tangent with *II'*. Also, since point *C* and *D* are both on the *PP'*, they each represent an input mix with the same cost of production. *Allocative efficiency* is, therefore, achieved at point *C*, where the cost of production is minimized; and it is represented by the ratio of *OD/OB*. Thus, *1-OD/OB* measures allocative efficiency, as it measures the possible reduction in cost from using the correct input proportions, which suggests that, although the firm may be technically efficient, it may still be able to improve its productivity. The total inefficiency could be decomposed as the sum of technical and allocative inefficiency, with

the ratio *1-OD/OA*, which measures the possible reduction in cost from moving from the observed point *A* to the cost minimizing point *C*.

7.3 Deterministic Production Frontier

Of greater significance, was the influence Farrell's work exerted on the later works by Aigner and Chu (1968), Seitz (1971), Timmer (1971), Afriat (1972) and Richmond (1974). These works, although, are different in a number of respects (either by utilizing linear programming techniques, or by modifications to least squares techniques requiring all residuals to be non-positive). They all estimate a 'deterministic' production frontier, in which the error term is assumed not to be affected in any way, by either the measurement error or other statistical noise, leaving the only source of error as the technical inefficiency, which occurs in the production processes. Aigner and Chu (1968) considered the idea of this deterministic production frontier using a parametric frontier function

$$Y_i = f(x_i; \beta) \qquad\qquad i = 1,2,3,...,N \qquad\qquad (7.1)$$

in the log-linear Cobb-Douglas form, which could be defined as

$$\ln Y_i = \beta_0 + \sum_j \beta_j \ln x_{ni} \qquad\qquad (7.2)$$

where Y_i is the maximum output obtainable from x_i, x_i is a vector of inputs, and β is a vector of unknown parameters of the intercept and the slope terms to be estimated. Since the production frontier represents the maximum output attainable from each input level, it reflects the current state of technology in producing that particular output. Firms operate either on the frontier (in which case they are technically efficient) or beneath the frontier (in which case they are technically inefficient).

Aigner and Chu (1968) suggested the estimation of β by the mathematical programming method based on a cross-section of N firms within a given industry [6]. Specifically, they suggested the minimization of a linear programming problem of the form

$$\sum_{i=1}^{N}|Y_i - f(x_i;\beta)| \qquad\qquad \text{subject to} \quad Y_i \le f(x_i;\beta) \qquad (7.3)$$

Alternatively, the minimization is achieved by a quadratic programming problem of minimize

$$\sum_{i=1}^{N}[Y_i - f(x_i;\beta)]^2 \qquad\qquad \text{subject to} \quad Y_i \le f(x_i;\beta) \qquad (7.4)$$

In order to characterize differences in output among firms with identical input vectors or to explain how a given firm's output lies below the frontier, $f(x_i;\beta)$, a disturbance term has been implicitly, not explicitly, assumed. Although these procedures do indeed produce estimates of β, they are subjected to a notable problem. The deterministic production frontier is very sensitive to outliers as they do not produce standard errors for the estimates. Hence, all the measurement errors and unobservable shocks are precluded from the model. Therefore, with the absence of a more detailed specification of the errors, the effectiveness of these estimators becomes questionable.

The above problem has led to the development of the so-called 'probabilistic' frontiers by Timmer (1971) and Dugger (1974), who employed the same type of mathematic programming discussed above in obtaining estimators of β. However, in these models, some specified proportions of the observations are allowed to lie above the frontier, in order to solve the problem of outliers' sensitivity. Nevertheless, these models are still subjected to several drawbacks. Firstly, the selection of this proportion is fundamentally random, lacking explicit economic or statistical justification. Secondly, the reconciliation of the observations above the frontier is achieved by appealing to measurement errors in the extreme observations, which is again very arbitrary. Finally, by employing the mathematic

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[6] Aigner, Lovell, and Schmidt, (1977), pp.24

programming techniques discussed previously, the problem of estimation without known statistical properties remains.

In an attempt to impose a statistical basis on the models proposed earlier, Schmidt (1976) explicitly added a one-side disturbance to the model suggested by Aigner and Chu (1968), as shown in equation (7.1), which yielded

$$Y_i = f(x_i; \beta) \exp\{\varepsilon_i\} \qquad\qquad i = 1,2,3,...,N \qquad\qquad (7.5)$$

where $\varepsilon_i \leq 0$. Given a distributional assumption for the disturbance term, this model can then be estimated, e.g. by maximum-likelihood techniques, specifically, if $-\varepsilon_i$ is assumed to have an exponential distribution, this model can be estimated by the linear programming technique. On the other hand, if $-\varepsilon_i$ is assumed to have a half-normal distribution, the model can be estimated by the quadratic programming. This, consequently, implies that if the error term associated with the technical inefficiency effects follows a one-sided distribution, then linear programming estimates proposed by Aigner and Chu (1968) are the maximum likelihood estimates of the deterministic frontier model. This finding of Schmidt (1976) has an immense significance for studies of frontier analysis, as it has later led to the wide use of maximum likelihood estimation techniques in the stochastic production frontier analysis. However, unfortunately, this observation was of little practical value for Schmidt's own model, as the usual regularity conditions for the application of maximum likelihood are violated. Aigner, Lovell and Schmidt (1977) mentioned this issue stating that 'since $Y_i \leq f(x_i; \beta)$, the range of the random variable Y depends on the parameters to be estimated. Therefore, the usual theorems cannot be invoked to determine the asymptotic distributions of parameter estimates. Under these circumstances it is not clear just how much we know about the frontier after having estimated it.'

Aigner, Amemiya and Poirier (1976) suggested a more realistic error component approach, as compared to the purely one-sided one suggested by Schmidt (1976). They assumed

$$\varepsilon_i = \begin{cases} \varepsilon_i^* / \sqrt{(1-\theta)} & \text{if} \quad \varepsilon_i^* > 0, \qquad i = 1,...,N, \\ \varepsilon_i^* / \sqrt{\theta} & \text{if} \quad \varepsilon_i^* \le 0 \end{cases} \qquad (7.6)$$

where the error, ε_i^*, are independent normally distributed random variables with $N(0,\sigma^2)$

for $0 < \theta < 1$, otherwise ε_i^* has either the negative or positive truncated normal distribution,

when $\theta = 1$, or $\theta = 0$, respectively.

The justification for this error term is that firms differ in two respects: first, in their

ability to utilize the best practice technology, which is the source of the one-sided error, and

second, in the input quantity or measurement error in output, which leads to a symmetric

error. The parameter θ is interpreted as the measure of relative variability in the two error

sources. As θ is approaching 1, the positive error component has a large variance, and

hence, a small influence on the likelihood function, and the negative error dominates. Thus,

it gives rise to the full frontier as the limiting case, $\theta = 1$. On the other hand, when $\theta = \frac{1}{2}$,

the likelihood function has the form of a mixture of two half-normal, each with equal

influence; thus it becomes the case of the 'average' function.

The most important contribution of this error structure proposed by Aigner,

Amemiya and Poirier (1976) is that, through the parameter θ, it allows the placement of the

fitted function to be estimated alongside with the other parameters of interest, β. Thus, this

ameliorates the argument against the average function such as that of Aigner and Chu

(1968), as well as the criticisms that accompany the strict use of the frontier or envelop

function as the appropriate industry production function, c.f. Timmer (1971). Nevertheless,

this interpretation of θ as a measure of the relative variability of error sources, although it is

a more accommodating specification compared to the previous literatures, is still only

implicit in this formulation.

7.4 Early Development of Stochastic Production Frontier

The stochastic production frontier originated with two branches of literature published nearly simultaneously, i.e. Meeusen and van der Broeck in June 1977, and Aigner, Lovell and Schmidt in July 1977. Both studies were developed in the production frontier context, and had the composed error terms that include a traditional symmetric random noise component, as well as, a new one-sided inefficiency component. Thus, these models allow for technical inefficiency, and at the same time, acknowledge the fact that random shocks beyond the control of producers could affect the output. Hence, it overcomes the problems associated with the deterministic approaches described earlier. The model was developed directly from the model of Schmidt (1976)

$$Y_i = f(x_i; \beta) \exp\{\varepsilon_i\} \qquad\qquad i = 1,2,3,...,N \qquad\qquad (7.7)$$

but under the error structure

$$\varepsilon_i = V_i - U_i \qquad\qquad (7.8)$$

where V_i is the error component representing the symmetric disturbance, and is assumed to

be independently and identically distributed as $N(0, \sigma_v^2)$

U_i is the non-negative error component that is intended to capture the effects of technical inefficiency, and is distributed independently of V_i, also, it is assumed to be independently and identically distributed (*iid.*).

According to this model, producers operate on or beneath their stochastic production frontier, $Y_i \leq f(x_i; \beta)$, following the specification of $U_i \geq 0$. The only difference between models of Meeusen and van den Broeck (1977) and Aigner, Lovell and Schmidt (1977) is that the error component is assumed to have an exponential distribution in the former, and either a half-normal or an exponential distribution in the later. However, either distributional assumption implies the same thing that the composed error, ε_i, is negatively skewed, and statistical efficiency requires that the model be estimated by maximum likelihood.

Aigner et al. (1977) explained the logic behind this specification by which the production process was subjected to two economically distinguishable random disturbances with different characteristics. The non-negative disturbance, U_i, reflected the fact that each firm's output must lie on or below its frontier, with any deviation from the frontier results from factors under firm's control such as defect products, and inefficient management. At the same time, the frontier itself could also vary randomly across firms, or over time. This interpretation implies that the frontier is 'stochastic', with random disturbance V_i being either higher than, less than, or equals to zero resulting from external event (both favourable and unfavourable), such as errors in observation and measurement, luck, political disturbance, and climate change.

The output-oriented technical efficiency (TE_i) of each producer can be measured by the ratio

$$TE_i = \frac{Y_i}{f(x_i; \beta) \exp\{V_i\}} \tag{7.9}$$

Thus, the productive inefficiency can be distinguished from other stochastic sources of disturbance. Y_i achieves its maximum feasible value of $f(x_i; \beta)$ if and only if $TE_i = 1$. Otherwise $TE_i < 1$ provides a measure of the shortfall of observed output from maximum feasible output in an environment characterizes by $\exp\{V_i\}$, which is allowed to vary across producers.

Given the assumption of a half-normally distributed technical inefficient error component, the density function of V is

$$f(V) = \frac{1}{\sqrt{2\pi}\sigma_V} \exp\left\{-\frac{V^2}{2\sigma_V^2}\right\} \tag{7.10}$$

and the density function of U is

$$f(U) = \frac{2}{\sqrt{2\pi}\sigma_U} \exp\left\{-\frac{U^2}{2\sigma_U^2}\right\} \tag{7.11}$$

Thus, the joint density function of U and V becomes

$$f(U,V) = \frac{2}{2\pi\sigma_U\sigma_V}\exp\left\{-\frac{U^2}{2\sigma_U^2} - \frac{V^2}{2\sigma_V^2}\right\} \tag{7.12}$$

Since $\varepsilon = V - U$, the joint density function of U and ε is

$$f(U,\varepsilon) = \frac{2}{2\pi\sigma_U\sigma_V}\exp\left\{-\frac{U^2}{2\sigma_U^2} - \frac{(\varepsilon+U)^2}{2\sigma_V^2}\right\} \tag{7.13}$$

The marginal density function of ε is obtained by integrating U out of $f(U, \varepsilon)$, which yields

$$f(\varepsilon) = \int_0^\infty f(U,\varepsilon)dU$$

$$= \frac{2}{\sqrt{2\pi}\sigma}\left[1 - \Phi\left(\frac{\varepsilon\lambda}{\sigma}\right)\right]\exp\left\{-\frac{\varepsilon^2}{2\sigma}\right\} \tag{7.14}$$

$$= \frac{2}{\sigma}\phi\left(\frac{\varepsilon}{\sigma}\right)\Phi\left(-\frac{\varepsilon\lambda}{\sigma}\right)$$

where $\sigma = \left(\sigma_U^2 + \sigma_V^2\right)^{1/2}$, $\lambda = \sigma_U/\sigma_V$, and $\Phi(\cdot)$ and $\phi(\cdot)$ are the standard normal and cumulative distribution and density functions, respectively. This density $f(\varepsilon)$ is asymmetric around zero, with its mean and variance given by

$$E(\varepsilon) = -E(U) = -\sigma_U\sqrt{\frac{2}{\pi}}$$

$$V(\varepsilon) = \frac{\pi-2}{\pi}\sigma_U^2 + \sigma_V^2 \tag{7.15}$$

As $\lambda \to 0$, then either $\sigma_V^2 \to +\infty$ or $\sigma_U^2 \to 0$, thus, the symmetric error dominates in the determination of ε. The model reverts back to an average production function model with no technical inefficiency. Whereas, when $\lambda \to +\infty$, then either $\sigma_V^2 \to 0$ or $\sigma_U^2 \to +\infty$, the one-sided error component dominates the symmetric error component in the determination of ε. The model thus, reverts back to the deterministic production frontier model, with no statistical noise.

In the early period of the frontier production analysis, this area of the literature suffered from a major drawback which limited its usage. Individual observation's technical inefficiency could not be estimated, as it was not possible to decompose individual residuals into their two components. It was not until Jondrow *et al* (1982) provided a solution to this problem that the appeal of the stochastic frontier production function became greatly enhanced. Jondrow *et al* (1982) estimated the technical inefficiency of each producer, U_i, using either the mean or the mode of the conditional distribution of U_i given ε_i, $\left[U_i|V_i - U_i\right]$, which contained whatever information ε_i contained concerning U_i. They showed that if U_i was distributed as $N^+(0, \sigma^2_U)$, the conditional distribution of U given ε would become

$$
\begin{aligned}
f(U|\varepsilon) &= \frac{f(U,\varepsilon)}{f(\varepsilon)} \\
&= \frac{1}{\sqrt{2\pi}\sigma_*}\exp\left\{-\frac{(U-\mu_*)^2}{2\sigma_*^2}\right\} \bigg/ \left[1-\Phi\left(-\frac{\mu_*}{\sigma_*}\right)\right]
\end{aligned}
\tag{7.16}
$$

where $\mu_* = -\varepsilon\sigma_U^2/\sigma^2$ and $\sigma_*^2 = \sigma_U^2\sigma_V^2/\sigma^2$. And since $f(U|\varepsilon)$ is distributed as $N^+(\mu_*, \sigma^2_*)$, thus, either the mean or the mode of this distribution can serve as a point estimator for U_i. This can be written by

$$
\begin{aligned}
E(U_i|\varepsilon_i) &= \mu_{*i} + \sigma_*\left[\frac{\phi(-\mu_{*i}/\sigma_*)}{1-\Phi(-\mu_{*i}/\sigma_*)}\right] \\
&= \sigma_*\left[\frac{\phi(\varepsilon_i\lambda/\sigma)}{1-\Phi(\varepsilon_i\lambda/\sigma)} - \left(\frac{\varepsilon_i\lambda}{\sigma}\right)\right]
\end{aligned}
\tag{7.17}
$$

and
$$
M(U_i|\varepsilon_i) = \begin{cases} -\varepsilon_i\left(\dfrac{\sigma_U^2}{\sigma^2}\right) & \text{if } \varepsilon_i \leq 0 \\ 0 & \text{otherwise} \end{cases}
\tag{7.18}
$$

where $E(U_i|\varepsilon_i)$ represents the mean, and $M(U_i|\varepsilon_i)$ represents the mode. Once the point estimates of U_i are obtained, estimates of the technical inefficiency of each producer can be obtained from

$$TE_i = \exp\{-\hat{U}_i\} \tag{7.19}$$

where $\hat{U}_i$ can be either $E(U_i|\varepsilon_i)$ or $M(U_i|\varepsilon_i)$

Battese and Coelli (1988) have proposed the alternative point estimator of individual producer's technical inefficiency as

$$TE_i = E\left(\exp\{-\hat{U}_i\}|\varepsilon_i\right) = \left[\frac{1-\Phi(\sigma_* - \mu_{*i}/\sigma_*)}{1-\Phi(-\mu_{*i}/\sigma_*)}\right]\exp\left\{-\mu_{*i} + \frac{1}{2}\sigma_*^2\right\} \tag{7.20}$$

However, regardless of which estimator is used, the estimates of technical efficiency are *inconsistent* since the variation associated with the distribution of $(U_i|\varepsilon_i)$ is independent of *i*. This problem is, unfortunately, hard to solve, and these estimates are the best possible estimates that can be achieved with the cross-sectional data[7].

The half-normal and exponential distribution assumptions of the one-sided inefficiency error component models discussed up until now assume single-parameter distributions. In order to allow for more flexibility, the assumption concerning the distribution of the one-sided inefficiency error components has been relaxed in many works. Two-parameter distributions such as the Gamma distribution have been proposed by Greene (1980), as well as the Gamma and truncated normal distributions proposed by Stevenson (1980). The literature has extended even to include the calculation of the four-parameter Pearson family of distributions by Lee (1983).

In Stevenson (1980), the half normal distribution of the inefficiency error component has been generalized by allowing U to follow a truncated normal distribution, with U_i followed $N^+(\mu, \sigma_U^2)$. In contrast to the normal and the half-normal distribution, the truncated normal distribution is a two-parameter distribution, with one parameter characterizing the placement and the other characterizing the spread of its mode, μ, and σ_U. It generalizes the half-normal distribution by allowing the normal distribution, which is truncated below zero, to have a non-zero mode. Thus, the truncated normal distribution

contains an additional parameter μ to be estimated, and so provides a more flexible representation of the pattern of efficiency in the data. The truncated normal density function for non-negative U is given by

$$f(U) = \frac{1}{\sqrt{2\pi}\sigma_U \Phi(\mu/\sigma_U)} \exp\left\{-\frac{(U-\mu)^2}{2\sigma_U^2}\right\} \tag{7.21}$$

where μ is the mode of the normal distribution, which is truncated from below at zero. If μ = 0, the density function would collapse back to the half normal density function given earlier. The joint density function of U and V is

$$f(U,V) = \frac{1}{2\pi\sigma_U\sigma_V \Phi(\mu/\sigma_U)} \exp\left\{-\frac{(U-\mu)^2}{2\sigma_U^2} - \frac{V^2}{2\sigma_V^2}\right\} \tag{7.22}$$

and the joint density of U and ε is

$$f(U,\varepsilon) = \frac{1}{2\pi\sigma_U\sigma_V \Phi(\mu/\sigma_U)} \exp\left\{-\frac{(U-\mu)^2}{2\sigma_U^2} - \frac{(\varepsilon+U)^2}{2\sigma_V^2}\right\} \tag{7.23}$$

The conditional distribution of $f(U|\varepsilon)$ is

$$
\begin{aligned}
f(U|\varepsilon) &= \frac{f(U,\varepsilon)}{f(\varepsilon)} \\
&= \frac{1}{\sqrt{2\pi}\sigma_*[1-\Phi(-\tilde{\mu}/\sigma_*)]} \exp\left\{-\frac{(U-\tilde{\mu})^2}{2\sigma_*^2}\right\}
\end{aligned}
\tag{7.24}
$$

where $f(U|\varepsilon)$ is distributed as $N^+(\tilde{\mu}_i, \sigma_*^2)$, with $\tilde{\mu}_i = \left(-\sigma_U^2\varepsilon_i + \mu\sigma_V^2\right)/\sigma^2$ and $\sigma_*^2 = \sigma_U^2\sigma_V^2/\sigma^2$. Thus, as in the case of the half-normal distribution, either the mean or the mode of $f(U|\varepsilon)$ can be used to estimate the technical efficiency of each producer, with

$$E(U_i|\varepsilon_i) = \sigma_*\left[\frac{\tilde{\mu}_i}{\sigma_*} + \frac{\phi(\tilde{\mu}_i/\sigma_*)}{1-\Phi(-\tilde{\mu}_i/\sigma_*)}\right] \tag{7.25}$$

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[7] Kumbhakar and Lovell, (2000)

and $\quad M(U_i|\varepsilon_i) = \begin{cases} \tilde{\mu}_i & if \quad \tilde{\mu}_i \geq 0 \\ 0 & otherwise \end{cases}$ (7.26)

Point estimates of the technical efficiency of each producer can be obtained by substituting either $E(U_i|\varepsilon_i)$ or $M(U_i|\varepsilon_i)$ into $TE_i = E(\exp\{-\hat{U}_i\}|\varepsilon_i)$, giving

$$TE_i = \left[\frac{1 - \Phi(\sigma_* - (\tilde{\mu}_i/\sigma_*))}{1 - \Phi(-\tilde{\mu}_i/\sigma_*)} \right] \exp\left\{ -\tilde{\mu}_i + \frac{1}{2}\sigma_*^2 \right\}$$ (7.27)

Unfortunately, the estimates of technical efficiency under the truncated normal distribution are, as in the case of half-normal distribution, still inconsistent[8].

7.5 Stochastic Production Frontier with Panel Data

Cross-sectional data used in the early development of the stochastic frontier production estimation provides merely a snapshot of producers and their efficiency. Panel data, on the other hand, provides more reliable evidences about the behaviour of firms as it observes the performance of each producer through a sequence of time periods. Schmidt and Sickles (1984) identify three difficulties with cross-sectional stochastic production frontier models including, firstly, the maximum likelihood estimation of the stochastic production frontier model, as well as the subsequent separation of its technical inefficiency, requiring strong distributional assumptions on each error component. However, having access to panel data and its repeated observations on sampled producers would permit the use of conventional panel data estimation techniques in the estimation of the technical efficiency, for which some of these techniques do not require strong distributional assumptions. Thus, it enables the relaxation of some of the strong distributional assumptions normally associated with

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[8] Kumbhakar and Lovell (2000)

cross-sectional data, and as a result, produces estimates of technical efficiency with more desirable statistical properties.

Secondly, maximum likelihood estimation also requires an assumption that the technical inefficiency error component is independent of the regressors, whist in reality, it is not uncommon that technical inefficiency is correlated with the input vectors selected by the producers. Again, this problem can be avoided by the use of panel data, as not all panel data estimation techniques require the assumption of independence of the technical efficiency error component from the regressors.

Finally, as mentioned earlier, although the technical efficiency of producers could be estimated using either the Jondrow *et al* (1982) or the Battese and Coelli (1988) technique, the estimates are inconsistent, given that the variance of the conditional mean or the conditional mode of $(U_i|\varepsilon_i)$ for each individual producer does not go to zero as the size of the cross section increases. This is due to the fact that the variation associated with the distribution of $(U_i|\varepsilon_i)$ is independent of *i*. This problem could be solved by the use of a sufficiently long panel data, since it involves adding more observations on each producer, and as $T \rightarrow +\infty$, the estimation of the technical efficiency became consistent, a condition that could not typically be achieved with cross sectional data.

The early literatures of panel data stochastic production frontier (Pitt and Lee (1981), Schmidt and Sickles (1984)) were based on the assumption of time-invariant efficiency, in which, although technical efficiency was allowed to vary across producers, it was assumed to be constant through time for each producer. Technology used in the production process was assumed in these models to be fixed, with no allowance for any improvement in technical efficiency that might occur in the production process. Thus, this assumption of time invariance of technical efficiency might be considered tenuous in long panels, particularly, in the highly competitive environments. Later developments led to the relaxation of this assumption, and hence, enabled the technical efficiency to vary across

producers as well as through time for each producer. A time indicator could be included among the regressors in these models (Cornwell, Schmidt and Sickles (1990), Kumbhakar (1990), and Battese and Coelli (1992)), enabling one to disentangle the effect of technical change from that of technical efficiency change.

7.5.1 Time-Invariant Models

Pitt and Lee (1981) were the first to extend the cross-sectional maximum likelihood estimation techniques to panel data. In their paper, frontier production function models were proposed and estimated with panel data on Indonesia weaving establishments. The production function is assumed takes the form of

$$Y_{it} = f(x_{it}; \beta) \exp\{\varepsilon_{it}\}$$

where $\varepsilon_{it} = V_{it} - U_i$ $\quad i = 1, 2, 3, ..., N, \quad t = 1, 2, 3, ..., T,$ (7.28)

t represents the tth time period. The technical inefficiency term, U_i, is assumed to be time-invariant, so that technical inefficiency remains with firm throughout the period of study. The distribution of V_{it} is assumed to be independently and identically distributed at $N(0, \sigma_v^2)$, while for U_i is independently and identically distributed at $N^+(0, \sigma_U^2)$. These distributional assumptions parallel those employed in the normal-half normal model proposed by Aigner, Lovell and Schmidt (1977), except that in Pitt and Lee model I (1981) the noise component, V_{it}, varies through time as well as across producers. The density function of U is

$$f(U) = \frac{2}{\sqrt{2\pi}\sigma_U} \exp\left\{-\frac{U^2}{2\sigma_U^2}\right\}$$ (7.29)

and the density function of V, which becomes time dependent, is given by

$$f(V) = \frac{1}{(2\pi)^{T/2} \sigma_V^T} \exp\left\{\frac{-V'V}{2\sigma_V^2}\right\}$$ (7.30)

Given the independence assumption, the joint density function of U and V is

$$f(U,V) = \frac{2}{(2\pi)^{(T+1)/2}\sigma_U\sigma_V^T}\exp\left\{-\frac{U^2}{2\sigma_U^2} - \frac{V'V}{2\sigma_V^2}\right\}$$ (7.31)

and the joint density function of and U and ε is

$$f(U,\varepsilon) = \frac{2}{(2\pi)^{(T+1)/2}\sigma_U\sigma_V^T}\exp\left\{-\frac{(U-\mu_*)^2}{2\sigma_*^2} - \frac{\varepsilon'\varepsilon}{2\sigma_V^2} + \frac{\mu_*^2}{2\sigma_*^2}\right\}$$ (7.32)

where

$$\mu_* = -\frac{T\sigma_U^2\bar{\varepsilon}}{\sigma_V^2 + T\sigma_U^2}$$

$$\sigma_*^2 = \frac{\sigma_U^2\sigma_V^2}{\sigma_V^2 + T\sigma_U^2}$$ (7.33)

$$\bar{\varepsilon} = \frac{1}{T}\sum_t\varepsilon_{it}$$

Thus, the marginal density function of ε is

$$f(\varepsilon) = \int_0^\infty f(U,\varepsilon)dU$$

$$= \frac{2[1-\Phi(-\mu_*/\sigma_*)]}{(2\pi)^{T/2}\sigma_V^{T-1}(\sigma_V^2 + T\sigma_U^2)^{1/2}}\exp\left\{-\frac{\varepsilon'\varepsilon}{2\sigma_V^2} + \frac{\mu_*^2}{2\sigma_*^2}\right\}$$ (7.34)

The estimates of producer-specific time-invariant technical efficiency can be obtained from

$$f(U|\varepsilon) = \frac{f(U,\varepsilon)}{f(\varepsilon)}$$

$$= \frac{1}{(2\pi)^{1/2}\sigma_*[1-\Phi(-\mu_*/\sigma_*)]}\exp\left\{-\frac{(U-\mu_*)^2}{2\sigma_*^2}\right\}$$ (7.35)

which is the density function of a variable distributed as $N^+(\mu_*, \sigma_*^2)$. And the point estimator of technical efficiency can be estimated by either the mean or the mode of this distribution. Thus,

$$E(U_i|\varepsilon_i) = \mu_{*i} + \sigma_*\left[\frac{\phi(-\mu_{*i}/\sigma_*)}{1-\Phi(-\mu_{*i}/\sigma_*)}\right]$$ (7.36)

and $\quad M\left(U_i \middle| \varepsilon_i\right) = \begin{cases} \mu_{*i} & if \ \varepsilon_i \le 0 \\ 0 & otherwise \end{cases}$ (7.37)

An alternative point estimator using the minimum squared error predictor suggested by Battese and Coelli (1988) can be written as

$$E\left(\exp\{-U_i\} \middle| \varepsilon_i\right) = \left[\frac{1 - \Phi\left(\sigma_* - \left(U_{*i}/\sigma_*\right)\right)}{1 - \Phi\left(-U_{*i}/\sigma_*\right)}\right] \exp\left\{-\mu_{*i} + \frac{1}{2}\sigma_*^2\right\}$$ (7.38)

The estimators of the technical inefficiency term, U_i, are then, unlike in the case of cross section data, consistent as $T \to +\infty$.

The above maximum likelihood technique used by Pitt and Lee (1981) in obtaining the estimates of producer-specific time-invariant technical efficiency is based on the normal-half normal distribution assumption suggested by Aigner, Lovell and Schmidt (1977). This assumption has later been generalized to the normal-truncated normal distribution for use with panel data context by Kumbhakar (1987) and Battese and Coelli (1989). The distribution of V_{it} is assumed to be independently and identically distributed at $N(0, \sigma_v^2)$, while U_i is independently and identically distributed at $N^+(\mu, \sigma_U^2)$. The truncated normal density function for $U \ge 0$ is given by

$$f(U) = \frac{1}{\sqrt{2\pi}\sigma_U \Phi(\mu/\sigma_U)} \exp\left\{-\frac{(U - \mu)^2}{2\sigma_U^2}\right\}$$ (7.39)

and for time-independent V is

$$f(V) = \frac{1}{(2\pi)^{T/2}\sigma_V^T} \exp\left\{\frac{-V'V}{2\sigma_V^2}\right\}$$ (7.40)

the joint density function of U and V is

$$f(U,V) = \frac{1}{(2\pi)^{(T+1)/2}\sigma_U \sigma_V^T \Phi(\mu/\sigma_U)} \exp\left\{-\frac{(U - \mu)^2}{2\sigma_U^2} - \frac{V'V}{2\sigma_V^2}\right\}$$ (7.41)

where $\quad \widetilde{\mu}_i = -\dfrac{\mu\sigma_V^2 - T\sigma_U^2\bar{\varepsilon}}{\sigma_V^2 + T\sigma_U^2}$

$$\sigma_*^2 = \frac{\sigma_U^2 \sigma_V^2}{\sigma_V^2 + T\sigma_U^2}$$

$$\bar{\varepsilon} = \frac{1}{T} \sum_t \varepsilon_{it}$$

(7.42)

The conditional distribution $(U|\varepsilon)$ is given by

$$f(U|\varepsilon) = \frac{f(U,\varepsilon)}{f(\varepsilon)}$$

$$= \frac{1}{(2\pi)^{1/2} \sigma_* [1 - \Phi(-\tilde{\mu}/\sigma_*)]} \exp\left\{-\frac{(U - \tilde{\mu})^2}{2\sigma_*^2}\right\}$$

(7.43)

which is distributed as $N^+(\tilde{\mu}, \sigma_*^2)$. And again, either the mean or the mode of this distribution could serve as the basis for a point estimate of producer-specific time-invariant technical efficiency, which are given by

$$E(U_i|\varepsilon_i) = \tilde{\mu}_i + \sigma_* \left[\frac{\phi(-\tilde{\mu}_i/\sigma_*)}{1 - \Phi(-\tilde{\mu}_i/\sigma_*)}\right]$$

(7.44)

and
$$M(U_i|\varepsilon_i) = \begin{cases} \tilde{\mu}_i & \text{if } \tilde{\mu}_i \geq 0 \\ 0 & \text{otherwise} \end{cases}$$

(7.45)

An alternative estimator is provided by the minimum squared error predictor as

$$E(\exp\{-U_i\}|\varepsilon_i) = \left[\frac{1 - \Phi(\sigma_* - (\tilde{\mu}_i/\sigma_*))}{1 - \Phi(-\tilde{\mu}_i/\sigma_*)}\right] \exp\left\{-\tilde{\mu}_i + \frac{1}{2}\sigma_*^2\right\}$$

(7.46)

The estimators obtained from these methods are also consistent as $T \to +\infty$.

The assumption made for these time-invariant models that technical efficiency is constant through time is a very strong one. This leads to a major drawback of this type of models as they do not make any allowance for technical change since the structure of production technology is assumed to be constant through time. Particularly, if the operating environment is competitive, it is hard to accept the notion that a firm will permit technical

inefficiency to remain within their production through very many time periods[9]. Thus, although the estimators obtained become consistent as T approaching infinity, however, in reality, the longer the panel is, the less tenable this assumption becomes.

7.5.2 Time Varying Models

Eventually, the assumption of constant technical efficiency through time was relaxed in a series of papers by Cornwell, Schmidt and Sickles (1990), Kumbhakar (1990), and Battese and Coelli (1992). Cornwell *et al.* (1990) and Kumbhakar (1990) are the first to propose a stochastic production frontier with time varying panel data technical efficiency. The model

$$Y_{it} = f(x_{it}; \beta) \exp\{\varepsilon_{it}\} \tag{7.47}$$

is specified to take the form of Cobb-Douglas production function, thus, it becomes

$$\ln Y_{it} = \beta_{ot} + \sum_n \beta_n \ln X_{nit} + V_{it} - U_{it} \tag{7.48}$$

where β_{ot} is the production frontier intercept common to all producers in period t.

Cornwell *et al.* (1990) employed the fixed-effects and the random-effects approach in estimating the frontier production function. Equation (7.48) becomes

$$\ln Y_{it} = \beta_{it} + \sum_n \beta_n \ln X_{nit} + V_{it} \tag{7.49}$$

where $\beta_{it} = \beta_{ot} - U_{it}$ is the intercept for producer i in period t. However, with an $I \times T$ panel, it becomes very difficult to obtain all the estimates of $I \cdot T$ intercepts β_{it}, the N slope parameters β_n,

and σ_V^2. Thus, they address this problem by specifying

$$\beta_{it} = \Omega_{it} + \Omega_{i2}t + \Omega_{i3}t^2 \tag{7.50}$$

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[9] Kumbhakar and Lovell, (2000)

which reduces the number of intercept parameters to $I \cdot 3$. Nevertheless, it still leaves quite a number of parameters to be estimated, in particular if the ratio of I/T is large.

Alternatively, Kumbhakar (1990) employs the maximum likelihood method in estimating the production frontier by assuming equation (7.48) with $\beta(t)$ as the parametric function of time,

$$\beta(t) = \left[1 + \exp\{\eta t + \omega t^2\}\right]^{-1} \tag{7.51}$$

This model contains two additional parameters to be estimated, η and ω. The function of $\beta(t)$ satisfies the properties which, firstly, $0 \le \beta(t) \le 1$, and secondly, $\beta(t)$ can be both monotonically increasing or decreasing, and both concave and convex, depending on the signs and magnitudes of the two parameters η and ω. The distributional assumptions on V_{it} assumed it to be distributed independently and identically with $N(0, \sigma_v^2)$, and U_i is assumed to be distributed independently and identically with $N^+(0, \sigma_U^2)$. The error terms are specified as

$$
\begin{aligned}
U_{it} &= \beta(t)U_i \\
\varepsilon_{it} &= V_{it} - U_{it} \\
&= V_{it} - \beta(t)U_i
\end{aligned}
\tag{7.52}
$$

The marginal density function of $\varepsilon_i = (\varepsilon_{i1}, ..., \varepsilon_{iT})'$, becomes

$$
\begin{aligned}
f(\varepsilon_i) &= \int_0^\infty f(\varepsilon_i, U_i) dU_i \\
&= \int_0^\infty \prod_t f(\varepsilon_{it} - \beta(t)U_i) f(U_i) dU_i \\
&= \frac{2}{(2\pi)^{(T/2)} \sigma_V^T \sigma_U} \int_0^\infty \exp\left\{-\frac{1}{2}\left[\frac{\sum_t (\varepsilon_{it} - \beta(t)U_i)^2}{\sigma_V^2} + \frac{U_i^2}{\sigma_U^2}\right]\right\} dU_i \\
&= \frac{2\sigma_* \exp\left\{-\frac{1}{2} a_{*i}\right\}}{(2\pi)^{T/2} \sigma_V^T \sigma_U} \int_0^\infty \frac{1}{\sqrt{2\pi}\sigma_*} \exp\left\{-\frac{1}{2\sigma_*^2}(U_i - \mu_{*i})^2\right\} dU_i
\end{aligned}
\tag{7.53}
$$

where $\displaystyle\int_0^\infty \frac{1}{\sqrt{2\pi}\sigma_*}\exp\left\{-\frac{1}{2\sigma_*^2}(U_i - \mu_{*i})^2\right\}dU_i = 1 - \Phi\left(-\frac{\mu_{*i}}{\sigma_*}\right)$ (7.54)

$$\mu_{*i} = \frac{\left(\sum_t \beta(t)\varepsilon_{it}\right)\sigma_V^2}{\left(\sigma_V^2 + \sigma_U^2 \sum_t \beta(t)^2\right)}$$

$$\sigma_*^2 = \frac{\sigma_V^2 \sigma_U^2}{\sigma_V^2 + \sigma_U^2 \sum_t \beta(t)^2} \quad (7.55)$$

$$a_{*i} = \frac{1}{\sigma_V^2}\left[\sum_t \varepsilon_{it}^2 - \frac{\sigma_U^2 \left(\sum_t \beta(t)\varepsilon_{it}\right)^2}{\sigma_V^2 + \sigma_U^2 \sum_t \beta(t)^2}\right]$$

The estimator for U_i can be obtained from the mean and mode of $U_i|\varepsilon_i$, which are given

by

$$E(U_i|\varepsilon_i) = \mu_{*i} + \sigma_*\left[\frac{\phi(-\mu_{*i}/\sigma_*)}{1 - \Phi(-\mu_{*i}/\sigma_*)}\right] \quad (7.56)$$

$$M(U_i|\varepsilon_i) = \begin{cases} U_{*i} & \text{if } \sum_t \beta(t)\varepsilon_{it} \geq 0 \\ 0 & \text{otherwise} \end{cases} \quad (7.57)$$

which $U_i|\varepsilon_i$ is distributed as $N^+(\mu_{*i}, \sigma_*^2)$.

Alternatively, the minimum squared error predictor of technical efficiency is

$$E\left(\exp\{-U_{it}\}|\varepsilon_i\right) = E\left(\exp\{-U_i\beta(t)\}|\varepsilon_i\right)$$
$$= \left[\frac{1 - \Phi(\beta(t)\sigma_* - (\mu_{*i}/\sigma_*))}{1 - \Phi(-\mu_{*i}/\sigma_*)}\right]\exp\left\{-\beta(t)\mu_{*i} + \frac{1}{2}\beta_t^2\sigma_*^2\right\} \quad (7.58)$$

An alternative time-varying stochastic production frontier model is proposed by Battese and Coelli (1992), using data on Indian paddy farmers, relaxing the half normal distribution assumption of the technical inefficiency error term, by assuming it to be truncated normal. It incorporates unbalanced panel data associated with observations on a sample of N firms over T time periods. Similar to the model proposed by Kumbhakar (1990), the model is defined by equation (7.48), but with the technical inefficiency term U_{it} of

$$U_{it} = \eta_{it} U_i$$
$$\eta_{it} = \exp\{-\eta(t-T)\} \qquad\qquad t \in \tau(i); i = 1,2,...,N \qquad (7.59)$$
$$U_{it} = \exp\{-\eta(t-T)\} U_i$$

where η is an unknown scalar parameter to be estimated, which determines whether inefficiencies are time varying or time invariant, and $\tau(i)$ represents the set of T_i time periods among the T periods involved for which observations for the ith firm are obtained. The function η_{it} satisfies the properties that firstly, $\eta_{it} \geq 0$, and secondly, η_{it} decreases at an increasing rate if $\eta > 0$, increases at an increasing rate if $\eta < 0$, or remains constant if $\eta = 0$. The distributional assumption is made that V_{it} is assumed to be an independently and identically distributed random error $N(0, \sigma_v^2)$, while U_{it} is assumed to be distributed as an independently and identically distributed as non-negative truncation of the $N^+(\mu, \sigma_U^2)$ distribution.

Based on these distributional assumptions, Battese and Coelli showed that $U_i | \varepsilon_i$ is independently and identically distributed with $N^+(\mu_{**i}, \sigma_*^2)$. Thus, the minimum mean squared error predictor of technical efficiency $TE_{it} = \exp(-U_{it})$ is

$$E[\exp(-U_{it})|E_i] = E[\exp\{-\eta_{it}U_i\}]$$
$$= \left\{ \frac{1 - \Phi[\eta_{it}\sigma_* - (\mu_{**i}/\sigma_*)]}{1 - \Phi(-\mu_{**i}/\sigma_*)} \right\} \exp\left[-\eta_{it}\mu_{**i} + \frac{1}{2}\eta_{it}^2\sigma_*^2 \right] \qquad (7.60)$$

where
$$\mu_{**i} = \frac{\mu\sigma_V^2 - \eta_i' E_i \sigma_U^2}{\sigma_V^2 + \eta_i'\eta_i\sigma_U^2}$$

$$\sigma_*^2 = \frac{\sigma_V^2\sigma_U^2}{\sigma_V^2 + \eta_i'\eta_i\sigma_U^2} \qquad (7.61)$$

and η_i represents the (T_i x 1) vector of η_{it} associated with the time periods observes for the ith firm. Notice that in this model, if technical efficiency is time invariant, $\eta = 0$ and

thus $\eta_{it} = 1$ and $\eta_i' \eta_i = T$, and the expressions for μ_{**i} and σ_*^2 collapse to their time-invariant version proposed by Battese and Coelli (1988), as discussed earlier.

This model by Battese and Coelli (1992) is by far the most commonly used model in the literature concerning the stochastic production frontier estimation, as it provides the consistent estimates of the technical inefficiency term with only one additional parameter, η, to be estimated. Nevertheless, this model has the one drawback that the technical efficiency is forced to be a monotonic function of time, as the exponential nature of the behaviour of the firm effects over time (shown in equation (7.59)) is a rigid parameterization[10]. Hence, in the period when there occurs both upward and downward movement of technical efficiency, this model will not be able to capture that movement, and thus, could not represent the true adjustment of the efficiency.

7.6 Conclusion

This chapter focused on presenting, and commenting on, the technical development of the stochastic production frontier. It started with the pioneer work of Farrell (1957) in which the concept of allocative and technical efficiency was first introduced. It then progressed further into the development of the deterministic production frontier (Aigner and Chu (1968), Seitz (1971), Timmer (1971), Afriat (1972) and Richmond (1974)), which is subjected to a notable problem as it does not allow for a disturbance term. Therefore, it becomes very sensitive to outliers such as measurement errors and unobservable shocks. This problem was solved later on by the development of the stochastic production frontier (Meeusen and van de Broeck (1977), Aigner *et al.* (1977)) in the 1970s by which the traditional symmetric random noise component was included into the model.

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[10] Uğur, (2003)

However, these early stochastic production frontier models are still subject to one very serious problem, resulting from the use of cross sectional data. The estimates of technical efficiency from these models are inconsistent. This problem can be solved by the use of a sufficiently long panel data, since it involves adding more observations on each producer. Therefore, the later generation of stochastic production frontier was developed in order to accommodate the use of panel data. Pitt and Lee (1981) were the first to extend the cross-sectional maximum likelihood estimation techniques to panel data. However, their model was still subjected to one important criticism. In their model, they assumed that technical inefficiency was constant through time, i.e. no technical improvement existed through out the entire period of study. Nonetheless, when the panel is involving a very long period of time and the operating environment is competitive, such an assumption becomes less tenable. The notion that any firm will permit technical inefficiency to remain with their production process for a long period of time becomes more difficult to accept.

Therefore, this led to the development of the time varying stochastic production frontier (Cornwell, Schmidt and Sickles (1990), Kumbhakar (1990), Battese and Coelli (1992)), in which the structure of the production technology was allowed to change through time. Firms were assumed to upgrade their technologies if technical inefficiencies existed in their production processes. However, although such development has eliminated the problem of the unattainable assumption of a constant production technology, it is still subject to a drawback, as technical efficiency is forced to be a monotonic function of time in this type of models[11]. Hence, such models would only be suitable in estimating efficiency for periods in which there are no major shifts of technical efficiency. Such a limitation is rather inconsistent with the need for a lengthy panel in order to guarantee a consistent estimate of efficiency. Therefore, further development is necessary to include a non-rigid parameterization of the technology progress over time, so that it will be possible to capture

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[11] Kumbhakar and Lovell (2000), and Uğur (2003)

the real movements of technical efficiency, without imposing too many untenable assumptions.

Chapter 8 – Thai Productivity and the Crisis

8.1 Introduction

In this chapter, the association between the effects of the 1997 economic crisis and the productivity level of Thai manufacturing sector is examined. The parametric distance function approach (Stevenson (1980), Pitt and Lee (1981), Battese, Coelli, and Colby (1989), Cornwell *et al* (1990), Kumbhakar (1990), Battese and Coelli (1992)) in measuring productivity (namely, the stochastic production frontier approach) is being employed. The treatment is extensive, but its focus is very specific. The concern of this chapter is to provide answers to the key research questions posed by the thesis (see details in Chapter 1). In sum, the main interests of this thesis are twofold. Firstly, the thesis provides an answer to *what happened to the Thai manufacturing sector in the post-crisis period compared to pre-crisis?* And secondly, it asks *what were the factors leading to the differences in the productivity level of the two periods?*

In order to resolve these concerns, the chapter is organized in the following practice. Section 8.2 provides a review of the computer software that can be used for estimating a stochastic production frontier. The two most widely used types of software, i.e. LIMDEP and FRONTIER 4.1, are introduced, evaluated and compared. Section 8.3 presents the particular stochastic frontier models (Pitt and Lee (1981), Battese, Coelli, and Colby (1989), and Battese and Coelli (1992)) that will be employed in the analysis. Section 8.4 involves further preliminary analysis (to Chapter 6 above). This section follows the method of explanatory data analysis (EDA), in which a simple analysis, with few assumptions, is carried out in order to allow the data to reveal its own structure, and therefore, preventing mistakes and biases that could arise from making unsuitable assumptions[1]. In Section 8.5, the main analysis will be conducted. A suitable model for representing the pre- and post-crisis will be

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[1] Engineering Statistics Handbook, The US Department of Commerce

selected here. Also, the results from the analysis will be given. And most importantly, the answer to the first research concern of 'what happened to the Thai manufacturing sector' will also be answered here. Finally, these results will be discussed and explained in Section 8.6. The answer to the last research concern will also be given. And finally, a concise conclusion for the chapter is provided.

8.2 Review of the Stochastic Frontier Software

A stochastic frontier (Meeusen and van de Broeck (1977), Aigner et al (1977), Green (1980), Stevenson (1980), Pitt and Lee (1981), Jondrow et al (1982), Battese, Coelli, and Colby (1989), Cornwell *et al* (1990), Kumbhakar (1990), Battese and Coelli (1992)) can be estimated using a different range of multi-purpose econometric software of which most can be adapted for the desired estimation. These include well-known statistical packages such as LIMDEP, Shazam, GUASS, SAS, STATA, etc. However, the most commonly used packages for estimating stochastic production frontiers and inefficiency are FRONTIER 4.1 and LIMDEP. LIMDEP 7.0 is a general-purpose econometric package developed by William H. Green, and is released in the Window version in 1998 (LIMDEP 7.0 Manual, (1995)). It is designed primarily for the non-standard econometric estimation of cross-section and panel data models. By contrast, FRONTIER 4.1 is a single purpose program, created by Tim Coelli, especially designed for the estimation of stochastic production frontiers. It utilizes the method of maximum likelihood to compute a wide variety of stochastic frontier models, for both cross-sections and panel data, in both balanced and unbalanced forms. FRONTIER 4.1 is employed in this thesis for carrying out the stochastic frontier estimations of the Thai productivity.

FRONTIER 4.1 follows a three-step procedure in estimating the maximum likelihood estimates of the parameters of a stochastic frontier production function[2]. In the first step, the ordinary least squares (OLS) estimates of the function are obtained. This provides unbiased estimators for all coefficients, except for the intercept term. These OLS estimates, excepting that of the intercept term, are then used as starting values in a two-phrase grid search across the parameter space of γ. The values of γ are considered from 0.1 to 0.9 in increments of size 0.1. The coefficient of the intercept term and the variance estimate are adjusted according to the corrected ordinary least squares presented in Coelli (1995), while other parameters μ and η are set to zero. Finally, the values selected in the grid search are used as the starting values in an iterative procedure, utilizing the Davidon-Fletcher-Powell Quasi-Newton method, to obtain the final maximum likelihood estimates.

FRONTIER 4.1 solves two general models: the error components model and the technical efficiency effects model. The error components model is formulated following the Battese and Coelli (1992) model

$$Y_{it} = f(X_{it}; \beta) \exp(V_{it} - U_{it})$$

where $\quad U_{it} = U_i \exp(-\eta(t-T))$ $\hspace{4cm}$ (8.1)

The imposition of one or more restrictions upon this model can provide a number of special cases, reflecting the main models proposed in the literature. These include the five models that will be tested in this thesis (details on these models are presented in the next section). Setting η to zero provides the time-invariant model set out in Battese, Coelli and Colby (1989). Furthermore, restricting the formulation of the previous model to a balanced panel data will result in the model suggested by Battese and Coelli (1998). The additional restriction of μ equals to zero will reduce the model to that in Pitt and Lee (1981) – their Model 1.

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[2] Coelli, (1996)

The technical efficiency effects model (TE), suggested by Battese and Coelli (1995), estimates stochastic frontiers, as well as predicted efficiencies of firm-specific variables. The latter may influence the firms' efficiency, by influences such as managerial experience, ownership characteristics, and time trends. This procedure attempts to identify the factors that affect differences in efficiencies between firms in an industry. FRONTIER 4.1 calculates this model by a single-stage estimation procedure, employing the formulation

$$Y_{it} = f(X_{it}; \beta) \exp(V_{it} - U_{it})$$

where $U_{it} = \delta' z_{it} + w_{it}$ (8.2)

and z_{it} is a vector of explanatory variables that influence the structure of the production process by which inputs x are converted to output Y. Similar to the error components model, this model specification can also encompass a number of other model specifications as special cases. If we set T=1 and z_{it} contains the value one and no other variables, then the model reduces to the truncated normal specification in Stevenson (1980), where δ_0, the only element in δ, will have the same interpretation as the μ parameter in Stevenson (1980).

Table 8.1: Distributional assumptions allowed by the two programs

Distribution	LIMDEP 7.0	FRONTIER 4.1
Cross-sectional production (cost) function		
Half-normal distribution	Yes	Yes
Truncated normal distribution	Yes	Yes
Exponential distribution	Yes	No
Panel Data production (cost) function		
Time-invariant firm-specific inefficiency		
Half-normal	Yes	Yes
Truncated normal	Yes	Yes
Time-variant firm-specific inefficiency		
Half-normal	No	Yes
Truncated normal	No	Yes
Effect-specific panel data production (cost) function	No	Yes

Source: Sena V., (1999)

When compared to LIMDEP 7.0, FRONTIER 4.1 is superior in many aspects[3]. The most distinctive advantage of FRONTIER 4.1 is that it is able to accommodate a wider range of assumptions about the error distribution term, as shown in Table 8.1. When the panel data are estimated, the inefficiency component can be specified as time-variant, or as a function of a vector of firm-specific variables, while the option of the inefficiency term is only limited to the simple time-invariant model in LIMDEP.

The second advantage of FRONTIER 4.1 is also very significant. FRONTIER 4.1 is the only program that can estimate an inefficiency model (Kumbhakar, Ghosh and McGuckin (1991), Reifschneider and Stevenson (1991), Huang and Liu (1994), Battese and Coelli (1995) in a one-step process. The inefficiency models may be estimated by two approaches: a one-step process and a two-step process. With the two-step procedure, the production frontier is first estimated and the technical efficiency of each firm is derived. These are subsequently regressed against a set of variables, z_{it}, which are hypothesized to influence the firms' efficiency. A problem with this method is the inconsistency arising from the assumptions about the distribution of the variates denoting inefficiencies (which will be discussed in more details in the next chapter). In the first stage, the variates representing inefficiencies (or, briefly, 'inefficiency') are assumed to be independently and identically distributed (*iid*) in the estimation procedure. However, in the second stage, the estimated inefficiencies are assumed to be a function of a number of firm specific factors, and hence, are not identically distributed unless all the coefficients of the factors are simultaneously equal to zero. FRONTIER solves this problem by incorporating the firm specific factors directly into the maximum likelihood estimate, and estimating all the parameters in one step.

Third, with FRONTIER 4.1, it is possible to test whether any form of stochastic frontier function at all is required, by testing for the significance of the γ parameter. The output file in FRONTIER 4.1 contains the likelihood ratio statistics of the one-sided error between the frontier model estimated, and the restricted OLS model. If we cannot reject

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[3] Herrero and Pascoe, (2002)

the null hypothesis that γ is equals to zero, this would imply accepting the hypothesis that σ_U^2 is not significantly different from zero, and hence that the U_{it} term should be removed from the model, leaving a specification with parameters that can be consistently estimated using ordinary least squares. In contrast, LIMDEP 7.0 does not provide any suitable statistics for such hypothesis testing.

Nevertheless, FRONTIER 4.1 does not come without drawbacks. One minor problem with this program is that the variables in the function are labelled by Greek letters, not by their original names, making variable identification a little troublesome in the cases where the list of regressors is very extensive[4]. Secondly, apart from the test of significance of the γ parameter, FRONTIER 4.1 does not provide any other diagnostic tests on the chosen functional form, nor on the properties of the stochastic noise. Therefore, in order to perform these tests, users have to implement them by running the program for each specification, and then calculating the likelihood ratio tests by hand, using the log likelihood values provided by the software.

Another point worth mentioning here is the choice of gradient method used by FRONTIER 4.1. It is generally accepted that nonlinear optimization is an intricate practical problem. It often cannot be solved explicitly, and an iterative algorithm is needed. The most commonly used algorithms are gradient methods. Those can take many forms, such as Newton's method, quadratic hill-climbing method, and the Newton-Raphson method. However, most of these methods require the calculation of the matrix of second partial derivatives, which can be troublesome (e.g. computationally burdensome, slow convergence, or even divergence). Hence, the developer of FRONTIER 4.1 decided that this task was probably best avoided, and turned their attention to Quasi-Newton methods[5]. This is a very effective class of algorithms that has been developed in order to eliminate the problem of deriving second derivatives altogether, and still retains excellent convergence properties.

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[4] Herrero and Pascoe, (2002)
[5] Coelli, (1996)

The Davidon-Fletcher-Powell Quasi-Newton method was selected by the author of FRONTIER 4.1 because it was a respected tool in econometric applications, and had also been recommended by Pitt and Lee (1981) for the estimation of stochastic frontier production function model.[6] Thus, the chosen DFP algorithm is extremely effective it being amongst the most widely used gradient methods.

8.3 Model Specifications

Using data from the Manufacturing Production Survey, published by the National Statistical Office of Thailand (available in year 1990, 1991, 1993, 1996, 1998, 1999, 2000, and 2002), the frontier Cobb-Douglas production functions are estimated and compared between two time periods, the pre-crisis period consists of year 1990, 1991, 1993, and 1996, and the post-crisis period consists of 1998, 1999, 2000, and 2002. The model is defined as

$$\ln Y_{it} = \beta_0 + \beta_1 \ln(K_{it}) + \beta_2 \ln(L_{it}) + (V_{it} - U_{it}) \tag{8.3}$$

This frontier function is then estimated for five basic models, using the computer software FRONTIER 4.1, developed by Coelli in 1996.

Model 8.1: the traditional OLS estimation of the Cobb-Douglas production function, in which an assumption is being made that no technical efficiency exists, and thus the U_{it} term is assumed to be zero. Thus, the model reduces to

$$\ln Y_{it} = \beta_0 + \beta_1 \ln(K_{it}) + \beta_2 \ln(L_{it}) + V_{it} \tag{8.4}$$

Model 8.2: following Battese and Coelli (1992), a technical inefficiency term U_{it} is defined by

$$U_{it} = U_i \exp(-\eta(t - T)) \tag{8.5}$$

where the technical inefficiency term is assumed to be time-variant, with the

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[6] Coelli, (1996), pp.12

non-negative truncation distribution, $N^+(\mu,\ \sigma_U{}^2)$. This model can accommodate unbalanced panel data. Hence, the missing years are treated as the missing data. They arise in the pre-crisis period for $i = 1, 2, 4$, and 7; and in the post-crisis period for $i = 1, 2, 3$, and 5.

Model 8.3: the time-variant production frontier with a half normal distribution of the stochastic technical inefficiency component. This is a special case of the Battese and Coelli model (1992). Thus,

$$U_{it} = U_i \exp\left(-\eta(t - T)\right)$$

where U_{it} is *iid*, and has the distribution $N^+(0,\ \sigma_U{}^2)$

Model 8.4: the time-invariant model presented by Battese, Coelli and Colby (1989), in which the technical inefficiency component term is assumed to have a non-negative truncated distribution. Hence,

$$U_{it} = U_i$$

where U_i is *iid*, and has the distribution $N^+(\mu,\ \sigma_U{}^2)$

Model 8.5: the model involves a time-invariant and half normal distributed inefficiency component, as suggested by Pitt and Lee (1981). This is commonly known as Pitt and Lee's Model 1.

$$U_{it} = U_i$$

where U_i is *iid*, and has the distribution $N^+(0,\ \sigma_U{}^2)$

Before proceeding any further, it is important to make a clarification here. Because of the limitations of the data, and the short time-series involved, the main focal point in estimating and comparing pre- and post-crisis productivity is not on technical change, but rather on technical efficiency, i.e. the distance from the production frontier. Figure 8.1a and

8.1b illustrate the distinction between the two concepts, using the conventional isoquants (like II') and factor price lines (like PP')

Figure 8.1a: Technical Progress
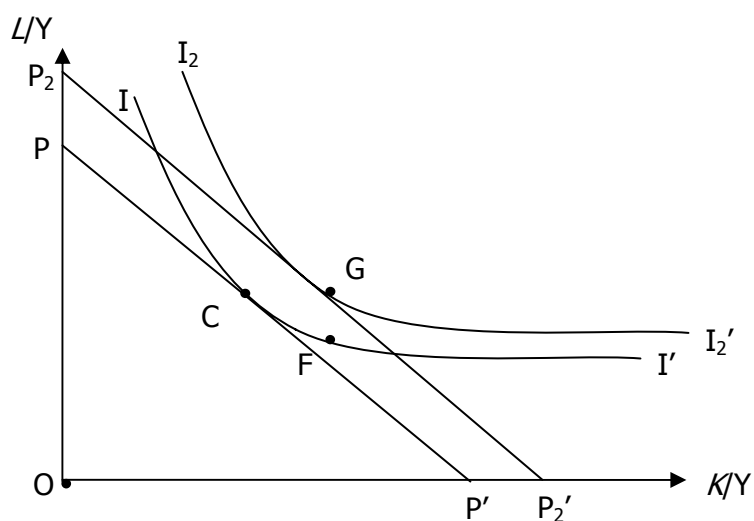
Figure 8.1b: Efficiency Improvement
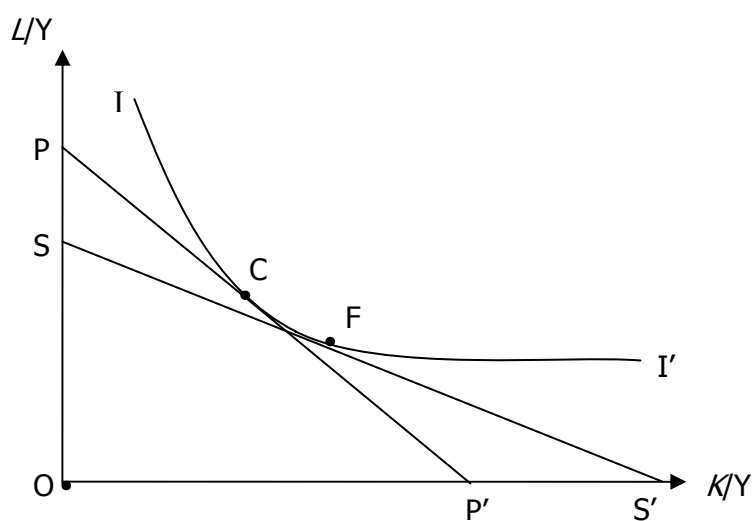
Figure 8.1a illustrates two states of equilibrium (C and G), where point C represents the equilibrium with lower technical advancement (and G with higher), and point F represents a disequilibrium (being then off the expansion path). Over time, with technical

progress, the industry may move from point C to point G, representing an equilibrium with better technical advancement. This will result in the *upward shift* of the production frontier.

Figure 8.1b illustrates the movement from initial equilibrium point C to new equilibrium point F. In period 1, point C represent the equilibrium point where the relative factor price line PP' is tangent with II'. Overtime, the capital-labour composition changes, and results in the shift from PP' to SS'. Hence point C becomes a disequilibrium from the standpoint of prices given by SS' and factor proportions shift to new values, as implied by the new equilibrium position in period 2 at point F. This will result in movements of observations below the frontier towards the frontier, representing improvement in the efficiency of production.

This thesis focuses on the latter case, in which the distance from the frontier is the main concern. The limitation in the data availability and the length of the time-series only permit the comparison between the pre- and post-crisis efficiency level, i.e. the distance from the frontiers, given the frontier representing the best technology available at the time.

8.4 Further Exploratory Data Analysis

Before attempting to fit a complicated model on a set of data, it is common for an analyst to first conduct an explanatory data analysis (EDA) in order to identify the overall pattern of the data set. In this thesis, an explanatory data analysis has already been conducted (in Chapter 6), using the simple ordinary least square estimates of the Cobb-Douglas production function in order to obtain a statistical summary of the structural change that happened post-crisis. However, the ordinary least square estimates could not provide any indication of the technical inefficiency component. Therefore, another set of explanatory data analysis should be conducted focusing on the technical inefficiency components. The results from these analyses should then provide a better overall understanding of the

inefficiency issue in the Thai manufacturing sector, and therefore, improve the basis of the further analysis in this thesis.

Simple frontier estimation of the pre- and post-crisis period has been carried out using the half-normal, time-invariant inefficiency model proposed by Pitt and Lee's Model I (1981). This choice of model owes something to the explanatory data analysis (EDA) of Chapter 6. Therefore, a simple model with the following specification is chosen

$$\ln Y_{it} = \beta_0 + \beta_1 \ln(K_{it}) + \beta_2 \ln(L_{it}) + (V_{it} - U_i) \tag{8.6}$$

which U_i is independently and identically distributed at $N^+(0, \sigma_U^2)$

Table 8.2a: maximum likelihood estimates of the pre- and post-crisis period

Variable	Parameter	MLE Estimates for Period	
		Pre-Crisis	**Post-Crisis**
Constant	β_0	7.0777	4.9410
		(1.1791)	(0.9972)
Ln Asset	β_1	0.2891	0.5084
		(0.0821)	(0.0666)
Ln Employ	β_2	0.5266	0.3123
		(0.1301)	(0.0829)
	σ^2	1.4181	0.4792
		(0.4835)	(0.1365)
	γ	0.5069	0.3447
		(0.2097)	(0.2204)
	n	89	88
	Log Likelihood	-119.9576	-79.4732

Note: Model used is Pitt and Lee's Model I (1981), or referred to as Model 8.5 above (p.212) in this chapter. Numbers of observation for pre- and post crisis period are also included.
Standard errors are in brackets.

The results of the coefficient estimates of capital and labour in both periods continue to confirm the findings by the OLS Cobb-Douglas production function carried out in Chapter 6. The capital coefficient, β_1, is 0.2891 in the pre-crisis period, and 0.5084 in the post crisis period. On the other hand, the coefficient estimates of labour, β_2, is 0.5266 in the pre-crisis, and 0.3123 in the post-crisis. These results (see Table 8.2a) suggest that there was a structural shift from labour intensive production in the pre-crisis period to capital

intensive production in the post-crisis period. However, the primary interest here is not on the coefficient estimates of inputs, but on the estimates of the efficiency level for each industry. The results are listed in Table 8.2b.

This table shows that the mean efficiency improves in the post-crisis period, when compared to the pre-crisis period. It rises from 0.5478 in the pre-crisis period to 0.7362 in the post crisis. A paired samples test confirms that these pre- and post-crisis mean efficiencies are statistically significantly different from each other. Twenty industries, out of the total 24, exhibit an improvement in their efficiency level; however, four industries exhibit a decline in efficiency. These four industries are: industry 9 – the publishing and printing industry; industry 10 – the coke, petroleum and nuclear industry; industry 14 – the basic metals; and industry 16 – the machinery and equipment industry.

Table 8.2b: Technical Efficiency Estimates

Industry	Pre-Crisis (n = 89)	Post-Crisis (n = 88)
Food	0.6686	0.8190
Tobacco	0.8587	0.9351
Textiles	0.5169	0.7030
Wearing Apparel	0.4520	0.8095
Leather Products	0.4620	0.6834
Footwear	0.3063	0.7217
Wood	0.3382	0.6020
Paper	0.5172	0.6720
Publishing	0.8296	0.7486
Petroleum	0.8360	0.7967
Chemical	0.5328	0.7296
Rubber & Plastic	0.5489	0.7832
Non-Metallic Mineral	0.6279	0.7141
Basic Metals	0.5647	0.5230
Fabricated Metal	0.4187	0.7378
Machinery	0.7741	0.7623
Computing	0.4682	0.9071
Electrical	0.5671	0.7297
Communication	0.7186	0.8244
Medical	0.3385	0.6267
Vehicles	0.7453	0.8387
Transport Equipment	0.3077	0.6514
Furniture	0.3636	0.6102
Jewellery	0.3854	0.7394
Mean	**0.5478** (0.0307)	**0.7362** (0.0093)

Note: Technical efficiencies were computed using the expression in equation (7.60) p. 201, based on the method derived by Pitt and Lee's Model I.
Standard errors are in brackets.

One characteristic that these four industries have in common is that they are all very domestically oriented. This is by the standard of the National Statistical Office, who define an industry to be domestically oriented if it exports less than 30 percent of its total production. These domestic oriented industries, as mentioned earlier in Chapter 4, were the segments of the manufacturing sector that have been most heavily hit by the crisis. This is due to the fact that they had to face a sharp decline in domestic demand resulting from the economic crisis; but, unlike the more export oriented segment, could not enjoy the benefits of higher export which came as a result of the cheaper Baht. Moreover, three out of these four industries, namely, the basic metals, the machinery and equipment, and the coke, petroleum and nuclear industry, are all heavy industries, which are known to be the industries that, generally, mostly affected during the timing of the economic.

This finding suggests that it is sensible to re-estimate the post-crisis data by dividing these industries into two segments, the domestic oriented and the non-domestic oriented industries. Also, time varying effect should be included, in order to examine the adjustment of these industries, in term of efficiency, in the post-crisis period. Therefore, the time-varying inefficiency model proposed by Battese and Coelli (1992) is selected for this analysis. For this model, the time varying parameter η could take the value less than 0 (implying that technical efficiency is deteriorating), equal to 0 (technical efficiency is constant), or higher than 0 (technical efficiency is improving). Therefore, this makes it very suitable for use in analyzing the pattern of efficiency adjustment in the post-crisis period. If the efficiency component of the post-crisis domestic and the non-domestic segments exhibit the same trend, either increasing or decreasing, there might not be a need for the sectoral analysis. If both segments exhibit increasing trends, then this would suggest that the domestic segment had been more heavily hit by the crisis. Hence a low efficiency level provided at the beginning of the post-crisis period, but over time, the efficiency level began to pick up. Therefore, the next important thing to examine is whether or not the difference

between the mean efficiency of these two segments is significant. If they are not significant, then there will be no need for sectoral analysis.

Table 8.3a: maximum likelihood estimates of the post-crisis period

Variable	Parameter	MLE Estimates for Models	
		Domestic*	**Non-Domestic[#]**
Constant	β_0	5.6689	6.5306
		(1.4651)	(1.0303)
Ln Asset	β_1	0.5506	0.5584
		(0.0619)	(0.1133)
Ln Employ	β_2	0.1856	0.1151
		(0.1271)	(0.1387)
	σ^2	0.0735	0.2921
		(0.0614)	(0.0750)
	γ	0.3260	0.0516
		(0.1930)	(0.0820)
	μ	0.3095	0.2457
		(0.2232)	(0.1199)
	η	0.2633	0.2919
		(0.0980)	(0.0913)
	n	15	73
	Log Likelihood	-5.2319	-63.1143

Note: * Domestic oriented industry is the industry that exports less than 30 percent of its total production
[#] Non-domestic oriented industry is the industry that exports more than or equal to 30 percent of its total production
Model used is Battese and Coelli (1992), see equations (8.3) and (8.5) above (p.212). Numbers of observation for domestic (n_1) and non-domestic (n_2) firms are also included.
Standard errors are in brackets.

The results from the domestic and non-domestic analyses indicate that the post-crisis efficiency level exhibit an increasing trend, and this holds true for both domestic oriented and non-domestic oriented industries. The value of the time-variant parameter η is slightly, but *insignificantly*, higher in the non-domestic oriented industry, when compared to the domestic oriented industry, with $\eta_{domes} = 0.2633$ and $\eta_{non\text{-}domes} = 0.2919$ (see Table 8.3a). This indicates that the non-domestic segment has a slightly, but *insignificantly*, higher rate of technical improvement. One possible explanation for the higher rate of technical improvement in the non-domestic segment could lie in the fact that industries that are competing in the world market would be forced to become more efficient in order to survive,

while those in the domestic market are faced with a less fierce competitive environment, and hence, can afford to be less efficient. However, in the case of the Thai manufacturing industry, such phenomenon doesn't seem to have very strong effect.

Table 8.3b shows the mean technical efficiency estimates for both segments. The paired samples tests for each post-crisis year suggest that there is no significant difference between the mean technical efficiency estimates of the domestic and the non-domestic segment, for any year in the study. Hence, with neither a significant different between the mean efficiency estimates, nor the rate of technical improvement, it is possible to conclude from this exploratory data analysis that there is no real difference in the structure of these two segments in the Thai manufacturing sector, as well as no difference in their adjustment patterns post-crisis. Therefore, it is sensible to analyze all these industries in one aggregate model, rather than several sub-segment models.

Table 8.3b: Mean Technical Efficiency Estimates

Year	Domestic* (n_1 = 15)	Non-Domestic# (n_2 = 73)
1998	0.4106	0.4697
	(0.0659)	(0.287)
1999	0.4988	0.5565
	(0.0612)	(0.554)
2000	0.5819	0.6448
	(0.0515)	(0.173)
2002	0.7661	0.7843
	(0.0062)	(0.0671)

Note: * Domestic oriented industry is the industry that exports less than 30 percent of its total production
Non-domestic oriented industry is the industry that exports more than or equal to 30 percent of its total production
Technical efficiencies were computed using the expression in equation (7.60) p.201, based on the method derived by Battese and Coelli (1992), see equations (8.3) and (8.5) above (p.212). Standard errors are in brackets.

8.5 Principal Empirical Results

Empirical results for the five models specified earlier in Section 8.3 are presented in Table 8.4, with Table 8.4a and Table 8.4b presenting the pre-crisis and the post-crisis results,

respectively. For the pre-crisis period, all five models provide similar results for the output elasticity of inputs. In all models, the output elasticity of capital, β_1, has a value ranging between 0.28 and 0.38, with β_1 of Model 8.1 equals to 0.3430, of Model 8.2 equals to 0.3785, of Model 8.3 equals to 0.3496, of Model 8.4 equals to 0.2813, and of Model 8.5 equals to 0.2891. The paired samples tests indicate that these results are significantly lower than the output elasticity of labour, β_2, which has a range of between 0.50 and 0.56, with β_2 of Model 8.1, Model 8.2, Model 8.3, Model 8.4, and Model 8.5 equals to 0.5098, 0.5505, 0.5199, 0.5625, and 0.5266, respectively. These figures suggest, in unison, that in the pre-crisis period, the Thai manufacturing sector is rather labour intensive, and thus, confirming the finding from the OLS estimation of Cobb-Douglas production function presented in Chapter 6.

The t-statistics show that parameter β_0, β_1, and β_2 from all five models are significantly different from zero, and hence, should all be included in the models. Estimated values of the test parameter of the stochastic production function (γ) are somewhat diverse. They are 0.4235, 0.5712, 0.3464, and 0.5069 for Model 8.2, Model 8.3, Model 8.4, and Model 8.5, respectively. The value of γ has an important implication for the validity of the technical inefficiency term, and therefore, for the validity of the frontier production function.

The parameter $\gamma = \dfrac{\sigma_U^2}{\left(\sigma_V^2 + \sigma_U^2\right)}$ must have a value between 0 and 1 for use in an iterative

maximization process. If the value of γ is equal to zero, it implies that $\sigma_U^2 = 0$, therefore indicating that no technical inefficiency existed in the production process, and thus, that the traditional average production function (where producers are assumed to always work on their production function) is the superior model. On the other hand, if γ has the value of one, it implies that $\sigma_V^2 = 0$, and that therefore the production function takes the form of a full deterministic frontier without the statistic noise, V_{it}, with all deviations from the

production frontier being explained by technical inefficiency. Otherwise, the greater the value of γ, the higher the inefficiency that occurs in the production process.

Table 8.4a: maximum likelihood estimates of the pre-crisis period

Variable	Parameter	MLE Estimates for Models				
		Model 8.1	Model 8.2	Model 8.3	Model 8.4	Model 8.5
Constant	β_0	5.6532	5.7608	6.0695	7.3335	7.0777
		(0.9189)	(0.9962)	(1.3185)	(1.1877)	(1.1791)
Ln Asset	β_1	0.3430	0.3785	0.3496	0.2813	0.2891
		(0.8156)	(0.0956)	(0.0996)	(0.0832)	(0.0821)
Ln Employ	β_2	0.5098	0.5505	0.5199	0.5625	0.5266
		(0.1171)	(0.1235)	(0.1285)	(0.1270)	(0.1301)
	σ^2	0.9447	1.0755	1.6781	0.9738	1.4181
			(0.3156)	(0.6668)	(0.2014)	(0.4835)
	γ	-	0.4235	0.5712	0.3464	0.5069
			(0.1749)	(0.2090)	(0.1614)	(0.2097)
	μ	-	1.3350	-	1.1615	-
			(0.4080)		(0.3228)	
	η	-	-0.0775	-0.0803	-	-
			(0.0428)	(0.0861)		
	n	89	89	89	89	89
	Log Likelihood	-122.2279	-116.5374	-119.30346	-117.9199	-119.9576

Note: Models used are described above in p.211-212. Numbers of observation for the pre-crisis period is 89.
Standard errors are in brackets.

Table 8.4b: maximum likelihood estimates of the post-crisis period

Variable	Parameter	MLE Estimates for Models				
		Model 8.1	Model 8.2	Model 8.3	Model 8.4	Model 8.5
Constant	β_0	4.5200	6.4825	6.5214	5.1586	4.9410
		(0.8872)	(0.9987)	(1.2427)	(0.9533)	(0.9972)
Ln Asset	β_1	0.5101	0.5022	0.5131	0.5130	0.5084
		(0.0607)	(0.0654)	(0.0687)	(0.0765)	(0.0666)
Ln Employ	β_2	0.3181	0.2064	0.1783	0.3151	0.3123
		(0.0739)	(0.1019)	(0.1135)	(0.1030)	(0.0829)
	σ^2	0.3808	0.2555	0.3255	0.3651	0.4792
			(0.0356)	(0.0841)	(0.1442)	(0.1365)
	γ	-	0.0809	0.2611	0.2737	0.3447
			(0.0803)	(0.2357)	(0.2019)	(0.2204)
	μ	-	0.2875	-	0.6322	-
			(0.0834)		(0.3111)	
	η	-	0.2649	0.2767	-	-
			(0.0851)	(0.1026)		
	n	88	88	88	88	88
	Log Likelihood	-80.8550	-71.4005	-74.0212	-77.6189	-79.4732

Note: Models used are described above in p.211-212. Numbers of observation for the post-crisis period is 88.
Standard errors are in brackets.

Notably, the results in the post crisis period indicate a totally different situation for the Thai economy. The *t*-statistics indicate that all parameters β_0, β_1, and β_2 are significantly differed from zero and should be included in the model, except the output elasticity of labour, β_2, in Model 8.3. However, in the post-crisis period, for all five models, the paired samples tests indicate that the output elasticity of capital is significantly higher than that of labour. The β_1s vary slightly from 0.50 to 0.52. More specifically β_1 has the value of 0.5101, 0.5022, 0.5131, 0.5130, and 0.5084 in Model 8.1, Model 8.2, Model 8.3, Model 8.4, and Model 8.5, respectively. The β_2s vary over the range of 0.18 and 0.32, with those of Model 8.1, Model 8.2, Model 8.3, Model 8.4, and Model 8.5 taking on the values of 0.3181, 0.2064, 0.1783, 0.3151, and 0.3123 respectively. These figures suggest a structural shift in the manufacturing sector from labour intensive, in the pre-crisis period, to capital intensive, in the post-crisis period. This is, again, consistent with the results from the standard OLS estimated production function discussed earlier in Chapter 6.

In addition, the value of the time-variant parameter, η, which determines whether the efficiency is declining or improving over-time, indicates an opposite trend for the pre- and post-crisis period. In both time-variant models (namely, in Model 8.2 and Model 8.3), the pre-crisis η has a negative value, which suggests that the technical efficiency in this period is declining over-time. On the other hand, the post-crisis η shows a positive value in both models, implying that efficiency is actually improving throughout this period. These figures of η, again, suggest some kind of technological shift in the manufacturing sector between the pre- and post-crisis period.

However, before any further interpretation of the results can be undertaken, various specification tests of the production frontier have to be conducted, in order to select the most suitable model for the analysis. First, the validity of the technical inefficiency term has to be tested, so as to confirm whether a stochastic production function is a superior measure to the traditional average production function. Specifically, this test can be done

through the checking of the γ value. The hypothesis for such a test is specified with the null hypothesis H_0: γ = 0. The value of γ = 0 implies that σ_U^2 = 0, and thus, the technical inefficiency term U_{it} = 0, suggesting that technical inefficiency did not exist in the production process. Therefore, the model reverts (from the production frontier) back to the traditional production function, which is estimated by mean output, having only one statistical error term, V_{it}.

The second hypothesis that needs to be tested concerns the distribution parameter, μ, which determines the distributional assumption of the technical inefficiency term, U_{it}. The technical inefficiency component is generally assumed to be a non-negative truncation of the $N^+(\mu, \sigma_U^2)$ distribution. However, if the null hypothesis H_0: μ =0 cannot be rejected, U_{it} would, instead, have a non-negative half-normal distribution, $N^+(0, \sigma_U^2)$, and the model reverts to the Battese, Coelli and Colby (1989) model.

The final hypothesis is concerned with the time-variant parameter, η, which determines the time-varying effects of the production frontier. Given the specification that $U_{it} = U_i \exp(-\eta(t-T))$, if the parameter η has a value equal to zero, the inefficiency term, U_{it}, will reduce to U_i, indicating that technical inefficiency is time-invariant. This suggests that any inefficiency in the production process remains there for the entire period of concern, and no technical improvement had been made available in such period. Thus, in order to test for the time-varying effects of the production frontier, the hypothesis test should be specified with the null hypothesis H_0: η = 0, which if it cannot be rejected, implies that $U_{it} = U_i$, and the inefficiency is time-invariant.

These hypothesis tests involving the parameters in the frontier function can be performed using the generalized likelihood ratio test statistic, defined by

$$\Lambda = -2[\ln(H_0) - \ln(H_1)] \qquad (8.6)$$

where $\ln(H_0)$ is the log likelihood value of a restricted frontier model, specified by a null hypotheses H_0, and $\ln(H_1)$ is the log likelihood value of the general frontier model under the alternative hypothesis H_1. This test statistic has approximately a chi-square distribution (or a mixed chi-square in the case that involves testing $H_0: \gamma = 0$), with degrees of freedom equal to the difference between the parameters involved in the null and alternative hypotheses. The test statistics are presented in Table 8.5.

Before proceed any further, a point should be noted here concerning the distribution of γ. The parameter γ does not have a regular χ^2 distribution, but a mixture of χ^2 distribution $\frac{1}{2}\chi^2(0)+\frac{1}{2}\chi_c^2(1)$ where the distribution $\chi^2(0)$ is degenerate with a unit mass at zero, and the distribution $\chi_c^2(1)$ of the square of a positively truncated standard normal variable $N(0,1)$ is a chi-square with one degree of freedom[7]. This is due to the fact that an irregularity of the likelihood function occurs at the point where all firms are technically efficient ($\gamma = 0$). Thus $\sigma = 0$, and as σ is non-negative, σ is on the boundary of the parameter space. The first and second order derivatives of the log likelihood function become zero, which implies that the information matrix at $\sigma = 0$ is singular. However, these irregularities can be simplified by the reparameterization of the likelihood function, and then the maximized likelihood function, again, provides a valid likelihood ratio test statistic, as in the standard case, except it would have the mixed chi-square distribution, as stated earlier.

From Table 8.5a, the pre-crisis period, given the specifications of the stochastic frontier production function with time-varying and non-negative truncated distribution inefficiency component, i.e. Model 8.2, it is evident that the traditional average production function is not an adequate representation of the data, as the null hypothesis of $H_0: \gamma = \mu = \eta = 0$ is rejected. The significance of the variance parameter γ suggests that the technical inefficiency effects make a significant contribution to the production function.

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[7] Lee (1993), pp.424

Hence, a production function with the technical inefficiency component, U_{it}, should be employed. Further, the hypotheses involve the assumptions that the half-normal distribution is an adequate representation of the inefficiency term. That is H_0: $\mu = \eta = 0$, as well as, H_0: $\mu = 0$ are also rejected, suggesting that the technical inefficiency component has the non-negative truncated normal distribution, $N^+(\mu, \sigma_U^2)$. However, the hypothesis that the technical inefficiency has the time-invariant structure, specifically H_0: $\eta = 0$, could not be rejected. This suggests that U_{it} is in fact equal to U_i, and inefficiency does indeed stay with the production process overtime. Hence, it could be concluded that Model 8.2 (the Battese and Coelli (1992) model) does not apply to the data set of the pre-crisis period.

Table 8.5a: Tests of hypotheses for parameters of the technical inefficiency component in the pre-crisis period

Assumptions	Null Hypothesis	χ^2-statistic	$\chi^2_{0.95}$ -value	Decision
Model 8.2	$\gamma = \mu = \eta = 0$	11.3809	7.045*	Reject H_0
Model 8.2	$\mu = \eta = 0$	6.8403	5.99	Reject H_0
Model 8.2	$\mu = 0$	5.5321	3.84	Reject H_0
Model 8.2	$\eta = 0$	2.7649	3.84	Cannot Reject H_0
Model 8.4	$\gamma = \mu = 0$	8.6160	5.138*	Reject H_0
Model 8.4	$\mu = 0$	4.0754	3.84	Reject H_0

Note: Hypotheses are tested by the general likelihood ratio test $\Lambda = -2[\ln(H_0) - \ln(H_1)]$

Table 8.5b: Tests of hypotheses for parameters of the technical inefficiency component in the post-crisis period

Assumptions	Null Hypothesis	χ^2-statistic	$\chi^2_{0.95}$ -value	Decision
Model 8.2	$\gamma = \mu = \eta = 0$	18.9090	7.045*	Reject H_0
Model 8.2	$\mu = \eta = 0$	16.1453	5.99	Reject H_0
Model 8.2	$\mu = 0$	5.2413	3.84	Reject H_0
Model 8.2	$\eta = 0$	12.4368	3.84	Reject H_0

Note: Hypotheses are tested by the general likelihood ratio test $\Lambda = -2[\ln(H_0) - \ln(H_1)]$

A further set of hypothesis tests has been conducted, with the specification of a frontier production function with time-invariant and non-negatively truncated technical

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* Any likelihood ratio test statistic involving a null hypothesis which includes the restriction that γ is zero does not have a chi-square distribution because the restriction defines a point on the boundary of the parameter space. In this case the likelihood ratio statistic has been shown to have a mixed chi-square distribution. In this case, critical values for the generalized likelihood ratio test are obtained from Table 1 in Kodde and Palm (1986). A simplifies version of this table is also presented in Appendix B.

inefficiency error component (i.e. Model 8.4). The results indicate that this model, when compared to the traditional average production function, is still a superior one, as the null hypothesis of H_0: $\gamma = \mu = 0$ is rejected. Therefore U_{it} is not equal to zero, and should be included in the model. Also, the half-normal distribution assumption is not an adequate representation of the inefficiency term, since H_0: $\mu = 0$ is also rejected. Hence, U_{it} should be distributed with $N^+(\mu, \sigma_U^2)$. Therefore, it could be concluded that the stochastic production frontier with time-invariant and non-negative truncated normal distribution technical inefficiency component U_{it}, namely, the model suggested by Battese, Coelli and Colby (1989) is an appropriate model for the analysis of the data set in the pre-crisis period.

For the post-crisis period, given the specifications of Model 8.2, which the technical inefficiency term is assumed to be time-variant, $U_{it} = U_i \exp(-\eta(t - T))$, and has non-negative truncated normal distribution, $N^+(\mu, \sigma_U^2)$, the null hypothesis of H_0: $\gamma = \mu = \eta = 0$ is tested in order to confirm whether or not the traditional average production function is an adequate representation of the data. The result presented in Table 8.5b indicates that this null hypothesis should be rejected, therefore, suggesting that there exist inefficiencies in the production process, and hence, the stochastic frontier production function is the appropriate model to be used.

Furthermore, it is evident, again, from results presented in Table 8.5b that the half-normal distribution is not an adequate representation of the inefficiency term, as the assumptions that H_0: $\mu = \eta = 0$ as well as H_0: $\mu = 0$ are both rejected. The post-crisis production frontier should have the technical inefficiency component with normal, non-negative truncated distribution. Further, the hypothesis stating that the post-crisis period should be represented with the time-invariant technical inefficiency model, i.e. H_0: $\eta = 0$, is also rejected, implying that there is enough evidence for the existence of technical improvement in the post-crisis period. Therefore, Model 8.2, the stochastic frontier production function with time-varying and non-negative truncated distribution inefficiency

component suggested by Battese and Coelli (1992) is the appropriate model for the post-crisis productivity analysis.

Table 8.6: Technical Efficiency Estimates

Industry	Pre-Crisis	Post-Crisis			
		1998	1999	2000	2002
Food	0.3827	0.6509	0.7159	0.7717	0.8565
Tobacco	0.7159	0.7210	0.7752	0.8207	0.8886
Textiles	0.2767	0.4639	0.5513	0.6310	0.7604
Wearing Apparel	0.2412	0.5751	0.6506	0.7167	0.8198
Leather Products	0.2617	0.3706	0.4640	0.5527	n/a[#]
Footwear	0.1770	0.4292	0.5193	0.6026	n/a[#]
Wood	0.1944	0.3056	0.4002	0.4935	0.6580
Paper	0.2909	0.3292	0.4238	0.5157	0.6752
Publishing	0.6432	0.4076	0.4992	0.5847	0.7270
Petroleum	0.7157	0.3583	0.4522	0.5420	0.6953
Chemical	0.2967	0.4173	0.5083	0.5929	0.7330
Rubber & Plastic	0.3023	0.5316	0.6123	0.6840	0.7975
Non-Metallic Mineral	0.3572	0.4411	0.5304	0.6126	0.7473
Basic Metals	0.3177	0.2591	0.3526	0.4477	n/a[#]
Fabricated Metal	0.2325	0.4250	0.5155	0.5992	0.7377
Machinery	0.5257	0.4627	0.5503	0.6301	0.7598
Computing	0.2745	0.7181	0.7728	0.8187	0.8873
Electrical	0.3189	0.4347	n/a[#]	n/a[#]	0.7415
Communication	0.4488	0.5958	0.6685	0.7318	n/a[#]
Medical	0.1982	0.3159	0.4104	0.5031	n/a[#]
Vehicles	0.4824	0.5751	0.6506	0.7167	0.8198
Transport Equipment	0.1846	0.2764	0.3705	0.4652	0.6355
Furniture	0.2071	0.3177	0.4123	0.5049	0.6669
Jewellery	0.2191	0.4225	0.5130	0.5970	n/a[#]
Mean	**0.3444**	**0.4502**	**0.5356**	**0.6146**	**0.7559**
	(*n* = 89)	(*n* = 88)	(*n* = 88)	(*n* = 88)	(*n* = 88)

Note: Technical efficiencies were computed using the expression in equation (7.60) p.201, based on the method derived by Battese, Coelli and Colby (1989) (referred to as Model 8.4 in this chapter (p.212)) for the pre-crisis period and Battese and Coelli (1992) for the post crisis period (referred to as Model 8.2 in this chapter (p.211)).

Hence, given the specifications of Model 8.4 (Battese, Coelli and Colby (1989)) for the pre-crisis period, and Model 8.2 (Battese and Coelli (1992)) for the post-crisis period, the technical efficiencies of the industries together with the estimated mean technical efficiencies are calculated according to equation (7.60). The values obtained are presented in Table 8.6. The mean efficiency in the pre-crisis period is 0.3444. It increased significantly in the post-crisis period to 0.4502 in 1998, 0.5356 in 1999, 0.6146 in 2000, and 0.7559 in

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[#] Data is not available for that period, thus, no values of technical efficiencies are calculated

2002. Twenty industries, out of the total 24[8], showed an increase in efficiency in the immediate year post crisis, which is in accordance to the preliminary results from the exploratory data analysis reported in section 8.4. Only 4 industries, namely, industry 9 - the publishing and printing industry, industry 10 – the coke, petroleum and nuclear industry, industry 14 – the basic metals, and industry 16 – the machinery and equipment industry, displayed a decrease in efficiency in 1998 when compared to the pre-crisis period. Nevertheless, most of them, except industry 10, picked up in efficiency, and reached a higher level of efficiency in the later years (the reason for such performance of industry 10 was already discussed in Chapter 6, and earlier in Section 8.4 of this chapter).

8.6 Implication of the Results

Comparing the results from this chapter to those from the OLS model in Chapter 6, it is obvious that there have been many improvements in the depth of the findings. The coefficient estimates of inputs β_1 and β_2 are still in accordance with those in Chapter 6, indicating the structural shift from labour-intensive in the pre-crisis period to the capital-intensive in the post-crisis period. However, there are some additional, more 'in depth' findings that only become apparent when the assumption of full efficiency in the production process, made in the ordinary least square estimates, is relaxed. Firstly, since the stochastic frontier allowed the technical inefficiency to exist, the level of the technical inefficiency could then be estimated from such model. Secondly, the model could be tested for the time varying effects, which would indicate whether or not there are changes in the technical progress in those time periods of study. And thirdly, if technical progress does exist, then it would be possible to estimate its progress over time.

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[8] A list of industry names is provided in the Appendix A.

The results from Model 8.4, the stochastic production frontier with time-invariant and non-negative truncated normal distribution technical inefficiency component suggested by Battese, Coelli and Colby (1989), indicate that during the seven years from 1990 to 1996 in the pre-crisis period, the manufacturing sector of Thailand experienced no technical improvement as the null hypotheses that involved the time varying parameter $\eta = 0$ could not be rejected. Thus, the technical inefficiency was time-invariant. In addition, the sector was labour intensive as the estimate of the labour coefficient was 0.5625, much higher when compared to the estimate of the capital coefficient, which had the value of only 0.2813. Moreover, the sectors mean efficiency level was considerably low, at only 0.3444, with many industries scoring less than 0.2, including industry 6, 7, 20 and 22.[9]

Prior to the crisis in July 1997, Thailand had enjoyed a sustained and high growth rate, with an average growth of 9.49 percent per annum. The investment level in the country had also been sizeable; the capital stock growth in the manufacturing sector during a decade from 1986 to 1996 was as high as an average of 14.0 percent per annum. The growth rate of domestic firms' assets was 22.5 percent and 14.9 percent, between 1994 and 1995 and between 1995 and 1996, respectively.[10] With such an extensive investment in capitals and assets, one would expect to find empirical support for a model that involves a positive time varying parameter, η, which would suggest shifts in the production frontier, therefore indicating improvements in production technology. However, by considering the interest rate factor, the explanation for such a model becomes more apparent. During the early 1990s, Thai economy was growing at a favourably rate, hence, investors flooded the country with further investments. Consequently, the country's national savings fell short of financing the countless investment projects, driving the domestic saving rate to a very high level[11]. Combined with the policy of the Bank of Thailand (BOT) of the time, in order to attract capital inflow into the country, the interest rates were kept at a very high level.

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[9] A list of industry names is provided in the Appendix A.
[10] National Development and Social Board, NESDB, Thailand
[11] Jitsuchon, (2002)

During 1994 and 1995, the domestic fixed saving rate was so high that it reached more than 14 per cent per annum. Therefore, it is certain that the majority of investment projects would not generate sufficient returns to service debt at such a high level of interest rate. Thus, many of these loans were channelled into risky projects in highly cyclical sectors (such as real estate and the stock market), rather than into the manufacturing sector. As a result, non-productive investment expanded dramatically. In Bangkok, the amount of new office space quadrupled between 1994 and 1997[12]. To worsen the situation, many of the investments that did go into the manufacturing sector appeared to have been allocated inefficiently. Hence, despite the average capital stock growth of 14.0 per cent per annum during the 1986 to 1996, the contribution to the growth of economy was only 2.1 per cent per annum.[13] It was also reported (Dollar *et al.* (2000)) that about two-thirds of the total investment made in the manufacturing sector during 1994 to 1997 was in machinery and equipment, and one-third was in plants and land. Thus, a large fraction of manufacturers in Thailand were reported to have owned unnecessary spacious plants and offices.

On the labour side, compared to the relatively high investment cost during the late 1980s and the beginning of 1990s, unskilled labour was fairly abundant and inexpensive in Thailand[14]. However, with the rapid expansion the economy experienced the early 1990s, demand for goods and services increased considerably. However, without a sufficient level of investment in the manufacturing sector, the pressure from the increase in demand fell solely on the labour market. Wages were rising very rapidly between 1990 and 1997, at an annual rate of 4.6 percent for those with secondary school and lower education level, and at 7.0 percent for those with university degrees[15]. This tight labour market situation played a significant role in the labour-intensive manufacturing sector of Thailand, and was blamed for contributing to the economic collapse of 1997.

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[12] Dollar and Hallward-Driemeier, (2000)
[13] National Development and Social Board, NESDB, Thailand
[14] Laplamvanit, (1999)
[15] Dollar and Hallward-Driemeier, (2000)

The post-crisis results suggest that in the five immediate years after the crisis, the manufacturing sector of Thailand had shown signs of a structural shift from labour intensive to capital intensive production. The capital coefficient, β_1, increased from 0.2813 in the pre-crisis period to 0.5022, while the labour coefficient, β_2, declined from 0.5625 to 0.2064. It is interesting to see that there is evidently a switch of the dominance between capital and labour in the pre- and post-crisis periods. In addition, the value of η in the post-crisis period is significantly differ from zero, and takes a positive value, suggesting that efficiency in this model is time varying, and that there was a general advance in the technology used in this sector over the post-crisis years. The mean efficiency levels were higher in the post-crisis period compared to the pre-crisis, and were increasing over the years, from 0.3444 in the pre-crisis period, to 0.4502, 0.5356, 0.6146, and 0.7559 in 1998, 1999, 2000 and 2002, respectively.

From these results, the adjustment in the structure of the manufacturing sector between the pre- and post-crisis period are seen to have been considerable in terms of its speed and intensity. One common explanation for such an improvement in performance of the post-crisis economy would have its root in the so-called 'shakeout' process[16]. Generally, immediately after an economic crisis, with its large and rapid reduction in demand, downward pressures would be placed greatly on the levels of prices. Thus firms would be forced to compete with each other in producing products (very often homogenous products) at the lowest possible cost[17]. Firms that are less able in doing so would be pushed out of the business, and this shakeout process would continue until all the less productive firms have been forced to exit the industry[18]. Many factors determine the firms' ability to endure the shakeouts. These include the cost of production, advancement in R&D, brand loyalty, experience in the industry, progression in technology, and allocative as well as technical efficiency. Firms with higher cost of production would be less able to adjust to the

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[16] Low, (2000)
[17] Utterback and Suárez, (1993)
[18] Jovanovic and MacDonald, (1994)

downward pressures of price, as well as firms with low brand loyalty would have to rely solely on lowering price in competing. Poorer technology, lesser allocative and technical efficiency would result in higher production cost, with this affecting firms' competitiveness. Hence, the overall performance of the crisis affected economy could tend to improve in the post-crisis period after the shakeouts. Therefore, this would explain the occurrences seen from the post crisis results shown earlier. In sum, the economic crisis in 1997 could have triggered shakeout in the manufacturing sector of Thai economy, and played an important role in the selection process, where only firms with a better foundation would survive, resulting in a positive reformation of the economy as a whole. This, therefore, created the sound foundation for the next phrase of growth of the economy that could be expected to be healthier and more sustainable.

Unfortunately, there has not been any direct collection of evidence on the shakeout of Thai manufacturers for the post-crisis period. However, the total number of establishments, as well as the number of establishments that ceased operation, could provide some general guide on this issue. The total number of establishments in the manufacturing sector of Thailand that involved more than 10 persons engaged in the operation had declined from 23,677 in 1996 to 20,807 in 1998; and then declined further to 20,794 in 1999, and 20,608 in 2000, accounting for 12.12, 12.18 and 12.96 percent reductions, when compared to the 1996 pre-crisis level, respectively (see Table 8.7a). These figures imply that some establishments had been effected by the crisis and hence had been forced out of businesses. This can be explored further by looking at the figures for the entry and exit of establishments. Unfortunately, there is no such official data collected by the National Statistics Office. Fortunately, it has been possible to acquire unpublished data collected by the Ministry of Commerce, Thailand, on the number of firms in the manufacturing sector that ceased, as well as launched, operations in each year. The data, however, are not strictly comparable as they comprise a wider set of firms than the data of Table8.7a. Specifically the new data include micro-firms (i.e. firm with less than 10 persons

engaged in the business). An advantage of this set of data is that it is considered to be very

reliable, as it is gathered for taxation purposes. The new data is presented in Table 8.7b

below.

Table 8.7a: Number of establishment in the manufacturing sector of Thailand with more than 10
persons engaged in the business.

Period	Number of Non-Micro Establishments
1996	23,677
1998	20,807
1999	20,794
2000	20,608
2002	20,216

Source: Annual Manufacturing Industrial Survey, National Statistic Office, Thailand

Table 8.7b: Number of establishments in the manufacturing sector that ceased and launched
operations (including both micro- and non micro-firms)

Period	Establishments that ceased operation	Establishments that launched operation
1994	352	3,930
1995	446	4,028
1996	479	3,885
1997	607	3,046
1998	925	2,346
1999	742	2,937
2000	763	3,599
2001	1,116	3,962
2002	1,695	5,250

Source: Ministry of Commerce (Thailand)

It can be seen from the figures in Table 8.7B that there was indeed an increasing

trend in the number of firms that ceased operation in the immediate aftermath of the crisis.

The number of firms that ceased operation in the pre-crisis period was 352 firms in 1994,

increased to 446 firms in 1995, and to 479 firms in 1996. These figures shot up markedly in

the post-crisis period. Thus, the number of firms that ceased operation in 1997 was 607 and

this then rose drastically to 925 in 1998. The situation improved in 1999 and 2000, with 742

and 763 firms ceasing their operations, respectively. Nevertheless, the crisis has proven to

have a long-standing effect, for the number of firms that ceased operation shot up once

again in 2001 and 2002. The increase in the number of firms that ceased operation in the

post-crisis period may well have led to the observed improvement in post-crisis efficiency,

as firms with low efficiency were pushed out of the business, leaving the sector (an average) with better overall efficiency.

When looking at the figures on the number of establishments that launched operations, it can be seen that there was a drop in the number of firms launching operations in the immediate post-crisis period. The number of firms that launched operations in 1997 dropped from 3,885 in 1996 to 3,046, which implies that people were put off from investing in an economic situation of crisis. This figure declined further in 1998, as the Thai economy was facing a severe problem of 'credit crunch', with just 2,346 firms launching operation. The situation improved from 1999 onward as the economy started to show some improvement in performance and the government of Dr. Thaksin Shinawatra, who came into office in February 2000, imposed several effective economic stimulation packages. One thing that can be seen in the figures (on the number of establishments that launched operations) is that although there has been some drop in numbers, post-crisis, the overall level of establishments was fairly steady. One explanation may be that these figures include micro-firms, as well as non-micro firms. Micro-firms typically have low capital requirements for becoming established, and hence are not likely to have been much affected by the credit problem, post-crisis. This increase in the number of newly established firms could also have contributed to the efficiency improvements which occurred post-crisis. These newly established firms will tend to have higher efficiency than the existing ones, as a result of adjustments in financial markets (which will be discussed later in this section, see p.237), and hence they will have raised the hurdle of efficiency in the manufacturing sector.

The 1997 economic crisis had intensely affected the Thai economy. Severe adjustments had been experienced among most sectors during the initial post-crisis period. The economic growth data had recorded contractions, industrial sectors were left with excess capacity, employment declined, overall consumptions slumped, financial markets were faced with a liquidity crunch, and the currency drastically depreciated. However, among all these adjustments, one important point to notice was that the real wage rate

remained quite stable for the entire period, and this was especially so in the unskilled labour market [19] . Commonly, wage adjustment is one of the most important adjustment mechanisms at play during economic downturns. In particular, this applies when there is an absence of labour unions to impose wage rigidity. However, as revealed in the earlier section, the study of Thai labour market indicated that the impact of the crisis was less in terms of labour price adjustment, compared to quantity adjustment[20]. Unemployment in the manufacturing sector increased by more than 200 per cent in 1999, comparing to 1996, while the real monthly wage only decreased by 5.46 percent in the same period. Aside from the growth in unemployment, there was also a huge increase in underemployment, amounting to 343.78 per cent from 1996 to 1999. The possible explanation for this phenomenon lies in the existence of the minimum wage regulation imposed by Thai labour law. The minimum wage rate had not been altered during the adjustment period, and since the majority of labour in the manufacturing sector was unskilled and received wages very close to this minimum rate, the flexibility of labour price adjustment was somewhat limited[21]. Therefore, this left the labour market adjustments to come about through quantity adjustment, not price adjustment. This reduction in labour employment could have been one factor resulting in the shifting of the manufacturing sector from being labour intensive to being capital intensive.

Combined with the fact that after the IMF eased its monetary measures in August 1998, domestic interest rates had declined radically. The one-year fixed saving rate dropped from 12 percent per annum in late 1996 to less than 2 per cent, while the interbank rate plunged below 5 percent for the first time in November 1998. Therefore, the post-crisis relative price between labour and capital changed considerably. Thus, the real wage rate remained rather stable, while interest rate declined to a great extend, and thus the relative price (and thus, cost) of labour became more expensive, creating a great incentive for

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[19] Behrman, Deolalikar, and Tinakorn, (2001)
[20] Behrman, Deolalikar, and Tinakorn, (2001)
[21] Paitoonpong, (2002)

manufacturers to substitute capital for labour. Hence, this explain, partly, the shifting of the manufacturing sector from labour intensive to capital intensive production, as seen from the results presented earlier.

The fourth factor affecting the reconstruction of the post-crisis Thai economy could have been the healthier investment behaviour within the private sector. As discussed earlier, in the pre-crisis period, the Thai economy was dominated by speculative behaviours, and this, contributed to creating bubbles in real estate and stock markets. Although the private investment level was extremely high, much of it was concentrated on the unproductive sectors[22]. Vines and Warr (2003) suggested that high interest rates had brought about investment in speculative sectors, since they were almost the only sectors that could create sufficient returns to cover such high costs of investment.

Table 8.8: Private Investment Index (1995 based year, million baht or as stated)

Year	Private Investment Index	Domestic Cement Sales	Domestic Machinery Sales
1995	100.0	33,034	162,946
1996	95.0	37,082	192,712
1997	66.4	36,002	239,164
1998	31.8	20,633	262,866
1999	34.0	18,700	276,334
2000	41.7	18,020	319,447
2001	41.4	19,048	343,653
2002	50.2	23,020	331,142

Source: Bank of Thailand (BOT)

Table 8.8 presents the private investment index, as well as, the level of investments in some sectors. It is clear from the figures that the overall investment level declined significantly in the post-crisis period. Using 1995 as the based year, private investment declined from 95.0 in 1996 to 66.4 in 1997, and declined further to just 31.8 and 34.0 in 1998 and 1999, respectively. This reduction in investment comes without surprise considering the economic situation during that time. Immediately after the crisis in July 1997, the IMF imposed tight fiscal and monetary policies for Thailand. In addition, 58 financial institutions and 4 commercial banks were suspended. As a result, panic spread

[22] Doner and Ramsay, (1999)

across the financial sector, causing the interest rates to shoot up severely. To make matter worst, because of the crisis, Thailand faced a massive capital outflow within a very short period of time. Thus, severe cases of credit crunch and non-performing loans were experienced in all sectors, pushing the interest rates up even further. By December 1997, the interbank rate was at 21.73 per cent, and stayed at the two digits level until the IMF eased its policies in August 1998.

Nonetheless, one benefit that the Thai economy picked up from this financial crisis was the reformation of financial market structures. Before the crisis, financial institutions would make decision on loans based on collaterals (such as land) offered by borrowers[23]. As the price of real estate was growing at such a tremendous rate, this collateral served as a very secure guarantee for loans. However, after the crisis, real estate price declined immensely; and banks had to resort, instead, to investment project analysis for their decision making[24]. Therefore, loans would then be made only to those most productive investments, for which the highest rates of return were expected. Hence, this improved the chance of good manufacturers in getting access to loans, compared to the pre-crisis period.

Also, in late 1998s, interest rates dropped to a very low level compared to the pre-crisis period. This enhanced the ability of manufacturers to obtain loans, as now, unlike in the pre-crisis period, a reasonably good investment would be sufficient to attract a loan, which could be serviced by the interest reduction discussed above. Hence, it is not surprising to see that, despite the significant declined in the private investment index, there was a considerable increase in domestic machinery sales, from 192,712 millions Baht in 1996 to 239,164 millions in 1997, 262,866 millions in 1998, and 276,334 millions in 1999. This growth in machinery sales was in accordance with the demand to increase productivity capacity in some industries, especially those related to exports (such as electronics,

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[23] Warr and Nidhiprabha, (1996)
[24] Vines and Warr, (2003)

integrated circuits, and televisions set), which grew considerably post-crisis[25]. Therefore, this, again, supports the increase in the output estimate of the capital coefficient seen from the post-crisis analyses. One other figure that is worth mentioning here is the reduction in investment projects in the real estate sector, which was reflected in the domestic cement sales (figures in Table 8.8). The domestic cement sales index declined considerably in the post-crisis period, from 37,082 millions Baht in 1996 to only 20,633 millions in 1998, and declined further in 1999 and 2000. This reflected the sluggish condition in the real estate sector, as there were not yet many new building projects being invested in, due to the great excess supplies left in the economy from the pre-crisis period[26].

Consequently, it is fair to argue (based on these figures) that one of the reasons leading to the improvement in post-crisis technical efficiency might have resulted from the increase in productive capital investments, such as machinery and equipment. Such argument is also supported by the finding in Chapter 6, Section 6.4, in which the finding from the graphical exploratory data analysis suggested that there was an increase in the usage of the more productive capital, hence, raised the gross output over capital expenditure, GO/CE, ratio. On the other hand, the pre-crisis efficiency level suffered greatly from the unproductive investments, hence, leading to the declining competitiveness in Thai manufacturing sector, and consequently, building up the foundation for the 1997 economic crisis. However, the issue concerning the productive investments will be examined in more details later in Chapter 9, where several forms of capital investment will be analysed in order to determine their effects on the sector's efficiency.

The final explanation for the adjustment in the manufacturing sector lay in the effects of government policies during the post-crisis period. In the immediate post-crisis period, not many economic stimulus policies could be imposed, due to the IMF's austere attitude toward the recovering of the economy. It was not until mid 1998 that the IMF

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[25] Bank of Thailand (2001)
[26] Bank of Thailand (2001)

started to realize the possible mistakes of the policies it had imposed[27], and thus, relaxed its attitude on economic stimulus. The Thai government was then allowed to run budget deficits, and the looser monetary policies were then also becoming more acceptable. Taking this opportunity, the government of Thailand at the time quickly reacted to this change by implemented many industrial measures, focusing on solving problems of the production structure, and on enhancing competitiveness.

The first and foremost measure was to establish industry development institutes in order to enhance efficiency and competitiveness in the development of domestic industries in the long term[28]. These development institutes were considered as being of prime important to the development and improvement of the Thai economy, as the nature of the Thai manufacturing sector was comprised mainly of small and medium size enterprises (accounting for around 90 percent of the total number of establishments). Small and medium sized firms in Thailand were generally facing one common problems of lacking sufficient funds, and the ability to carry out useful research and development. Therefore, in July 1998, the Cabinet approved the establishment of two industry institutes, namely, the Automobile Institute and Electricity and Electronics Institute. Later in September of the same year, the Cabinet further approved the establishment of National Research and Development Institutes for Precious Stones and Ornaments, and then, for the Iron and Steel Institute of Thailand in December 1998. Later on 5th April 1999, the Cabinet approved the establishment of a Development Institute for Small and Medium Enterprises, as well as the establishment of the Microelectronics Technology Research and Development Centre, in April 2000.

Apart from these industry development institutes, two major economic stimulus packages were imposed, one in March 1999 and another in February 2000. In 1998, the Thai GDP contracted by 8 per cent, greatly affecting all segments of the society. Many

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[27] Stiglitz (2000)
[28] Poapongsakorn and Tangkitvanich, (2000)

businesses experienced severe difficulties as a result of the sharp contraction in demand, as well as the increase in their obligations (e.g. debt servicing). Non-performing loans (e.g. to stave off cash flow crises) increased sharply. This resulted in instability among financial institutions, which, in turn, affected credit intermediation to the real sector. Thus, private investment declined steadily, unemployment increased, incomes shrank, therefore, leading to widespread social ills. The Thai government carried out a substantial economic stimulus package by applying three externally sourced loans, with funds totalling of 1,450 million US dollar from the Overseas Economic Cooperation Fund (OECF), the Japanese Export-Import Bank (J.EXIM Bank), and the International Bank for Reconstruction and Development (IBRD)[29]. These loans were then used to support the expansion of public expenditures, as well as to fund the tax measures. The public expenditure measures were carried out, with one of the main objectives being stimulating the economy through productive investment[30]. Improvement in the competitiveness of manufacturing industries was the prime interest, and this was achieved through the assistance in the development of technology by the public sector through industry development institutes. As for the tax measures, they were directed at increasing the disposable incomes of individuals, thus stimulated private consumptions and in turn increased incentives for private investment. For this reason, the following tax measures were undertaken[31]: 1) the exemption of the first 50,000 Baht of net income from the personal income tax, 2) the reduction of the Value Added Tax (VAT) rate from 10 to 7 per cent, and 3) the elimination of the VAT of 1.5 per cent on gross revenue for small enterprises with sales between 600,000 and 1,200,000 Baht. It was believed (Poapongsakorn and Tangkitvanich, (2000)) that these economic stimulus measures would turn around the economy, and at the same time, would build up a more productive manufacturing sector.

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[29] Nukul's Commission Report, (1998)
[30] Poapongsakorn and Tangkitvanich, (2000)
[31] Poapongsakorn and Tangkitvanich, (2000)

The new government led by Dr. Thaksin Shinawatra, came into office in February 2000 and imposed a vast economic stimulus package covering all areas of society. Regarding the manufacturing sector, several policies were implemented, with the aim being to facilitate the restructuring, as well as the improvement, of the sector's productivity. Firstly, fifty nine industrial development projects were approved under the phrase II Industrial Restructuring Plan (2000 – 2004). The plan focused on upgrading Thailand's competitiveness through a set of strategies including allocating soft loans to 13 sectors, dispatching experts to provide technical assistance, and establishing funds and government organizations to support industrial development. Secondly, the master development plan of small and medium sized enterprises was introduced. The Ministry of Industry would act as the main coordinator, and would jointly devise the action plan with the involvement of both public and private sectors in order to promote SMEs. This included financial assistance given to SMEs through the SME promotion Fund, to provide soft loans to SMEs for business start-ups and upgrading. Independently of this bill, the Ministry of Finance initiated a package of financial support for SMEs, including an allocation of nearly 1 billion US dollar of credit for SMEs, through specialised financial institutions and the Bank of Thailand. Also, it established a 1 billion US dollar Venture Capital Fund, financed by structural adjustment loans from the World Bank, to invest in SMEs. Furthermore, the government also set up the Market for Alternative Investment (MAI), a special stock market with less stringent listing rules for SMEs[32].

Finally, the Cabinet approved, in July 2000, a comprehensive reform of the tariff structure to enhance industrial competitiveness and to meet international commitments. This reform focused on cutting tariffs on capital goods (i.e. machinery, mechanical appliances and parts, and electrical machinery equipment and parts), and on raw materials. It was expected that these measures would directly benefit manufacturers in a wide range of industries. The reduction in tariffs on capital goods would lower production costs for all

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[32] Poapongsakorn and Tangkitvanich, (2000)

sectors. At the same time, the removal of the import duty surcharge would reduce the degree of protection, and encouraged more efficient resource allocation.

Therefore, considering all policies mentioned above, it is reasonable to conclude that, although some stimulus measures might not perform so well as the others, these policies had, by various means, contributed to the structural change, as well as to the improvement in efficiency in the post-crisis Thai manufacturing sector, as suggested earlier by evidence in this chapter.

8.7 Conclusion

This chapter provided answers to the main research questions posed in Chapter 1. These research questions were sharpened to just two major concerns in Section 8.1. The first concern was with *what happened to Thai manufacturing sector in the post-crisis period compared to pre-crisis?* The econometric analysis suggests that the 1997 economic crisis had affected the Thai manufacturing sector in several ways. Firstly, the results of the output coefficient estimates of inputs showed that there exists a structural change in the manufacturing sector of Thailand from labour intensive in the pre-crisis period to capital intensive in the post-crisis period. Secondly, the overall efficiency of the sector had been improved in the post-crisis period, comparing to the pre-crisis overall efficiency level. And thirdly, the post-crisis period exhibited some technical efficiency change from year to year, indicating that the sector was becoming more attentive in improving its productivity, as compared to the pre-crisis period, which shows no sign of technical efficiency change.

The second main concern was *what factors led to the observed differences between the productivity of the two periods?* One possible reason for such transformation could have come from the shakeout process, in which the economic crisis led to a sharp decline in demand and, thus, to a more stringent competitive environment. Firms with less efficiency

would not be able to compete in these surroundings, and would be driven out of the business. The post-crisis economy was, then, left with only those highly productive manufacturers, therefore resulting in an improvement of the overall efficiency level. The second possible explanation might have come from real wage rigidity in the Thai labour market. In the post-crisis period, real wage level had not been reduced as much as one would expect, given the severity of the crisis. Adjustment in the labour market had been channelled through quantity (rather than price) adjustment. Thus, the number employed in the manufacturing sector declined rather significantly. Therefore, the shift towards higher capital intensity sector could partly be explained.

Another possible explanation for this structural shift could also be justified by the sharp decline in the post-crisis interest rates. After the ease of monetary measures in August 1998, domestic interest rate levels had declined radically. Combined with the rigid real wage, the relative price of capital, compared to labour, fell considerably, and, thus, capital was substituted for labours in many production processes. Unsurprisingly, the manufacturing sector displayed this trend towards greater capital intensity in the sector.

Furthermore, as a result of the decline in domestic interest rates, as well as the forced restructuring in the financial market by the IMF, domestic private investments were guided toward the more productive sectors, including the manufacturing sector. Financial institutions were no longer issuing loans to speculative and non-productive investment projects. Thus, the productive manufacturers' ability to access loans was enhanced. As a result, the overall productivity of the sector was improved.

Finally, the highly-favoured government policies (including the two economic stimulus packages) had played a major role in the improvement of the sector's productivity level. The Thai government had expressed prime concern in improving research and development in small and medium size enterprises, which represent the majority of firms in the sector. Many industrial development institutes were established with public funding, in order to promote the productivity and efficiency of those particular industries. Moreover,

many other policies were also implemented. These included measures such as lowering import tariff for capital goods, cutting income, as well as, value added taxes, and more importantly, providing soft loans for SMEs, in order to stimulate business start ups and upgrading.

Chapter 9 – Technical Efficiency Effects Models

9.1 Introduction

The purpose for this chapter is to examine one important issue raised in Chapter 6 and Chapter 8 concerning the effects of the capital investments on efficiency level. The results from Chapter 8 suggested that one of the reasons leading to a significant improvement of the post-crisis efficiency level in Thai manufacturing sector was the higher level of post-crisis investment in productive capital. The stochastic frontier production function, employed in Chapter 8, has also postulated the existence of technical inefficiency in the production process for producing a particular output; *if inefficiencies indeed exist and vary across producers or over time, there must exist some specific variables that affect such variations*. Therefore, the analysis of productive efficiency would not be completed without an examination on those variables that characterize the variation in producer performance.

These variables may influence technical efficiency in many ways; they could influence the structure of the technology by which conventional inputs are converted to outputs; or they may influence the efficiency with which inputs are converted into outputs[1]. Examples include the degree of competition, size of the firm, managerial experience, and ownership characteristics. There have been many attempts in incorporating these explanatory variables into the efficiency measurement models in a variety of ways, some more appropriate than the others, including Pitt and Lee (1981), Sickles, Good, and Johnson (1986), Deprins and Simar (1989a, 1989b), Kumbhakar, Ghosh and McGuckin (1991) and Reifschneider and Stevenson (1991), Bauer and Hancock (1993), Berger, Hancock, and Humphrey (1993), Huang and Liu (1994), Battese and Coelli (1995), and Berger and Mester (1997).

In this chapter, the relationship between capital investments and technical efficiency will be carefully examined. Several renowned models, linking efficiency with explanatory variables will be discussed, including their innovations as well as their limitations. The development of these models is examined in section 9.2, starting from the early literatures, in which these variables are assumed to influence the performance of firms directly through the influence on the structure of the production frontier, through to the two-stage approach, in which the explanatory variables are incorporated into the efficiency model, but are assumed to have no direct influence on the structure of the production frontier; and finally, concluding with the development of the single-stage approach models, in which the inefficiency component is assumed to be distributed independently, but not identically, and the parameters of the stochastic frontier and the inefficiency model are estimated simultaneously. Also, in Section 9.2.3 it surveys some recent empirical studies. Section 9.3 considers the specifications of the model that will be used later in the analysis of Thai manufacturing industry. The empirical results from this model are then presented in section 9.4. These results will then be discussed in details in section 9.5. And finally, conclusions will be reached in section 9.6.

9.2 Technical Efficiency Effects

In the early studies in which the issue of the explanatory variables were investigated, these variables are assumed to influence the performance of firms directly, through the influence on the structure of the production frontier. Pitt and Lee (1981), Sickles, Good, and Johnson (1986), and more recent studies, including Bauer and Hancock (1993), Berger, Hancock, and Humphrey (1993), and Berger and Mester (1997), are among those who follow this approach. The production frontier then takes the form of

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[1] Kumbhakar and Lovell, (2002)

$$\ln Y_i = \ln f(x_i, z_i; \beta) + V_i - U_i \qquad\qquad (9.1)$$

where $z = (z_1, ..., z_q)$ is a vector of explanatory variables that influence the structure of the production process by which inputs x are converted to output Y, and $\ln f(x_i, z_i; \beta)$ is the deterministic kernel of the stochastic production frontier $\ln f(x_i, z_i; \beta) + V$. In such a model, the parameter vector β to be estimated now includes both technological parameters as well as environmental parameters.

This model here has exactly the same structure as a conventional stochastic production frontier, discussed in the previous chapter, and all the estimation techniques expand upon those in the conventional models. However, with the assumption of independently and identically distributed error terms, U_i and V_i, the elements of z_i, as well as x_i, are assumed to be uncorrelated with each of these disturbance terms. Thus, these explanatory variables influence the performance of firms, not by influencing their efficiencies (of which they are assumed to be uncorrelated), but by influencing the structure of the production frontier bounding the relationship between inputs and outputs. Therefore, what is accomplished by this formulation is merely a more accurate characterization of production possibilities, and consequently, entails more accurate estimates of producer efficiencies.[2] Even so, a main concern of this formulation, namely the source of the variation in efficiency, remains to be explained.

9.2.1 Two-Stage Approach

Another approach, attempting to incorporate the explanatory variables into the efficiency model, has been developed utilizing the two-stage estimation procedure. In the first stage, a stochastic frontier $\ln Y_i = \ln f(x_i; \beta) + V_i - U_i$ is estimated, typically by the maximum likelihood estimation technique, under the usual distributional assumptions of identically and

independently distributed variates V_i, and U_i. The estimated efficiencies are then regressed against the explanatory variables in the second-stage regression of the general form

$$E\left(U_i \middle| V_i - U_i\right) = g\left(z_i; \delta\right) + w_i \tag{9.2}$$

where w_i is distributed independently and identically with $N(0, \sigma_w^2)$, and δ is a parameter vector to be estimated.

In this two-stage approach, it is hypothesized that the explanatory variables, z_i, influences the output, thus, the performance, of the firms indirectly through its effects on firms' efficiency. Technically speaking, these explanatory variables do not influence the structure of the production frontier, but instead, influence the efficiency with which producers approach the production frontier. Therefore, the elements of z_i are correlated with U_i if z_i have, indeed, effects on firms' efficiency. Unfortunately, this is obviously contradicted by the assumption of identically distributed U_i made in the first-stage in which $E(U_i)$ is a constant and is $= \left(2/\pi\right)^{1/2} \sigma_U$, while in the second-stage, it becomes $E\left(U_i \middle| V_i - U_i\right)$ which is varied with z_i, as shown in equation (9.2).

Moreover, this approach also suffers from another econometric problem, namely that since it must be assumed that the elements of z_i are uncorrelated with the elements of x_i, the maximum likelihood estimates of β, σ_V^2, and σ_U^2 are biased due to the omission of the relevant variables z_i in the first-stage estimation of the frontier. Consequently, the estimated efficiency obtained from the second-stage regression would also be biased, as it is estimated with a biased representation of the production frontier.

9.2.2 Single-Stage Approach

In order to overcome the drawbacks of the two-stage approach, Deprins and Simar (1989a,

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[2] Kumbhakar and Lovell (2000), pp.263

1989b) suggest a production frontier with

$$\ln Y_i = \ln f(x_i; \beta) - U_i \tag{9.3}$$

$$E(U_i | z_i) = \exp\{\delta' z_i\} \tag{9.4}$$

where β and δ are the technological and environmental parameter vectors to be estimated, and $\exp\{\delta' z_i\}$ expresses the systematic part of the relationship between technical inefficiency and the explanatory variables. Thus, the single-stage production frontier becomes

$$\ln Y_i = \ln f(x_i; \beta) - \exp\{\delta' z_i\} + w_i \tag{9.5}$$

where w_i is assumed to have zero mean and a constant variance. Also, w_i is not identically distributed since its support depends on z_i. This frontier model is nonlinear in the parameters and can be estimated by either nonlinear least squares, or by maximum likelihood estimation, if a suitable one-sided distribution for U_i is specified.

This approach is a very important improvement compared to the first two approaches mentioned. Firstly, it has achieved an explanation of efficiency, which is not a characteristic of the first approach, and further it provides an adjustment to raw efficiency scores, which reflects the nature of the operating environments in which they were carried out. Secondly, it has solved a problem left by the second approach, since the omitted variables and independence problems are avoided by incorporating the explanatory variables in a single frontier estimation stage. However, the major drawback of this approach is that it is based on a deterministic frontier model, which contains no symmetric error component to capture the effects of random noise in the production process.

Kumbhakar, Ghosh and McGuckin (1991) propose that a production frontier with random noise in the production process is introduced, through the error component V_i, so that

$$\ln Y_i = \ln f(x_i; \beta) + V_i - U_i \tag{9.6}$$

$$U_i = \delta' z_i + w_i \tag{9.7}$$

where the technical inefficiency term, U_i, is associated with the systematic component $\delta' z_i$

and a random component w_i. This therefore yields a single-stage production frontier model

$$\ln Y_i = \ln f(x_i; \beta) + V_i - (\delta' z_i + w_i) \tag{9.8}$$

However, because of the requirement that U_i has to be ≥ 0, w_i is required to be $\geq -\delta' z_i$,

which, in turn, should avoid imposing the condition that $\delta' z_i \geq 0$. Nevertheless, in order to

be able to derive the likelihood function, the restriction of $w_i \geq -\delta' z_i$, as well as a

distributional assumption of w_i and V_i, have to be imposed. To simplify this matter, they,

however, impose the distributional assumptions on U_i and V_i instead. They assume that V_i

is distributed with $N(0, \sigma_V^2)$ and that U_i has truncated normal structure, with variable mode

depending on z_i, $N^+(\delta' z_i, \sigma_U^2)$, which also do not require $\delta' z_i \geq 0$.

Reifschneider and Stevenson (1991), have formulated a model that can eliminate

the statistical problems that occur with this additive formulation in the Kumbhakar, Ghosh

and McGuckin (1991) model. They proposed a hybrid model that combines features of the

Deprins and Simar (1989a, b) model with features of the Kumbhakar, Ghosh and McGuckin

(1991) model. The technical inefficiency term is now defined as

$$U_i = g(z_i; \delta) + w_i \tag{9.9}$$

and the production frontier is, as equation (9.6), that:

$$\ln Y_i = \ln f(x_i; \beta) + V_i - U_i$$

The effects of random noise are captured by the error component V_i. The requirement that

$U_i = g(z_i; \delta) + w_i \geq 0$ is ensured by specifying a functional form for the systematic

component of inefficiency satisfying $g(z_i; \delta) \geq 0$, and also by assuming the distribution of

the random component of inefficiency w_i as $N^+(0, \sigma_w^2)$. Hence, the single-stage production

frontier becomes

$$\ln Y_i = \ln f(x_i;\beta) - g(z_i;\delta) + V_i - w_i \qquad (9.10)$$

The assignment of a one-sided distribution to w_i simplifies estimation of the model by eliminating the statistical problems with the additive formulation of Kumbhakar, Ghosh and McGuckin. However, this simplification does not come without cost, since the two conditions of $g(z_i;\delta) \geq 0$, and that w_i is *iid* $N^+(0, \sigma_w^2)$ are sufficient, but not necessary for $U_i \geq 0$. Also, the restriction of $w_i \geq 0$ has an interesting economic implication, for if $w_i \geq 0$, then $U_i \geq g(z_i;\delta)$, and thus inefficiency, U_i, is at least as great as the minimum possible inefficiency achievable in an environment characterized by the explanatory variables z_i. Hence, the function $g(z_i;\delta)$ in equation (9.9) can be interpreted as a deterministic minimum inefficiency frontier.

Huang and Liu (1994) proposed a model very similar to the Kumbhakar, Ghosh and McGuckin (1991) and Reifschneider and Stevenson (1991) models. With the same identification of the production frontier and the technical inefficiency relationship as those in Reifschneider and Stevenson (1991), they rearrange equation (9.10), so that

$$\ln Y_i = \ln f(x_i;\beta) + V_i - \left[g(z_i;\delta) + w_i\right] \qquad (9.11)$$

making it very similar to the model proposed by Kumbhakar, Ghosh and McGuckin (1991), (equation (9.8)), excepts that $\delta'z_i$ is replaced by $g(z_i;\delta)$. Therefore, the requirement that $U_i = \left[g(z_i;\delta) + w_i\right] \geq 0$ is met by truncating w_i below such that $w_i \geq -g(z_i;\delta)$, and by assigning a distribution to w_i such as $N(0, \sigma_w^2)$. Thus, instead of truncating a normal distribution with variable mode from below at zero as in Kumbhakar, Ghosh and McGuckin (1991), Huang and Liu (1994) truncated a normal distribution with zero mode from below at a variable truncation point $\left[-g(z_i;\delta)\right]$. This therefore allows $w_i \leq 0$, but enforces $U_i \geq 0$.

The essential novelty of this model lies in the fact that with the function $g(z_i;\delta)$ it is possible to introduce interactions between elements of z_i and elements of x_i. Thus, they

expand this function to

$$g(z_i, x_i; \delta) = \sum_q \delta_q z_{qi} + \sum_q \sum_n \delta_{qn} z_{qi} \ln x_{ni} \qquad (9.12)$$

The condition that has set the Huang and Liu (1994) model apart from all the other stochastic frontier models mentioned above is that they show that when the exogenous variables interact with the inputs, they can have non-neutral effects on technical efficiency, whereas all other variables assume that technical inefficiency is neutral, with respect to its impact on input usage.

Later in 1995, Battese and Coelli proposed a model that is essentially the same as that of Huang and Liu (1994), but with two exceptions. Firstly, their model is formulated within the panel data, rather than cross-sectional context. And secondly, they do not include inputs in their specification of $g(z_i; \delta)$. Their model, similar to those of Kumbhakar, Ghosh and McGuckin (1991), consists of the following specification:

$$\ln Y_{it} = \ln f(x_{it}; \beta) + V_{it} - U_{it}$$

$$U_{it} = \delta' z_{it} + w_{it} \qquad (9.13)$$

With the non-negativity requirement $U_{it} = \delta' z_{it} + w_{it} \geq 0$, the random variable w_{it} is defined by the truncation of the normal distribution with zero mean and variance σ_w^2, $N(0, \sigma_w^2)$, such that the point of truncation is $\delta' z_{it}$, i.e. $w_{it} \geq -\delta' z_{it}$. Thus, these assumptions are consistent with the distributional assumption that U_{it} is distributed as $N^+(\delta' z_{it}, \sigma_U^2)$. This formulation differs from that of Reifschneider and Stevenson (1991) in that the w_{it} are not identically distributed, and nor are they required to be non-negative. Further, the mean $\delta' z_{it}$ of the normal distribution is truncated at zero, to obtain the distribution of U_{it} where this variate is not required to be non-negative for every producer, so that $w_{it} \leq 0$ is possible in a relatively unfavourable environment.

The technical efficiency of the *i*th producer at the *t*th observation is, thus, given by

$$TE_{ti} = \exp\{-U_{it}\} = \exp\{-\delta'z_{it} - w_{it}\} \tag{9.14}$$

A predictor for this is provided by

$$E\left[\exp\{-U_{it}\}\middle|(V_{it} - U_{it})\right] = \left[\exp\left\{-\mu_{*it} + \frac{1}{2}\sigma_*^2\right\}\right] \cdot \left[\frac{\Phi\left[(\mu_{*it}/\sigma_*) - \sigma_*\right]}{\Phi(\mu_{*it}/\sigma_*)}\right] \tag{9.15}$$

where $\quad \mu_{*it} = \dfrac{\sigma_V^2(\delta'z_{it}) - \sigma_U^2(w_{it})}{\sigma_V^2 + \sigma_U^2}$ $\hspace{4cm}$ (9.16)

$$\sigma_*^2 = \frac{\sigma_V^2 \sigma_U^2}{\sigma_V^2 + \sigma_U^2} \tag{9.17}$$

This model by Battese and Coelli (1995) is one of the most commonly used models for evaluating the stochastic production frontier, when explanatory variables are being taken into consideration.

9.2.3 Recent Empirical Studies

Many recent empirical works have been conducted using the single-stage approach proposed by Battese and Coelli (1995). This section reviews a number of recent key contributions in order to provide illustrative examples for this approach mentioned in the previous section. Works that have been conducted in the manufacturing sector include Driffield and Munday (2001), who used three-digit data from the UK Censes of Production for the period of 1984 to 1992 to examine the determinants of technical efficiency in the UK manufacturing industry, focusing particularly on the role of foreign investment and spatial agglomeration of similar industry activities. Their results show that foreign ownership is a determinant of technical efficiency in the UK manufacturing industry, although the effect was found to be varying according to industry characteristics. In sectors that were relatively more productive and regionally concentrated, the effect of foreign investment was found to be higher.

As another example, consider the work of Battese et al. (2001) which used a stochastic frontier models in the study of technical efficiencies of firms in the Indonesian garment industry, in five different regions for the period from 1990 to 1995. The results showed that there were substantial efficiency differences among the firms across the five regions.

Uğur (2003) examined the technical efficiency levels in the Electrical and Optical Equipment industry in Irish manufacturing sector, and the factors that would affect these levels. They utilized the firm level panel data over the period from 1991 to 1999, and found that investment intensity and labour quality played an important role in explaining technical inefficiency levels. However, they found no significant relationship between export intensity and the technical inefficiency levels of individual firms in all but one sector.

Kneller and Stevens (2006) examined the two potential sources of inefficiency (namely, the differences in human capital and R&D) for nine industries in 12 OECD countries over the period of 1973 to 1991. They found that inefficiency in production does indeed exist and depends upon the level of human capital of the country's workforce. However, the evidence that the amount of R&D would affect the efficiency was shown to be less robust.

Apart from the works concentrated in the manufacturing sector, many empirical studies had also been conducted on the agricultural sectors. Examples include the work on the technical inefficiency of the Swedish lobster fishery by Eggert (2000), in which the level of, and determinants of, technical efficiency of Swedish demersal trawlers are analysed using a translog stochastic production frontier that included a model for vessel-specific technical efficiencies. This technical inefficiency effect was found to be highly significant in explaining the level of, and variation in, vessel revenues. This indicates that fishermen become more efficient, the longer they have been fishing, but that their vessels became less efficient when they became older, and finally, that the size of the vessel does not influence efficiency.

Coelli et al. (2003) applied a stochastic production frontier model to measure total factor productivity growth, technical efficiency change and technological change in Bangladesh crop agriculture for 31 observations from 1960/61 to 1991/92, using data for 16 regions. Their results revealed that technical change followed a U-shaped pattern, rising from the early 1970s. However, technical efficiency declined throughout. The combined effect of slow technical progress, dominated by the fall in technical efficiency, resulted in total factor productivity declining, with an increasing rate of decline. TFP change was shown to depend on 'green revolution' technology, and agricultural research expenditures.

Belloumi and Matoussi (2005) compared estimates of technical efficiency, obtained from the stochastic frontier approach for two samples of private and GIC farmers in Tunisia, which were characterized by a severe scarcity of water and a high degree of salinity. The technical inefficiency effects were modelled as a function of farm-specific socioeconomic factors, and environmental factors. The results showed that both systems were technically inefficient, but that the GIC farmers were technically less efficient, compared to the private ones, as they were more severely affected by water salinity.

These empirical examples provided very valuable illustrative examples for such a single stage approach developed by Battese and Coelli (1995), therefore, leading to a more accurate model specification which will be carrying out in the next section.

9.3 Model Specification

As stated earlier, the objective of this chapter is to examine a key issue raised in Chapter 8, concerning the relationship between the level of productive capital investments and the efficiency level. Ideally, in order to explore this, the data on each category of capital investment should be used as an explanatory variable in the technical efficiency effects model. Then the results of stochastic frontier estimation, both pre- and post-crisis, should

be compared. Unfortunately, such disaggregated data on capital categories were not available in the pre-crisis period. Therefore, an alternative method needs to be adopted. One way in which this difficulty could be solved is by testing the increase in capital investments against the inefficiency level in the post-crisis period. A negative relationship between the increase in a particular type of capital investment and the inefficiency level would imply that the improvement in the post-crisis efficiency level was, at some level, affected by the increase in that particular capital investment. And if it is possible to show that the increase in productive capital investments (i.e. in machinery and office appliance) has indeed had a negative effect on the inefficiency term, then it would verify the claim made in Chapter 8 that the improvement in the efficiency level was partly a result from the increase in investment in the more productive capitals.

Therefore, following Battese and Coelli (1995), the production frontier is assumed to take the form of the Cobb-Douglas production function, which can be expressed as

$$\ln Y_{it} = \beta_0 + \beta_1 \ln(K_{it}) + \beta_2 \ln(L_{it}) + (V_{it} - U_{it}) \tag{9.18}$$

where the technical inefficiency component is defined as

$$U_{it} = \delta_1 z_{1it} + \delta_2 z_{2it} + \delta_3 z_{3it} + w_{it} \tag{9.19}$$

Here, the technical inefficiency, U_{it}, is assumed to be influenced by the increase in capital investments in three major areas, i.e. land, machinery, and office appliances (in which land is assumed to proxy the unproductive, speculative capital investment[3], while machinery and office appliance are assumed to proxy the productive investment). This follows the method employed by Young (1995), in which capital input was divided into five categories, consisting of: residential buildings; non-residential buildings; other durable structures; transport equipment; and machinery. The addition to capital investment in land, z_{1it}, is measured by the ratio of the change in value of gross additions of land to the number of

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[3] Land is used to proxy the unproductive and/or speculative investment in this case, since, in the pre-crisis period, the Thai economy was characterized as being a 'bubble' economy, where many

employee. The addition to capital investment in machinery z_{2it} is measured by the ratio of the change in value of gross additions of machinery and equipment to the number of employee. And the addition to capital investment in office appliances z_{3it} is measured by the ratio of the change in value of gross additions of office appliances to the number of employees.

Therefore, the single-stage production frontier is estimated using the specification

$$\ln Y_{it} = \beta_0 + \beta_1 \ln(K_{it}) + \beta_2 \ln(L_{it}) - \delta_1 z_{1it} - \delta_2 z_{2it} - \delta_3 z_{3it} + V_{it} - w_{it} \quad (9.20)$$

and the technical efficiency of production for the ith industry at the tth observation is defined by

$$TE_{ti} = \exp\{-U_{it}\} = \exp\{-\delta_1 z_{1it} - \delta_2 z_{2it} - \delta_3 z_{3it} - w_{it}\} \quad (9.21)$$

The prediction of the technical efficiencies is based on the conditional expectation given by the model assumptions. The technical efficiency will take the value of one if an industry has an inefficiency effect equal to zero, and will be less than one otherwise.

Several parameters need to be tested, including the γ, δ_L, δ_M, and δ_{OF}. The variance-ratio parameter γ, as in the previous chapter, is important in determining whether a stochastic production frontier is a superior model, compared to the traditional average production function. If the null hypothesis $\gamma = 0$ cannot be rejected, the average production function would be a better representation of the post-crisis manufacturing sector, suggesting that no technical inefficiency is presented. The parameters δ_L, δ_M, and δ_{OF} indicate the effects of capital investment on technical inefficiency. If the null hypothesis of $\delta = 0$ cannot be rejected, then it suggests that particular capital does not have a significant effect on efficiency. Otherwise, the value of δ is expected to be negative if is it to improve the efficiency level of the production process, while on the other hand, a positive δ indicates

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manufacturers over-invested in the real estate sector, in order to benefit from the fast rate of price increase within it.

a reduction in efficiency. Tests of hypotheses on parameters can be performed using the generalized likelihood ratio test statistic defined by

$$\Lambda = -2[\ln(H_0) - \ln(H_1)]$$

This test statistic has approximately a χ^2 distribution, or a mixed χ^2 in the case that involves testing $\gamma = 0$, with degrees of freedom being equal to the difference between the numbers of parameters involved under the null and alternative hypotheses.

9.4 Empirical Results

The data set on the post-crisis manufacturing sector is estimated using the program FRONTIER 4.1, which uses equation (9.20) above based on the Battese and Coelli (1995) model. Three explanatory variables, including the addition to capital investment in land, machinery, and office appliance, are assumed to be influencing the efficiency of the industry's ability to convert inputs into outputs, and hence, affecting the production frontier indirectly. This model will, from here, be referred to as Model 9.6. The results from this estimation are presented in Table 9.1.

The estimation of the output elasticity of capital, β_1, and the output elasticity of labour, β_2, are in accordance to those estimated by the error components model in Chapter 8. The coefficient estimate of capital, β_1, is 0.5514, while it is 0.3003 for the coefficient estimate of labour, β_2. This suggests that the structure of the post-crisis manufacturing sector is capital intensive, once again confirming the results from the traditional average function discussed in Chapter 6, as well as the error components model in Chapter 8. The inefficiency coefficient estimate of the addition to land investment, δ_L, is 0.0017, indicating that the additional investment in land will result in a decline of efficiency, and hence to a deterioration in the sector's productivity. On the other hand, the inefficiency coefficient

estimate of the addition to machinery, δ_M, and of the addition to office appliances, δ_{OF}, are equal to -0.0000712, and -0.0012, respectively. These indicate that the additional investment in machinery, as well as in office appliances, will improve technical efficiency, and hence, the overall productivity of the sector.

Table 9.1: maximum likelihood estimates of the technical efficiency models for the post-crisis period

Variable	Parameter	MLE Estimates	
		Model 9.6	Model 9.7
Constant	β_0	4.1578	4.0997
		(1.0877)	(0.9060)
Ln Asset	β_1	0.5514	0.5447
		(0.1466)	(0.0911)
Ln Employ	β_2	0.3003	0.3152
		(0.1618)	(0.1179)
Land	δ_L	0.0017	0.0013
		(0.0007)	(0.0005)
Machinery	δ_M	-0.7120E-04	-0.6379E-04
		(0.2992E-04)	(0.2804E-04)
Office Appliance	δ_{OF}	-0.0012	-
		(0.0017)	-
	σ^2	0.3324	0.3380
		(0.0552)	(0.0549)
	γ	0.1186E-06	0.1000E-07
		(0.1166E-04)	(0.0002)
	n	88	88
	Log Likelihood	-76.4666	-76.8563

Note: MLE estimates of model 9.6 (equation (9.20) p.257) were obtained using the method of Battese and Coelli (1995) for a Cobb-Douglas production function and a technical inefficiency term U_{it} influenced by 3 capital components: land, machinery, and office appliances.
MLE estimates of model 9.7 (equation (9.22) p.261) were obtained using the method of Battese and Coelli (1995) for a Cobb-Douglas production function and a technical inefficiency term U_{it} influenced by 2 capital components: land and machinery.
Standard errors are in brackets.

These estimates are then tested for their significance, using likelihood ratio tests. Table 9.2 presents the test statistics obtained from these hypothesis tests. Firstly, the variance-ratio parameter, γ, is tested for the superiority of the production frontier against the average function. The null hypothesis may be formulated as $H_0 : \gamma = 0$. If it cannot be rejected, this would suggest that the post-crisis manufacturing sector had no inefficiency in the production process, and hence that the traditional average production function (which assumes all the producers are producing efficiently) is a more appropriate choice of model.

The results from the model estimation show that the estimated variance parameter (γ) presented in Table 9.1, has a value very close to zero, which suggests that the inefficiency effects could be of marginal significance. However, the result of the hypothesis test shown in Table 9.2 indicates that this null hypothesis should be rejected, as the calculated χ^2 statistic is equal to 8.7769. Therefore, it could be concluded that in the post-crisis period, although the efficiency level was rather high, some inefficiency in the production process still persisted. Therefore, the average production function is not an adequate representation of this period, hence, the frontier production function based on the Battese and Coelli (1995) model is found to be a more appropriate representation.

Table 9.2: Tests of hypotheses for parameters of the technical inefficiency component

Assumptions	Null Hypothesis	χ^2-statistic	$\chi^2_{0.95}$ -value	Decision
Model 9.6	$\gamma = 0$	8.7769	8.761[*]	Reject H_0
Model 9.6	$\delta_L = 0$	6.2336	3.84	Reject H_0
Model 9.6	$\delta_M = 0$	7.8351	3.84	Reject H_0
Model 9.6	$\delta_{OF} = 0$	0.7795	3.84	Cannot Reject H_0
Model 9.7	$\gamma = 0$	7.9974	7.045[*]	Reject H_0
Model 9.7	$\delta_L = 0$	7.8487	3.84	Reject H_0
Model 9.7	$\delta_M = 0$	7.5070	3.84	Reject H_0

Note: Hypotheses are tested by the general likelihood ratio test $\Lambda = -2[\ln(H_0) - \ln(H_1)]$

Following this, the next set of hypothesis tests should be conducted in order to investigate whether or not each of the technical inefficiency explanatory variables δ_L, δ_M, and δ_{OF} are significant. If any of the null hypotheses H_0 : δ_L = 0, or H_0 : δ_M =0, or H_0 : δ_{OF} = 0 cannot be rejected, then that particular explanatory variable should be dropped out of the model and another model specification would be needed. The results from these tests are also shown in Table 9.2. The null hypotheses H_0 : δ_L = 0, as well

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[*] Any likelihood ratio test statistic involving a null hypothesis which includes the restriction that γ is zero does not have a chi-square distribution because the restriction defines a point on the boundary of the parameter space. In this case the likelihood ratio statistic has been shown to have a mixed χ^2 distribution. In this case, critical values for the generalized likelihood ratio test are obtained from

as $H_0: \delta_M = 0$ are both rejected at the 95% significance level, indicating that the additions to the land investment and machinery investment, do indeed, have significant effects on the inefficiency level, and thus on the efficiency of the industry's ability to convert inputs into outputs. However, the hypothesis $H_0: \delta_{OF} = 0$ cannot be rejected, hence this implies that the effect of the addition to office appliance investment is not significant, and therefore, this variable should be dropped out of the model.

Consequently, a new specification for the Battese and Coelli (1995) single-stage production frontier becomes

$$\ln Y_{it} = \beta_0 + \beta_1 \ln(K_{it}) + \beta_2 \ln(L_{it}) - \delta_L z_{Lit} - \delta_M z_{Mit} + V_{it} - w_{it} \qquad (9.22)$$

and the technical efficiency of production for the ith industry at the tth observation is

$$TE_{ti} = \exp\{-U_{it}\} = \exp\{-\delta_L z_{Lit} - \delta_M z_{Mit} - w_{it}\} \qquad (9.23)$$

which from here, will be referred to as Model 9.7.

The coefficient estimates for Model 9.7 are also presented in Table 9.1. In accordance to the estimation in Model 9.6, the coefficient estimates of the output elasticity of capital β_1, and the output elasticity of labour, β_2, are equal to 0.5447 and 0.3152, respectively, suggesting that the structure of the manufacturing sector is capital intensive. Moreover, the inefficiency coefficient estimate of the addition to land investment is 0.0013, indicating a positive relationship between technical inefficiency and the additional investment in land. Therefore, this positive sign of the coefficient estimate is suggesting that the more investment in land the manufacturing sector undertakes, the less efficient it would become. This would lead to a decline in the sector's productivity through the effect on the firms' efficiency, due to their reduced ability to translate inputs into outputs. On the other hand, the inefficiency coefficient estimate of the addition to machinery is equal to -

Table 1 in Kodde and Palm (1986). The simplified version of this table is also presented in Appendix B.

0.00006379. This implies that additional investment in machinery will improve technical efficiency, and hence, the overall productivity of the sector.

Once again, significance tests are needed, and are conducted employing the likelihood ratio tests. The hypothesis test for the variance-ratio parameter, γ, rejects the null hypothesis H_0: $\gamma = 0$ at 95% significant level thus, again, indicating that the inefficiency still exists, and confirming the superiority of the Battese and Coelli (1995) type of production frontier, against the traditional OLS average production function for the this set of data. Hypothesis tests on the significance of the technical inefficiency explanatory variables δ_L, and δ_M indicate that both H_0: $\delta_L = 0$ and H_0: $\delta_M = 0$ are rejected. These results imply that the additions to both land and machinery investment, although relatively small, do indeed have significant effects on the inefficiency level, and thus, on the efficiency of the industry's ability to convert inputs into outputs. Therefore, it is fair to conclude that the post-crisis manufacturing sector could be modelled by the production frontier of equation (9.22), in which the technical inefficiency exists in the production process, and is affected on some level by the two explanatory variables, i.e. the addition to land and machinery investment.

The technical efficiency estimates of the industries, together with the mean technical efficiency, are calculated according to the specification of equation (9.23) above. The values obtained are presented in Table 9.3. It should be noted here, once more, that data for 2001 are unavailable, as the National Statistical Office (NSO) failed to conduct the survey in that year. Therefore, observations for 2001 are treated as missing observations. The grand mean efficiency for the post-crisis period is considered relatively high at 0.8496, suggesting that in the post crisis period, most of the industries were operating rather close to the production frontier, with only industry 10 – the coke, petroleum and nuclear industry, and industry 13 – the non-metallic mineral products, that showed rather low efficiency, comparatively. The explanation for such a dramatic decline in the efficiency level for

industry 10 in 2002 (with the efficiency level calculated at only 0.1000) lies in the problem of a statistical artefact. Prior to 2001, this industry was dominated by one single stage-owned company, the Petroleum Authority of Thailand PCL (PTT), which had been very inefficient and had been facing with a severe problem of debt. Therefore, in 2001, the company was restructured, and was ordered to increase its registered capital by 8,500 million Baht (around 220.79 million US dollar). This has, therefore, led to a 'pseudo-increase' in its input, and hence, has reduced its measured efficiency level as estimated by the Battese and Coelli (1995) model. For industry 13, the decline in its efficiency level in 1999 was the result of decreasing demand for products in this category, such as cement, lignite, gypsum, and ballclay, following the declining in the construction and mining sector. However, the situation improved in 2000 owing to the assistance from the joint-venture partner[4], which resulted in the higher export of these products, from being very domestic oriented to being rather export oriented, with more than 30 percent of its total production going overseas by 2000.

The annual mean efficiency is 0.8334, 0.8354, 0.8824, and 0.8447, for 1998, 1999, 2000, and 2002, respectively. One interesting point here is that the annual mean efficiency is showing a small, but insignificant, increasing trend, except for 2002, in which it declined from the level of the year 2000. Such a decline has largely resulted from the sharp decline in the efficiency level of industry 10 (the coke, petroleum and nuclear industry) in 2002. Without industry 10, the mean efficiency is then 0.8381, 0.8511, 0.8873, and 0.8885 for 1998, 1999, 2000, and 2002, respectively. This shows an increasing trend, as expected. However, once tested for statistical significances with null hypothesis $H_0: \mu_{98} = \mu_{99} = \mu_{00} = \mu_{02}$, the null hypothesis could not be rejected at 5 percent level of significance. Hence, it could be concluded that this increasing trend is, unfortunately, insignificant.

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[4] Bank of Thailand, (1999, and 2000)

Table 9.3: Technical Efficiency Estimates of the TE Effects model

Industry	1998	1999	2000	2002
Food	0.8445	0.8532	0.8674	0.8724
Tobacco	0.9037	0.9201	0.9563	0.9939
Textiles	0.8820	0.9351	0.9693	0.9242
Wearing Apparel	0.9524	0.9689	0.9779	0.9408
Leather Products	0.8374	0.8887	0.9339	n/a[#]
Footwear	0.9558	0.9809	0.9404	n/a[#]
Wood	0.8497	0.9045	0.9200	0.8761
Paper	0.7891	0.8388	0.8545	0.8634
Publishing	0.7886	0.7902	0.8125	0.8353
Petroleum	0.7261	0.4893	0.7749	0.1000
Chemical	0.8119	0.8442	0.7980	0.8593
Rubber & Plastic	0.8370	0.9327	0.8880	0.9182
Non-Metallic Mineral	0.5498	0.3258	0.6923	0.7270
Basic Metals	0.7659	0.7780	0.7465	n/a[#]
Fabricated Metal	0.8133	0.8475	0.8976	0.8963
Machinery	0.8827	0.8422	0.9063	0.8878
Computing	0.9897	0.9467	0.9472	0.9933
Electrical	0.9404	n/a[#]	n/a[#]	0.9234
Communication	0.8553	0.9409	0.9819	n/a[#]
Medical	0.8859	0.9586	0.9706	n/a[#]
Vehicles	0.6866	0.6658	0.7463	0.7535
Transport Equipment	0.8163	0.8341	0.9284	0.8940
Furniture	0.7556	0.7831	0.9300	0.9450
Jewellery	0.8826	0.9442	0.8559	n/a[#]
Mean	**0.8334**	**0.8354**	**0.8824**	**0.8447**
Mean	**0.8496** ($n = 88$)			

Note: Technical Efficiency estimates were obtained using the method of Battese and Coelli (1995) for a Cobb-Douglas production function and a technical inefficiency tern U_{it} influenced by 3 capital components: land, machinery, and office appliances. Because office appliances were insignificant, computation used equation (9.22) which in this thesis is referred to as Model 9.7 (see p.261)

9.5 Implication of the Results

The results from Model 9.7, the stochastic production frontier with the technical inefficiency explanatory variables (i.e. the addition to land and machinery investment) suggested by Battese and Coelli (1995), indicates that in the 5 post-crisis years, from 1998 to 2002, the manufacturing sector of Thailand experienced a structural shift from being labour intensive to being capital intensive. The coefficient estimates of the post-crisis output elasticity of

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[#] Data is not available for that period, thus no values of technical efficiencies are calculated

capital and the output elasticity of labour are equal to 0.5447 and 0.3152, respectively. This finding is coincided with the conclusions in both the traditional average Cobb-Douglas production function in chapter 6, and the Battese and Coelli (1992) error components model in Chapter 8.

The factors behind such structural shift have already been explained in the previous chapter, which involves 5 main causes. First, the shakeouts of the firms with less efficiency and less technology advancement leading to the improvement in the overall efficiency level of the industries, and of the sector as a whole. Second, the reduction of the amount of labour used in the production processes as a result of the labour quantity adjustment to the crisis, leading to shifts in the output elasticity of inputs used. Third, the adjustment in relative price, due to the reduction in the interest rates as well as the rigidity in wage, results in the substitution of capital for labour in the production process, hence, shifting the structure from labour intensive to capital intensive. Furthermore, the government policies in facilitating capital investment including the soft loans provision for businesses that need capital upgrading or start-ups, and the tariffs reduction for import of capital goods, also bring about this structural shift. And finally, the post-crisis financial market reformation has resulted in a healthier investment environment in which the ability to access to loans for firms with good investment projects is greatly enhanced. Therefore, capital investment in the manufacturing sector increases, especially in the more productive investment area such as machinery.

In fact, this last argument, the factor concerning the investment behaviour in the manufacturing sector, is the main focal point of this chapter. The graphical exploratory data analysis in Chapter 6 has revealed the improvement in the gross output - capital expenditure ratio, GO/CE, in the post-crisis period. Such finding implied that there might be an increase in the usage of the more productive capital, and hence, leading to the increase in the gross output produced. Later in Chapter 8, it was argued that although the level of total private investment declined significantly in the post-crisis period, the

manufacturing sector was benefited by the healthier investment behaviour resulting from the financial market reformation in form of the increase in efficiency level. Dollar and Hallward-Driemeier (2000) stated that because the pre-crisis interest rates were so high, the majority of the investments in that period were speculative investments, such as those in the stock market and the real estate sector, which was the only type of investments that could possibly generate sufficient returns. Therefore, the manufacturing sector suffered from such circumstances. It is also argued that even the pre-crisis investment projects within the manufacturing sector itself were also concentrated heavily on the unproductive areas[5], such as investment in plants and land, since it generated higher returns compared to the returns from the production of outputs. Also, many domestic manufacturers preferred to invest their funds in real estate by building larger plants, as well as acquiring more land, as these increased the value of their company. Thus, by the time of the 1997 crisis, majority of manufacturers were reported to have excessive land and plant size. Fortunately, the post-crisis investment environment has turned favourable for the productive investments. Increase in productive investments could be seen as a result of the reduction in domestic interest rates and the financial institutes' lending behaviour.

The analysis in this chapter is the verification for such arguments. The non-zero variance-ratio parameter, γ, indicates that although the efficiency level is rather high, there still exist inefficiency in the post-crisis production process. The positive value of δ_L, in which although small but significant, suggests that the higher the investment these industries made in land, the lower the efficiency in their production processes become, and therefore, leading to the decline in the sector productivity through the effects on the firms' ability to translate inputs into outputs. This result is in accordance with the argument made earlier that many Thai manufacturers were already invested excessively in land and real estate prior to the crisis. Thus, further investment in this area would not generate much more efficiency, and in some cases might have even resulted in a decline in efficiency. Therefore,

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[5] Dollar and Hallward-Driemeier, (2000)

it seems reasonable to argue that Thai manufacturing sector had suffered from the over-investment in unproductive capital prior to the 1997 economic crisis, therefore, leading to low level of efficiency, and productivity. Consequently, the competitiveness of the country declined, and hence, brought about the decline of export growth, which was at that time the main driving force of the country's economic growth. The declining export, the weakening economic growth, the bubble in real estate and stock market, as well as, the bulky external debt, had become an excellent motive for currency speculators to attack the Thai Baht, creating the starting point of the 1997 economic crisis.

Nevertheless, this crisis could still be seen as being beneficial for the Thai manufacturing sector. The post-crisis efficiency and productivity have improved significantly. One of the reasons, shown in this chapter, might have been partly coming from the post-crisis financial restructuring, which benefits this sector by allowing more productive investments (especially the capital investments) to take place. The negative value of δ_M, in which is used to proxy the productive types of investment, suggests that the increase in investments of machinery and equipment has improved the post-crisis efficiency of the manufacturers, and as a result, enhance their ability to convert inputs into outputs and thus, increase their productivity. As a result, post-crisis Thai manufacturing sector became better off in terms of productivity and competitiveness, and therefore, creating a stronger foundation for competing against other economies in the world market. Additionally, the negative sign of the technical inefficiency variable δ_M also implies that there is still room for Thai manufacturing sector to improve their efficiency further by the increase in investments in machinery and equipment. As once mentioned by Krugman (1994) that growth based only on the higher use of resource mobilization could not be sustained in the long-run, therefore, growth should be built up from technology progress and efficiency, or the so-called 'efficiency-led sustainable growth'.

9.6 Conclusion

With the pre- and post-crisis structural shift in the manufacturing sector, as well as the significant improvement in the post-crisis efficiency, observed in the previous chapter, it is faired to allege that there existed some specific causes that affected such variations in the manufacturing sector. Therefore, this analysis of the productive efficiency would not be considered complete without the examination on at least one of the factors suggested previously to be causing such variations. Hence, in this chapter, the relationship between the capital investments and technical efficiency had been examined, based on the Battese and Coelli (1995) model. The estimation of the output elasticity of capital and the output elasticity of labour are in accordance to those estimated by the error components model in the previous chapters. Two explanatory variables, the addition to capital investment in land and the addition to capital investment in machinery and equipment, are concluded to be significantly related to efficiency. The positive value of the coefficient of additional investment in land suggests that the higher the investment these industries made in land, the lower their efficiencies become. While the negative value of the coefficient of additional investment in machinery and equipment suggest that the increase in investments of machinery and equipment will improve the efficiency of the manufacturers, and as a result, enhances their ability to convert production inputs into marketable outputs. These results verify the argument made in Chapter 8 stating that the post-crisis efficiency improvement is partly caused by the increase in productive capital improvement brought about by the post-crisis financial market restructuring as well as the reduction in the domestic interest rates. Therefore, this implies that the pre-crisis Thai manufacturing sector had suffered from the insufficient productive capital investments, but this condition has improved since the aftermath of the crisis, and therefore, leading to the improvement of the efficiency and productivity level in the post-crisis period.

Although the analysis in this chapter has fulfilled its objective in relating the capital investment with the efficiency level, however, this analysis is still somewhat limited due to the limitation from the data availability. Such an analysis could be greatly enhanced if more data could be collected in order that all the factors leading to such improvement in the productivity level previously discussed (including the shakeouts, the reduction in the labour used, the adjustment in the relative price, and the government's post-crisis stimulus packages) could be included in the model and be tested. Therefore, further research is suggested to be conducted along this direction.

Chapter 10 – Conclusion

10.1 Research Overview

The main objective of this thesis (as suggested by its title) is to examine productivity trends in the Thai manufacturing sector using pre- and post-crisis evidence relating to the 1997 economic crisis. The structure of this thesis has been built around the attempt to answer the three main set of research questions posed in Chapter 1. The first set of research questions concerned the measurement of the pre-crisis productivity level and, also, examined the efficiency trend within that period. The second set of questions involved the measurement of the post-crisis productivity, and its adjustment during the recovery period. Finally, the third set of questions were aimed at making a comparison between the two periods, and hence, drawing out the implications on the effects of the crisis and its effects, as well as the adjustments that led to the observed improvements seen in the post-crisis period.

The thesis started by providing an overview of the development of the Thai economy since the period of laying foundation in the 1950s, as it was believed that a good understanding of such a development process would create a better comprehension of the origins of the crisis. It then proceeded further to investigate the genesis of the 1997 economic crisis, as well as examining the consequences that the crisis had for the Thai economy. Five main causes of the crisis have been identified including: the slowdown of export growth; mistakes in financial policies; the problem of asymmetric information and over-investment; attacks on the currency; and responses to the currency devaluation. The effects of the crisis were categorized into two areas: economic growth, and employment,. Nevertheless, the focal point of this thesis is not an aggregate economic effects, but rather on the effects of the crisis on the productivity level of the Thai manufacturing sector.

Therefore, much effort had been put into appropriate measurement of the productivity levels in both the pre- and post-crisis periods.

The outline of this chapter is as the following: Section 10.2 will summarize the key research findings concerning the productivity level of the manufacturing sector. Three sets of key hypotheses will be tested, aiming at the rejection of null hypotheses, and the acceptance of the alternative. Answers to the three main sets of research questions will be drawn from such hypothesis tests. Section 10.3 concludes other findings of this thesis. Section 10.3.1 reviews the genesis of the crisis by classifying the roots of it into 5 main causes. Section 10.3.2 considers other consequences of the 1997 crisis for the Thai economy, including the effects on GDP growth and employment. Section 10.4 identifies the research contributions, and also provides policy implications. And finally, section 10.5 offers future research suggestions.

10.2 Answers to the Research Questions

The organization of this thesis had been based on attempts to answer the three sets of research questions which were posed in Chapter 1. Much effort had been put into ensuring the results were reliable and robust. This effort was directed at the search for a trustworthy data source, a reliable method of measurement, and a rigorous and appropriate set of models. Moreover, in order to enrich the context of the results achieved, much exploratory analysis was conducted, and many alternative hypotheses were tested. The key findings are presented in the form of answers to the research questions. Thus:

Question 1:   *What was the productivity/efficiency level of the pre-crisis manufacturing industry? Is it true that the sector had low efficiency, and had not been improving its*

productivity, despite the growing competition from the newly developing countries such as China and Vietnam?

As mentioned above, in order to pursue for the answer to these two questions, a set of hypotheses had been set up, with the null hypothesis stating that 'the productivity/efficiency level in the pre-crisis period was reasonably high, as the level of capital investment during that period was also high. Therefore, the deterioration of competitiveness, and hence the 1997 economic crisis, were not caused by low productivity productivity/efficiency levels.' In order to test such a hypothesis, the stochastic production frontier approach has been selected for the measurement of productivity in the Thai manufacturing sector. The findings (presented in Chapter 8) revealed that the pre-crisis efficiency level of the Thai manufacturing sector had been low, with the mean efficiency level of 0.3444, and with many sectors exhibiting efficiency levels as low as just 20 percent. Moreover, the findings also suggested that during the seven years from 1990 to 1996, the Thai manufacturing sector experienced no obvious technical improvement whatsoever. This finding might seem uncharacteristic at first, considering the period's extraordinary growth rate, as well as the substantial rate of investment during the early 1990s. Prior to the crisis in July 1997, Thailand had enjoyed a long and considerable growth period, with an average GDP growth of 9.49 percent per annum. The investment level in the country had also been sizeable; the average capital stock growth in the manufacturing sector (between 1986 and 1996) was as high as 14.0 per cent per annum.

However, once one looks into the details of capital investments during the pre-crisis period, one would no longer be surprised by such findings. Dollar and Hallward-Driemeie (2000) claimed that the majority of that growth in capital was channelled into risky projects and highly cyclical investments (such as the real estate sector and the stock market), rather than into the more productive manufacturing sector. The soaring level of interest rates prevented entrepreneurs from investing in an ordinary investment projects, as they could

hardly yield sufficient returns[1]. Therefore, this had entailed the growth in the productivity of the manufacturing sector, and hence, had led to decline in the competitiveness of Thai manufacturing products.

Furthermore, findings from Chapter 9 also suggested that excessive investment in real estate had prevented manufacturers from investing sufficiently in technology advancement and efficiency upgrading of the production processes. Therefore, the productivity of Thai manufacturers was deteriorating even further. Combined with the fierce competition from the newly developing countries such as China and Vietnam (where there resources were still abundant and the cost of labour were still very cheap), this became one of the main reasons behind the decline in Thailand's export growth.

These findings, therefore, support the rejection of the null hypothesis discussed above. The alternative hypothesis stating that 'the productivity/efficiency level in the pre-crisis period was low, as investment made during that period were concentrated mainly in the unproductive areas. Therefore, the deterioration of competitiveness, and hence the 1997 economic crisis, were indeed caused by low productivity/efficiency level' is, instead, accepted. Consequently, this provides the answers to the first set of research questions. The productivity/efficiency level of the pre-crisis manufacturing industry was low, and did not show any sign of improvement during the seven-year period covered in this study, despite the growing competition from the newly developing countries.

Question 2: What was the productivity/efficiency level of the manufacturing sector in the post-crisis period? Did it improve, or did it deteriorate during the 5-year period of study?

The structure of this thesis was built in such a way that it facilitated the pursuit of answers to the questions above. A second set of hypotheses was set up, with the null hypothesis

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[1] Jitsuchon, (2002)

(aiming to be rejected) hypothesizing that 'the productivity/efficiency level in the post-crisis period was lower, when compared to the pre-crisis period.' As in the case of pre-crisis productivity measurement, the stochastic production frontier approach was used in measuring the post-crisis productivity level in the manufacturing sector.

The findings in Chapter 8 implied that the appropriate model to represent the data set from the post-crisis period is the stochastic frontier estimation with time varying inefficiency component (i.e. the model suggested by Battese and Coelli (1992)). The results from such a model suggested that the mean efficiency levels were higher in the post-crisis period, comparing to the pre-crisis level, but most importantly, it demonstrated a rising trend in efficiency. The efficiency level in 1998 was 45.02 percent, which had increased to 53.56 percent in 1999, 61.46 percent in 2000, and 75.59 percent in 2002. However, not all industries exhibited an immediate improvement in their efficiency levels post crisis. Twenty industries (out of the total of 24) showed an increase in efficiency in 1998, just a year after the crisis broke off. However, another four industries (namely, the publishing and printing industry, the coke, petroleum and nuclear industry, the machinery and equipment industry, and the basic metals industry) revealed a decline in efficiency level during 1998, when compared to the pre-crisis level. Nevertheless, most of them, except the coke, petroleum and nuclear industry, recovered and achieved a higher level of efficiency in later years. It is sensible to explain such finding in terms of the common characteristic all these four industries. Under the standard set by the National Statistical Office, these industries were considered to be domestic industries (which exported less than 30 percent of its total production), and they were the segments in the manufacturing sector that had been most heavily hit by the crisis, due to their inability to exploit the benefits of improved competitiveness, resulting from the cheaper Baht.

These results led to the rejection of the null hypothesis, which alleged that in the 5 immediate years after the crisis, the manufacturing sector of Thailand had experienced deterioration in its efficiency level, when compared to the pre-crisis level. They, instead,

suggested the acceptance of the alternative hypothesis, claiming that 'the productivity/efficiency level in the post-crisis period was higher, when compared to the pre-crisis period.' Therefore, the answers to the second set of research questions are that: the post-crisis productivity/efficiency level of the Thai manufacturing sector was higher when compared to the pre-crisis level, and that during the period of 5 post-crisis years examined in this thesis, the efficiency level of Thai manufacturing sector exhibited an increasing trend.

Question 3:   *What are the possible explanations for the difference in pre- and post-crisis productivity level? Did capital investment play a significant role in accounting for such difference?*

This set of questions is aimed at making a comparison between the structures of the pre- and post-crisis Thai manufacturing sector, and hence, drawing out the implications on the effects of the crisis, which have led to improvements in the post-crisis efficiency. In order to do so, a third set of hypotheses was set up, with the null hypothesis stating that 'the deterioration in the post-crisis productivity/efficiency level was a result of the reduction in the amount of capital investment, due to the problem of the domestic credit crunch during 1997 and 1998'.

The comparison between the structures of the Thai manufacturing sector in the pre- and post-crisis period were attempted in Chapter 6 and 8, in which it was demonstrated that there was a sign of a structural shift from a labour intensive manufacturing sector in the pre-crisis period to a capital intensive one in the post-crisis. The output elasticity of capital shifted from 0.2813 in the pre-crisis period to 0.5022 post-crisis. In contrast, the output elasticity of labour declined from 0.5625 pre-crisis to only 0.2064 post-crisis. The justification for such a switch of dominance between capital and labour in the pre- and post-crisis periods, as well as the improvement in the post-crisis efficiency level,

can be sought in a complex set of explanations. The first possible explanation came from the shakeout process. In which it, the economic crisis had caused a sharp decline in demand, and hence had created a more stringent competitive environment in which firms had to compete. In these conditions, firms with less efficiency would not be able to survive, and would be expected to be driven out of business. Thus the post-crisis economy was left with only highly productive manufacturers, resulting in an improvement in the overall efficiency level.

The second explanation came from the effects of real wage rigidity on the Thai labour market. In the post-crisis period, the real wage level had not been reduced much, given the severity of the crisis. Adjustment in the labour market had been channelled, largely, through quantity, rather than price, adjustment. Thus, the number of working hours in the manufacturing sector declined significantly. Hence, the dominance of the capital inputs became more evident, resulting in the structural shift towards greater capital intensitivity.

The third explanation for such a structural shift could also be based on the observed sharp decline in post-crisis interest rates. After the easing of monetary measures in August 1998, domestic interest rates had declined significantly[2]. Combined with the rigid nominal wage (resulting from unaffected minimum wage rates imposed by the Department of Labour), the relative price between capital and labour changed considerably, and in form of relatively cheaper capital, and thus, labour was substituted by the higher use of capital in many production processes (Behrman, Deolalikar, and Tinakorn (2001), Na Ranong (2000), Paitoonpong (2001, 2002)). Unsurprisingly, the manufacturing sector especially displayed this trend towards greater capital intensivity.

Furthermore, as a result of the decline in domestic interest rates, as well as the enforced restructuring of the financial market caused by the IMF intervention, domestic private investment was guided toward the more productive areas. Financial institutions no

longer issued loans to speculative and non-productive investment projects, thus, productive manufacturers' ability in accessing to loans were enhanced [3]. As a result, the overall productivity of the sector was improved. This explanation had also been suggested by the analysis utilizing the technical efficiency effects model suggested by Battese and Coelli (1995) in Chapter 9. The findings there revealed that the Thai manufacturing sector was still experiencing the adverse effect of the pre-crisis excessive investment in unproductive sectors. Therefore, further improvement in the post-crisis productivity could yet be achieved through an increase in productive investment, and reduction in unproductive investment.

Finally, the highly-favoured government policies, including the two economic stimulation packages, have played a major role in the improvement of the manufacturing sector's productivity level. The Thai government has placed prime emphasis on improvements in the research and development capabilities of the small and medium size enterprise (SME), as they dominated the manufacturing sector (Poapongsakorn and Tangkitvanich (2000)). Many industry development institutes were established with public funding, in order to promote the productivity and efficiency of small firms in those particular industries (Bank of Thailand (2000, 2001, and 2002)). Moreover, many other policies were also implemented. These include measures such as lowering the import tariff for capital goods, cutting income, as well as lowering value added taxes, and more importantly, providing soft loans to SMEs to be used in business starting ups and upgrading (Poapongsakorn and Tangkitvanich (2000)).

These findings, therefore, reject the above null hypothesis, and *accept* the alternative hypothesis stating that 'the improvement in the post-crisis productivity/efficiency level was partly a result of the increase in the amount of productive capital investment, despite the decline in the total amount of capital investment.' The answer to this final set of research questions is that there are five possible explanations for the difference in the pre-

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[2] Laplamwanit, (1999)
[3] Vines and Warr, (2003)

and post-crisis productivity level, including the shakeout process, rigid real wages, changes in the relative prices between capital and labour, financial marker restructuring, and finally, the government's economic restructuring policies. Also, an increase in the investment of more productive capital investment was shown (in Chapter 9) to be playing a significant role in the improvement of the post-crisis efficiency level.

10.3 Further Findings

The 1997 economic crisis affected Thailand in a very profound way and on an extensive scale. It is believed among the Asian economists (Phongpaichit and Baker (1998), Radelet and Sachs (1998), Sussangkarn (1998, 1999), Lane, Ghosh, Hamann, Phillips, Schulze-Ghattas, and Tsikata (1999), Laplamwanit (1999), Vines and Warr (2003), Williams and Nguyen (2005)) that the origin of the crisis was prompted by a complex set of causes. This section concludes the findings of this thesis concerning the genesis and the consequences of such crisis.

10.3.1 Genesis of the Crisis

This thesis has shown that the answer to the question on the causes of the crisis was not a simple one, and there was not one single cause or explanation, but a multifaceted set of problems that precipitated the crisis of such intensity. The thesis has classified these problems into five main categories: the slowdown of export growth, the mistakes in financial policies, the problem of asymmetric information and over-investment, the attacks on the Baht, and the responses to the currency devaluation.

The Thai economy, as Krugman (1994, 2001) has pointed out, had deep-rooted structural problems. The rapid growth during the late 1980s and the early 1990s was built

up mainly by the strong export growth, which was driven largely by the two most important assets the Thai economy owned: cheap labours and extensive natural resources. However, such growth, based on the higher use of inputs and high resource mobilization, rather than the progress of technology and improvements in efficiency, was impossible to sustain in the long-run. This claim is substantiated in the case of Thailand. Unfortunately, by 1996, the two key assets Thailand processed, and had relied on most had seemed to reach their limits (Sussangkarn (1998), Phongpaichit and Baker (1998)). Between 1982 and 1994, real wages rose considerably, with an approximate 70 percent increase over these thirteen years. To worsen the situation, from the mid 1990s onward, the Thai export sector had experienced increased competition from other developing Asian countries, who had recently opened up their economies (also with abundant resources and much cheaper labours) to foreign direct investment. In this context, by employing the stochastic frontier estimation method presented in Chapter 8, it became possible to verify that the Thai manufacturing sector had not been experiencing any significant technical progress since 1990. Therefore, while other countries had been improving their technology, Thailand had been largely standing still, and was exhausting its natural resources and its supply of labour. Consequently, the country was inescapably losing its competitiveness, and was faced with severe reductions in its export growth.

Although the problems of poor productivity growth and declining competitiveness did take place long before the occurrence of the crisis (according to the results from Chapter 8, Thai manufacturing sector had not been improving its production technology since as early as 1990), nevertheless, these problems were concealed at the time. The relatively stable growth of more than two decades had lulled the polity into complacency regarding the risks they might be running. Mistakes in investment (e.g. the excessive investment in the real estate and other non-productive sectors, as suggested by the findings in Chapter 9) had almost always been rescued by high growth. But it was this high growth itself that led to the accumulation of structural problems. Related institutions were

inadequately prepared to deal with the consequences of mistakes, and no arrangement had ever been properly set up to mitigate these affects. One obvious example was the financial market liberalization of the early 1990s. The Bangkok International Banking Facility (BIBF) was initiated in 1993 in order to facilitate the flow of foreign currency account transactions, aiming to increase the amount of investment which could be used for upgrading the country[4]. However, as Chapter 4 had revealed, such liberalization was carried out before the supervision and the regulation of financial institutions had been overhauled to take into account the new environment that would be opened up by such a policy. Consequently, with a large number of private financial institutions directly involved in capital account transactions, the Bank of Thailand (BOT) had lost its ability to regulate the flow of capital in and out of the country, and hence, its ability into control the country's money supply. Combined with the country's fixed exchange rate regime, a massive wave of foreign capital rushed into the country, in pursuit of the virtually risk-free currency environment.

The result of this financial policy mistake was devastating. Although the amount of foreign capital inflow was high, the sum of foreign direct investment was minimal. The substantial amount of capital inflow, combined with the public belief that the BOT would bail out financial institutions in trouble, posed a serious problem of moral hazard in the banking sector. As a result, Thai financial institutions began to engage in risky lending behaviour. This situation was worsened by the problem of adverse selection, where firms generally had better information on risks involved in their investment projects than did banks. Alas, for the case of Thailand, loans were given to speculative and unproductive investments in the real estate sector and the stock market, as these were the investments which yielded the highest returns at that time (Vines and Warr (2003)). By 1995, the supply of real estate development projects was exceeding its demand severely, and yet real estate developers continued to borrow and build (Pongpaichit and Baker (1998)). This plethora of bad investment projects hurt the Thai economy severely. The results from Chapter 9 suggested

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[4] Nukul's Commission Report, (1998)

that excessive investment in unproductive sectors had prevented any improvement in efficiency of the manufacturing sector. It also implied that without such investments, the Thai manufacturing sector would have been better off, and might be able to avoid losing its competitiveness to countries like China and Vietnam.

Worse still, the massive capital inflow generated by capital account liberalization had caused domestic firms to become over-reliant on external debt as a mean of financing their new investments. This had put them, as well as the financial institutions, in a position which was extremely vulnerable to external factors. After the second half of 1996, concerns about the sluggish export growth, the bubble economy, and the over-valued currency had become widespread. Currency speculators started some sporadic attacks on the Baht, as they expected the Thai authorities would soon devalue the exchange rate in order to deal with the economic difficulties. However, the Bank of Thailand (BOT) was forced to resist these depreciation pressures as the devaluation of the Baht would put many firms and financial institutions in a ravaged situation, concerning the amount of foreign debt they had. Unfortunately, the currency attacks did not stop, and the BOT was obligated to defend the Baht until, finally, Thailand had ran out of its foreign reserves, and was virtually bankrupted.

More unfortunate, it was alleged (Ghosh and Phillips (1999), Stiglitz (2000)) that the mistakes in the recovering program of the IMF had pushed the situation in Thailand even further downhill. The suspension of financial institutions had created panic across the economy. The stringent fiscal and monetary policies had left no prospect for business to recover. As a result, Thailand had to suffer a far greater impact of the crisis than it should have.

10.3.2 Other Consequences of the Crisis

Thai economy experienced severe adjustments in many ways. The crisis had resulted in a decline in domestic demand, both on consumption and investment. The failure of financial

institutions also led to tight liquidity conditions, which, combined with the decline in demand, resulted in widespread collapse and insolvency of domestic businesses. Measured economic growth had unprecedently become negative (viz. contraction, which was a condition that had not happened in Thailand for over fifteen years). The overall GDP growth declined dramatically, with the non-agricultural sectors experiencing much larger negative impact than the agricultural sector. The construction sector experienced the largest negative impact in the period following the crisis. The manufacturing sector had also been heavily hit, though the impact was uneven within the sector. Industries that experienced the most severe downturn were the domestic oriented industries (those that exported less than 30 percent of total production), i.e. the petrochemical industry, the basic metal, and the construction materials industries. The export oriented industries were affected by the economic crisis to a much lesser extent. The majority of producers in these industries had, as in the other industries, experienced a very tight liquidity situation, severe shortage of funds, and decreased in inter-firm domestic trade credits. Nevertheless, the depreciation in the Baht had improved their competitiveness in the export markets, and thus, had, to a certain extent, been able to mitigate the negative effect of the crisis.

On the employment side, at the time of the crisis, Thailand still had relatively large agricultural and informal sectors; therefore, they were able to absorb labour laid off by other sectors that were directly hit by the crisis. Hence, the decline in the total number employed was somewhat moderate, with only a 2.87 percent decline in employment between the period from 1996 to 1998. On the other hand, the influence was much more severe in the construction sector (which was the main part of the real-estate-driven 'bubble' economy). The average employment in this sector declined by 41 percent between 1995 and 1999. On the other hand, unemployment increased from 1.7 percent in 1995 to 4.4 percent in 1998, which although a significant increase, was still considered moderate, given the severity of the crisis. One of the main reasons for this was that a substantial number of those considered employed were, in reality, underemployed. The number of the

underemployed increased significantly after the economic crisis, from 580,700 persons in 1996 to 938,400 persons in 1998, 953,900 persons in 1999, and 982,700 persons in 2000. This increase in the underemployment level implied a reduction in the number of working hours, and thus, suggested that Thai labour market was able to absorb the negative impacts of the economic crisis through the adjustment of working hours, as well as the headcounts.

10.4 Research Contributions and Policy Suggestions

This thesis has pushed forward the research area concerning the productivity of Thailand, as well as the research on the effects of the 1997 economic crisis, to a significant extent. It has opened up a new area of empirical research on the productivity measurement that has never been adapted to the case of Thailand before, by using the frontier analysis approach (Pitt and Lee (1981), Battese, Coelli, and Colby (1989), Battese and Coelli (1992), Battese and Coelli (1995) in the measuring of productivity. Most of the works (World Bank Report (1993), Marti (1996), Tinakorn and Sussangkarn (1996 and 1998), Collins and Bosworth (1997), Sarel (1997), and Dollar *et al.* (1998)) on productivity measurement carried out concerning the Thai economy employed either the growth accounting approach (Tinakorn and Sussangkarn (1996, 1998), Sarel (1997)) or the econometric approach (Marti (1996), Sarel (1997). However, both approaches are subject to some major drawbacks. The stochastic production frontier used in this thesis is superior to those approaches in that it was not depend on the strong assumption of constant returns to scale as in the growth accounting case, and also is not subject to the neglect of the technical inefficiency component, as is the econometric approach.

Moreover, this thesis is the first literature which provides measurements of both the pre- and post-crisis productivity/efficiency levels of the Thai manufacturing sector by

utilizing the same source of data, and through the same model selection process. Therefore, it is the only empirical study that could compare the pre- and post-crisis efficiency level with minimal bias caused by the sensitivity of data and methodology. The findings from such comparison have revealed several interesting effects of the crisis, which had never been mentioned before in any literatures regarding the productivity of Thai economy. Firstly, this thesis discovered that there was a significant structural shift in the Thai manufacturing sector, from being labour intensive in the pre-crisis period to being capital-intensive post-crisis. Secondly, it also identified that the post-crisis efficiency level as having improved significantly when compared to the pre-crisis level. Furthermore, there was also an increasing trend in the improvement of technology used by the industries in the manufacturing sector, therefore, indicating that the improvement in the efficiency level was to some extent a result of improvement in technology.

The technical efficiency effects model (Battese and Coelli (1995)) analyzed in Chapter 9 also verified such finding. The negative relationship between the technical inefficiency component and the improvement in the machinery variable implied that the higher the investment made in productive factor inputs (such as machinery), the higher the efficiency of the sector became. The positive relationship between the technical inefficiency component and the improvement in land variable also suggested that Thailand, even many years after the crisis, was still suffering from the negative effects of the over-investment in unproductive capital inputs (i.e. land and real estate) left by the bubble economy in the early 1990s. Therefore, improvement in the sector's efficiency could still be achieved if the industries were able to transform this unproductive capital into more productive capital investments, such as investment in better production equipment.

In addition, the results from this thesis imply that one of the reasons Thailand started to lose its competitiveness during mid 1990s was due to the lack of productivity growth in the economy. The rapid economic growth during the late 1980s and the early 1990s was mainly the result of the higher use of factor inputs and better resource

mobilization, such as the increasing use of labour in the industrial sectors resulting from the declining agricultural sector. Such growth was impossible to sustain in the long-run, as either the input resources would run out, or the economy would run into diminishing returns. Therefore, in other to generate future sustainable growth, as well as to avoid future crises similar to this one in 1997, it is very important that the relevant authority is focused on economic development, not just on the nominal growth rate, but also on the quality of the growth, i.e. the improvement of the productivity, technical progress, and also the efficiency level, which is referred by Krugman as 'efficiency-led sustainable growth'.

Moreover, the country's long-run productivity and competitiveness have to be well planed in advance. It is very important that the National Economic and Social Development Board (NESDB) puts more emphasis on the issue of productivity and competitiveness when the future National Development Plan is drawn up, so that it will help to guide the formulation of government budgets and policies at the national level. Finally, as one of the major factor leading to the crisis of 1997 stemmed from the failure of the public and the private sectors to deal with the aggregate economic mistakes and external shocks. Therefore, some new specific institutions and arrangements should be established in order to provide the necessary guidance and the control, should these unfavourable occasions occur again in the future.

10.5 Further Research Suggestions

Although the analyses in this thesis have enhanced the research on the area of productivity in Thailand to a great extent, due to the limitations of data as well as the scope of the thesis itself, there are still many areas of research that could be carried out. An appealing extension of this thesis would be to enrich the dataset with new inefficiency explanatory variables to include other causes of such inefficiency (e.g. interest rate, debt burden,

advancement in R&D). Also, if possible, a technical efficiency effects model should also be analyzed using the pre-crisis data, so as to examine in more detail the causes of the crisis. Moreover, when longer post-crisis time-series data become available, a further analysis, similar to the one in this thesis, should be undertakes in order to examine the long-term effects of such a crisis.

A promising additional area of research might be to focus on the different segments of the economy, i.e. the service sector and the agricultural sector, which might provide some new insights into how different sectors would react to the same events, opening up the possibility of different detailed responses at the sectoral level.

Finally, it might also be constructive to compare the case of Thailand to other economies. Comparison between the adjustment of Thai manufacturing sector to those of other economies also affected by the 1997 crisis such as Indonesia, Malaysia, or South Korea should offer important insight into how difference in economic structure could affect the ability to recover and adjust after the event of the crisis. Also, a comparison between Thailand and Malaysia (which, unlike Thailand, refused any help from the IMF) should provide a new perspective on claims that mistakes were made in creating the IMF recovery package imposed on Thailand.

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Appendix

Appendix A - List of Thai Manufacturing Industry

Industry 1   Food Products and Beverages

Industry 2   Tobacco Products

Industry 3   Textiles

Industry 4   Wearing Apparel, except Footwear

Industry 5   Leather and Products of Leather, Leather Substitutes and Fur, except Footwear and Wearing Apparel

Industry 6   Footwear

Industry 7   Wood and Products of Wood and Cork, except Furniture

Industry 8   Paper and Paper Products

Industry 9   Publishing, Printing and Reproduction of Recorded Media

Industry 10   Coke, Refined Petroleum Products and Nuclear Fuel

Industry 11   Chemical and Chemical Products

Industry 12   Rubber and Plastic Products

Industry 13   Other Non-Metallic Mineral Products

Industry 14   Basic Metals

Industry 15   Fabricated Metal Products, except Machinery and Equipment

Industry 16   Machinery and Equipment

Industry 17   Office, Accounting and Computing Machinery

Industry 18   Electrical Machinery and Apparatus

Industry 19   Radio, Television and Communication Equipment and Apparatus

Industry 20   Medical, Precision and Optical Instruments, Watches and Clocks

Industry 21   Motor Vehicles

Industry 22   Other Transport Equipment

Industry 23   Furniture

Industry 24   Jewellery and Related Articles

Appendix B - Mixed Chi-Square distribution

df \ α	.25	.10	.05	.025	.01	.005	.001
1	0.455	1.642	2.706	3.841	5.412	6.635	9.500
2	2.090	3.808	5.138	6.483	8.273	9.634	12.810
3	3.475	5.528	7.045	8.542	10.501	11.971	15.357
4	4.776	7.094	8.761	10.384	12.483	14.045	17.612
5	7.257	8.574	10.371	12.103	14.325	15.968	19.696
6	8.461	9.998	11.911	13.742	16.074	17.791	21.666
7	8.461	11.383	13.401	15.321	17.755	19.540	23.551
8	9.648	12.737	14.853	16.856	19.384	21.232	25.370
9	10.823	14.067	16.274	18.354	20.972	22.879	27.133
10	11.987	15.377	17.670	19.824	22.525	24.488	28.856
11	13.142	16.670	19.045	21.268	24.049	26.065	30.542
12	14.289	17.949	20.410	22.691	25.549	27.616	32.196
13	15.430	19.216	21.742	24.096	27.026	29.143	33.823
14	16.566	20.472	23.069	25.484	28.485	30.649	35.425
15	17.696	21.718	24.384	26.856	29.927	32.136	37.005
16	18.824	22.956	25.689	28.219	31.353	33.607	38.566
17	19.943	24.186	26.983	29.569	32.766	35.063	40.109
18	21.060	25.409	28.268	30.908	34.167	36.505	41.636
19	22.174	26.625	29.545	32.237	35.556	37.935	43.148
20	23.285	27.835	30.814	33.557	36.935	39.353	44.646

Source: Kodde D. and Palm F., (1986), pp.1246

Appendix C – Outputs from Pitt and Lee's Model I (Further Preliminary Analysis)

Appendix C-1: Pre-crisis Results

Output from the program FRONTIER (Version 4.1c)

instruction file = PreME.ins
data file =   Pre.dta

 Error Components Frontier (see B&C 1992)
 The model is a production function
 The dependent variable is logged

the ols estimates are :

```
                 coefficient      standard-error      t-ratio

  beta 0        0.56531947E+01  0.91888768E+00  0.61522151E+01
  beta 1        0.34295852E+00  0.81557484E-01  0.42051140E+01
  beta 2        0.50979795E+00  0.11706427E+00  0.43548551E+01
  sigma-squared  0.94469411E+00
```

log likelihood function = -0.12222788E+03

the estimates after the grid search were :

```
  beta 0        0.62303932E+01
  beta 1        0.34295852E+00
  beta 2        0.50979795E+00
  sigma-squared  0.12460087E+01
  gamma         0.42000000E+00
   mu is restricted to be zero
   eta is restricted to be zero
```

```
 iteration =     0  func evals =     19  llf = -0.12030866E+03
     0.62303932E+01 0.34295852E+00 0.50979795E+00 0.12460087E+01 0.42000000E+00
 gradient step
 iteration =     5  func evals =     62  llf = -0.11996637E+03
     0.69967355E+01 0.29006218E+00 0.53053946E+00 0.13658803E+01 0.49125890E+00
 search failed. loc of min limited by rounding
 iteration =    10  func evals =    147  llf = -0.11995756E+03
     0.70776979E+01 0.28907392E+00 0.52662747E+00 0.14180628E+01 0.50685569E+00
```

the final mle estimates are :

```
                 coefficient      standard-error      t-ratio

  beta 0        0.70776979E+01  0.11790660E+01  0.60028003E+01
  beta 1        0.28907392E+00  0.82131265E-01  0.35196575E+01
  beta 2        0.52662747E+00  0.13012665E+00  0.40470378E+01
  sigma-squared  0.14180628E+01  0.48351959E+00  0.29327930E+01
```

```
  gamma            0.50685569E+00   0.20967287E+00   0.24173642E+01
   mu is restricted to be zero
   eta is restricted to be zero


log likelihood function =  -0.11995756E+03

LR test of the one-sided error =   0.45406240E+01
with number of restrictions = 1
 [note that this statistic has a mixed chi-square distribution]

number of iterations =      10

(maximum number of iterations set at :    100)

number of cross-sections =     24

number of time periods =       7

total number of observations =     89

thus there are:     79  obsns not in the panel


covariance matrix :

  0.13901967E+01 -0.38684727E-01 -0.54719597E-01  0.25384273E+00  0.12360813E+00
 -0.38684727E-01  0.67455446E-02 -0.74823052E-02 -0.96475825E-02 -0.48244897E-02
 -0.54719597E-01 -0.74823052E-02  0.16932945E-01  0.14574635E-02  0.61943561E-03
  0.25384273E+00 -0.96475825E-02  0.14574635E-02  0.23379119E+00  0.90998702E-01
  0.12360813E+00 -0.48244897E-02  0.61943561E-03  0.90998702E-01  0.43962713E-01



technical efficiency estimates :


     firm          eff.-est.

       1          0.66861022E+00
       2          0.85869480E+00
       3          0.51692203E+00
       4          0.45199161E+00
       5          0.46204248E+00
       6          0.30632259E+00
       7          0.33817814E+00
       8          0.51721575E+00
       9          0.82961421E+00
      10          0.83596564E+00
      11          0.53284969E+00
      12          0.54886345E+00
      13          0.62786467E+00
      14          0.56471842E+00
      15          0.41871860E+00
      16          0.77405296E+00
      17          0.46816988E+00
      18          0.56708604E+00
      19          0.71861499E+00
      20          0.33846383E+00
      21          0.74534804E+00
      22          0.30771676E+00
      23          0.36360339E+00
```

```
       24                0.38544069E+00


mean efficiency =   0.54779454E+00




summary of panel of observations:
(1 = observed, 0 = not observed)

  t:   1   2   3   4   5   6   7
  n
  1    1   1   0   1   0   0   1   4
  2    1   1   0   1   0   0   1   4
  3    1   1   0   1   0   0   1   4
  4    1   1   0   1   0   0   1   4
  5    1   1   0   0   0   0   1   3
  6    1   1   0   1   0   0   1   4
  7    1   1   0   1   0   0   1   4
  8    0   1   0   1   0   0   1   3
  9    1   1   0   1   0   0   1   4
 10    0   1   0   0   0   0   1   2
 11    1   1   0   1   0   0   1   4
 12    1   1   0   1   0   0   1   4
 13    1   1   0   1   0   0   1   4
 14    1   1   0   1   0   0   1   4
 15    1   1   0   1   0   0   1   4
 16    1   1   0   1   0   0   1   4
 17    1   1   0   1   0   0   1   4
 18    0   1   0   1   0   0   1   3
 19    1   1   0   1   0   0   1   4
 20    1   0   0   1   0   0   1   3
 21    1   1   0   1   0   0   1   4
 22    1   1   0   1   0   0   1   4
 23    1   1   0   1   0   0   1   4
 24    1   1   0   0   0   0   1   3

      21  23   0  21   0   0  24  89
```

Appendix C – Outputs from Pitt and Lee's Model I (Further Preliminary Analysis)

Appendix C-2: Post-crisis Results

Output from the program FRONTIER (Version 4.1c)

instruction file = PostME.ins
data file =   Post.dta

 Error Components Frontier (see B&C 1992)
 The model is a production function
 The dependent variable is logged

the ols estimates are :

                  coefficient   standard-error   t-ratio

  beta 0   0.45196422E+01 0.88726413E+00 0.50939084E+01
  beta 1   0.51014675E+00 0.60700774E-01 0.84042874E+01
  beta 2   0.31814141E+00 0.73918569E-01 0.43039444E+01
  sigma-squared   0.38076334E+00

log likelihood function = -0.80855025E+02

the estimates after the grid search were :

  beta 0   0.48323959E+01
  beta 1   0.51014675E+00
  beta 2   0.31814141E+00
  sigma-squared   0.46559763E+00
  gamma   0.33000000E+00
   mu is restricted to be zero
    eta is restricted to be zero

 iteration =   0 func evals =   19 llf = -0.79485669E+02
     0.48323959E+01 0.51014675E+00 0.31814141E+00 0.46559763E+00 0.33000000E+00
 gradient step
 iteration =   5 func evals =   44 llf = -0.79473181E+02
     0.49408265E+01 0.50837069E+00 0.31236319E+00 0.47902716E+00 0.34453067E+00
 iteration =   8 func evals =   87 llf = -0.79473178E+02
     0.49409410E+01 0.50838051E+00 0.31234791E+00 0.47926260E+00 0.34465831E+00

the final mle estimates are :

                  coefficient   standard-error   t-ratio

  beta 0   0.49409410E+01 0.99718426E+00 0.49548927E+01
  beta 1   0.50838051E+00 0.66586739E-01 0.76348612E+01
  beta 2   0.31234791E+00 0.82923384E-01 0.37667049E+01
  sigma-squared   0.47926260E+00 0.13654149E+00 0.35100144E+01
  gamma   0.34465831E+00 0.22044906E+00 0.15634374E+01
   mu is restricted to be zero

```
   eta is restricted to be zero

log likelihood function =  -0.79473178E+02

LR test of the one-sided error =   0.27636930E+01
with number of restrictions = 1
 [note that this statistic has a mixed chi-square distribution]

number of iterations =      8

(maximum number of iterations set at :   100)

number of cross-sections =     24

number of time periods =      5

total number of observations =     88

thus there are:     32  obsns not in the panel


covariance matrix :

  0.99437644E+00 -0.41822800E-01 -0.20892511E-01  0.28158992E-01  0.53899565E-01
 -0.41822800E-01  0.44337939E-02 -0.32095063E-02 -0.17046003E-03 -0.40206578E-03
 -0.20892511E-01 -0.32095063E-02  0.68762876E-02 -0.72873596E-03 -0.15048955E-02
  0.28158992E-01 -0.17046003E-03 -0.72873596E-03  0.18643579E-01  0.25564473E-01
  0.53899565E-01 -0.40206578E-03 -0.15048955E-02  0.25564473E-01  0.48597789E-01



technical efficiency estimates :


     firm          eff.-est.

      1           0.81898032E+00
      2           0.93508104E+00
      3           0.70295378E+00
      4           0.80950666E+00
      5           0.68342552E+00
      6           0.72172206E+00
      7           0.60202389E+00
      8           0.67198106E+00
      9           0.74857382E+00
     10           0.79673521E+00
     11           0.72958517E+00
     12           0.78322121E+00
     13           0.71408711E+00
     14           0.52300900E+00
     15           0.73778208E+00
     16           0.76234736E+00
     17           0.90709317E+00
     18           0.72970955E+00
     19           0.82438416E+00
     20           0.62672567E+00
     21           0.83873201E+00
     22           0.65144628E+00
     23           0.61026618E+00
     24           0.73941322E+00
```

```
mean efficiency =   0.73619940E+00
```

```
summary of panel of observations:
(1 = observed, 0 = not observed)

  t:   1   2   3   4   5
  n
  1    1   1   1   0   1   4
  2    1   1   1   0   1   4
  3    1   1   1   0   1   4
  4    1   1   1   0   1   4
  5    1   1   1   0   0   3
  6    1   1   1   0   0   3
  7    1   1   1   0   1   4
  8    1   1   1   0   1   4
  9    1   1   1   0   1   4
 10    1   1   1   0   1   4
 11    1   1   1   0   1   4
 12    1   1   1   0   1   4
 13    1   1   1   0   1   4
 14    1   1   1   0   0   3
 15    1   1   1   0   1   4
 16    1   1   1   0   1   4
 17    1   1   1   0   1   4
 18    1   0   0   0   1   2
 19    1   1   1   0   0   3
 20    1   1   1   0   0   3
 21    1   1   1   0   1   4
 22    1   1   1   0   1   4
 23    1   1   1   0   1   4
 24    1   1   1   0   0   3

      24  23  23   0  18  88
```

Appendix D - Output from the Pre-Crisis Model 4 (Battese, Coelli, and Colby (1989))

Output from the program FRONTIER (Version 4.1c)

instruction file = PreE.ins
data file =   Pre.dta

 Error Components Frontier (see B&C 1992)
 The model is a production function
 The dependent variable is logged

the ols estimates are :

              coefficient   standard-error   t-ratio

 beta 0   0.56531947E+01 0.91888768E+00 0.61522151E+01
 beta 1   0.34295852E+00 0.81557484E-01 0.42051140E+01
 beta 2   0.50979795E+00 0.11706427E+00 0.43548551E+01
 sigma-squared 0.94469411E+00

log likelihood function = -0.12222788E+03

the estimates after the grid search were :

 beta 0   0.62303932E+01
 beta 1   0.34295852E+00
 beta 2   0.50979795E+00
 sigma-squared 0.12460087E+01
 gamma   0.42000000E+00
 mu   0.00000000E+00
  eta is restricted to be zero

 iteration =   0 func evals =   19 llf = -0.12030866E+03
    0.62303932E+01 0.34295852E+00 0.50979795E+00 0.12460087E+01 0.42000000E+00
    0.00000000E+00
 gradient step
 iteration =   5 func evals =   46 llf = -0.11948578E+03
    0.67240125E+01 0.28083414E+00 0.59471217E+00 0.12799744E+01 0.49141177E+00
    0.77736792E+00
 iteration =   10 func evals =   86 llf = -0.11791988E+03
    0.73334931E+01 0.28125972E+00 0.56250601E+00 0.97380733E+00 0.34636838E+00
    0.11615439E+01
 pt better than entering pt cannot be found
 iteration =   11 func evals =   95 llf = -0.11791988E+03
    0.73334931E+01 0.28125972E+00 0.56250601E+00 0.97380733E+00 0.34636838E+00
    0.11615439E+01

the final mle estimates are :

              coefficient   standard-error   t-ratio
 beta 0   0.73334931E+01 0.11877015E+01 0.61745255E+01
 beta 1   0.28125972E+00 0.83177197E-01 0.33814523E+01
 beta 2   0.56250601E+00 0.12700381E+00 0.44290481E+01
 sigma-squared 0.97380733E+00 0.20144854E+00 0.48340253E+01
 gamma   0.34636838E+00 0.16139926E+00 0.21460345E+01

```
     mu          0.11615439E+01  0.32283075E+00  0.35979965E+01
   eta is restricted to be zero
```

log likelihood function = -0.11791988E+03

LR test of the one-sided error =   0.86159889E+01
with number of restrictions = 2
 [note that this statistic has a mixed chi-square distribution]

number of iterations =   11

(maximum number of iterations set at :   100)

number of cross-sections =   24

number of time periods =   7

total number of observations =   89

thus there are: 79 obsns not in the panel

covariance matrix :

```
 0.14106348E+01 -0.43806267E-01 -0.64569113E-01  0.86722604E-01  0.88010819E-01
-0.80351869E-01
-0.43806267E-01  0.69184461E-02 -0.63348259E-02 -0.44221623E-02 -0.43591676E-02
 0.75998400E-02
-0.64569113E-01 -0.63348259E-02  0.16129969E-01  0.59971393E-03 -0.63965798E-03
 0.27062099E-02
 0.86722604E-01 -0.44221623E-02  0.59971393E-03  0.40581514E-01  0.24126997E-01
 0.80375819E-02
 0.88010819E-01 -0.43591676E-02 -0.63965798E-03  0.24126997E-01  0.26049722E-01
-0.38070631E-02
-0.80351869E-01  0.75998400E-02  0.27062099E-02  0.80375819E-02 -0.38070631E-02
 0.10421969E+00
```


technical efficiency estimates :

firm	eff.-est.
1	0.38267330E+00
2	0.71588217E+00
3	0.27666948E+00
4	0.24124861E+00
5	0.26173204E+00
6	0.17704686E+00
7	0.19439030E+00
8	0.29090070E+00
9	0.64315860E+00
10	0.71565743E+00
11	0.29673980E+00
12	0.30232863E+00
13	0.35722992E+00
14	0.31767256E+00
15	0.23252730E+00

```
16        0.52573475E+00
17        0.27449924E+00
18        0.31894090E+00
19        0.44879908E+00
20        0.19821586E+00
21        0.48239350E+00
22        0.18460789E+00
23        0.20713378E+00
24        0.21909572E+00
```

mean efficiency =   0.34438660E+00

summary of panel of observations:
(1 = observed, 0 = not observed)

```
 t:  1  2  3  4  5  6  7
 n
 1   1  1  0  1  0  0  1  4
 2   1  1  0  1  0  0  1  4
 3   1  1  0  1  0  0  1  4
 4   1  1  0  1  0  0  1  4
 5   1  1  0  0  0  0  1  3
 6   1  1  0  1  0  0  1  4
 7   1  1  0  1  0  0  1  4
 8   0  1  0  1  0  0  1  3
 9   1  1  0  1  0  0  1  4
10   0  1  0  0  0  0  1  2
11   1  1  0  1  0  0  1  4
12   1  1  0  1  0  0  1  4
13   1  1  0  1  0  0  1  4
14   1  1  0  1  0  0  1  4
15   1  1  0  1  0  0  1  4
16   1  1  0  1  0  0  1  4
17   1  1  0  1  0  0  1  4
18   0  1  0  1  0  0  1  3
19   1  1  0  1  0  0  1  4
20   1  0  0  1  0  0  1  3
21   1  1  0  1  0  0  1  4
22   1  1  0  1  0  0  1  4
23   1  1  0  1  0  0  1  4
24   1  1  0  0  0  0  1  3

    21 23  0 21  0  0 24 89
```

Appendix E - Output from the Post-Crisis Model 2 (Battese and Coelli (1992))

Output from the program FRONTIER (Version 4.1c)

instruction file = Post.ins
data file =   Post.dta

 Error Components Frontier (see B&C 1992)
 The model is a production function
 The dependent variable is logged

the ols estimates are :

              coefficient   standard-error   t-ratio

 beta 0   0.45196422E+01 0.88726413E+00 0.50939084E+01
 beta 1   0.51014675E+00 0.60700774E-01 0.84042874E+01
 beta 2   0.31814141E+00 0.73918569E-01 0.43039444E+01
 sigma-squared 0.38076334E+00

log likelihood function = -0.80855025E+02

the estimates after the grid search were :

 beta 0   0.48323959E+01
 beta 1   0.51014675E+00
 beta 2   0.31814141E+00
 sigma-squared 0.46559763E+00
 gamma   0.33000000E+00
 mu   0.00000000E+00
 eta   0.00000000E+00

 iteration =   0 func evals =   19 llf = -0.79485669E+02
    0.48323959E+01 0.51014675E+00 0.31814141E+00 0.46559763E+00 0.33000000E+00
    0.00000000E+00 0.00000000E+00
 gradient step
 iteration =   5 func evals =   49 llf = -0.74919813E+02
    0.48777400E+01 0.57566411E+00 0.22684648E+00 0.31431598E+00 0.19606425E+00
    0.48548592E-01 0.26450633E+00
 iteration =   10 func evals =   118 llf = -0.71401286E+02
    0.64819247E+01 0.50222504E+00 0.20640626E+00 0.25539936E+00 0.81227679E-01
    0.28806594E+00 0.26532005E+00
 pt better than entering pt cannot be found
 iteration =   12 func evals =   140 llf = -0.71400520E+02
    0.64825369E+01 0.50223172E+00 0.20643327E+00 0.25552501E+00 0.80892216E-01
    0.28754119E+00 0.26494515E+00

the final mle estimates are :

```
          coefficient     standard-error     t-ratio
```

```
 beta 0        0.64825369E+01  0.99867376E+00  0.64911457E+01
 beta 1        0.50223172E+00  0.65393424E-01  0.76801563E+01
 beta 2        0.20643327E+00  0.10190892E+00  0.20256644E+01
 sigma-squared 0.25552501E+00  0.35581196E-01  0.71814621E+01
 gamma         0.80892216E-01  0.80279621E-01  0.10076308E+01
 mu            0.28754119E+00  0.83448622E-01  0.34457273E+01
 eta           0.26494515E+00  0.85155020E-01  0.31113275E+01
```

log likelihood function = -0.71400520E+02

LR test of the one-sided error =   0.18909009E+02
with number of restrictions = 3
 [note that this statistic has a mixed chi-square distribution]

number of iterations =   12

(maximum number of iterations set at :   100)

number of cross-sections =   24

number of time periods =   5

total number of observations =   88

thus there are: 32 obsns not in the panel

covariance matrix :

```
 0.99734927E+00 -0.25721755E-01 -0.44201582E-01 -0.23354317E-02  0.49883623E-02
 0.76432224E-02  0.24280398E-01
-0.25721755E-01  0.42762999E-02 -0.43631926E-02  0.27350684E-03 -0.88245918E-03
-0.83109111E-03  0.13887025E-02
-0.44201582E-01 -0.43631926E-02  0.10385428E-01 -0.19036248E-03  0.10771420E-02
 0.86067390E-03 -0.42863484E-02
-0.23354317E-02  0.27350684E-03 -0.19036248E-03  0.12660215E-02  0.85701273E-03
 0.12317418E-02 -0.14602774E-02
 0.49883623E-02 -0.88245918E-03  0.10771420E-02  0.85701273E-03  0.64448176E-02
 0.21125396E-02 -0.38307837E-02
 0.76432224E-02 -0.83109111E-03  0.86067390E-03  0.12317418E-02  0.21125396E-02
 0.69636725E-02 -0.51660890E-02
 0.24280398E-01  0.13887025E-02 -0.42863484E-02 -0.14602774E-02 -0.38307837E-02
-0.51660890E-02  0.72513775E-02
```


technical efficiency estimates :

efficiency estimates for year   1 :

```
     firm          eff.-est.

      1         0.65085499E+00
```

2	0.72099438E+00
3	0.46385477E+00
4	0.57514448E+00
5	0.37059393E+00
6	0.42917342E+00
7	0.30556804E+00
8	0.32923494E+00
9	0.40753963E+00
10	0.35830181E+00
11	0.41730202E+00
12	0.53163311E+00
13	0.44109817E+00
14	0.25912143E+00
15	0.42495135E+00
16	0.46272951E+00
17	0.71815951E+00
18	0.43473938E+00
19	0.59584315E+00
20	0.31588410E+00
21	0.57514873E+00
22	0.27637816E+00
23	0.31770066E+00
24	0.42245784E+00

mean eff. in year   1 = 0.45018365E+00

efficiency estimates for year   2 :

firm	eff.-est.
1	0.71590682E+00
2	0.77515907E+00
3	0.55133478E+00
4	0.65059535E+00
5	0.46396206E+00
6	0.51928192E+00
7	0.40020924E+00
8	0.42378429E+00
9	0.49917373E+00
10	0.45220715E+00
11	0.50832694E+00
12	0.61230892E+00
13	0.53043818E+00
14	0.35257502E+00
15	0.51546496E+00
16	0.55030692E+00
17	0.77278536E+00
18	no observation in this period
19	0.66851304E+00
20	0.41044415E+00
21	0.65059907E+00
22	0.37053712E+00
23	0.41234582E+00

24   0.51303154E+00

mean eff. in year   2 = 0.53562137E+00

efficiency estimates for year   3 :

    firm   eff.-est.

     1   0.77165496E+00
     2   0.82067715E+00
     3   0.63104233E+00
     4   0.71672596E+00
     5   0.55269669E+00
     6   0.60260413E+00
     7   0.49350091E+00
     8   0.51565618E+00
     9   0.58468564E+00
    10   0.54199055E+00
    11   0.59289665E+00
    12   0.68402490E+00
    13   0.61259503E+00
    14   0.44771833E+00
    15   0.59927657E+00
    16   0.63013862E+00
    17   0.81872694E+00
    18   no observation in this period
    19   0.73183582E+00
    20   0.50308969E+00
    21   0.71672912E+00
    22   0.46517813E+00
    23   0.50494339E+00
    24   0.59702835E+00

mean eff. in year   3 = 0.61458331E+00

efficiency estimates for year   4 :

    firm   eff.-est.

     1   no observation in this period
     2   no observation in this period
     3   no observation in this period
     4   no observation in this period
     5   no observation in this period
     6   no observation in this period
     7   no observation in this period
     8   no observation in this period
     9   no observation in this period
    10   no observation in this period

```
    11   no observation in this period
    12   no observation in this period
    13   no observation in this period
    14   no observation in this period
    15   no observation in this period
    16   no observation in this period
    17   no observation in this period
    18   no observation in this period
    19   no observation in this period
    20   no observation in this period
    21   no observation in this period
    22   no observation in this period
    23   no observation in this period
    24   no observation in this period
```

mean eff. in year   4 =-NaN

efficiency estimates for year   5 :

```
    firm          eff.-est.

     1          0.85653855E+00
     2          0.88857409E+00
     3          0.76044372E+00
     4          0.81981814E+00
     5   no observation in this period
     6   no observation in this period
     7          0.65795577E+00
     8          0.67518707E+00
     9          0.72702138E+00
    10          0.69527796E+00
    11          0.73301672E+00
    12          0.79748794E+00
    13          0.74726501E+00
    14   no observation in this period
    15          0.73765198E+00
    16          0.75980169E+00
    17          0.88731197E+00
    18          0.74150689E+00
    19   no observation in this period
    20   no observation in this period
    21          0.81982028E+00
    22          0.63545716E+00
    23          0.66689399E+00
    24   no observation in this period
```

mean eff. in year   5 = 0.75594613E+00

summary of panel of observations:
(1 = observed, 0 = not observed)

```
 t:  1  2  3  4  5
 n
 1   1  1  1  0  1  4
 2   1  1  1  0  1  4
 3   1  1  1  0  1  4
 4   1  1  1  0  1  4
 5   1  1  1  0  0  3
 6   1  1  1  0  0  3
 7   1  1  1  0  1  4
 8   1  1  1  0  1  4
 9   1  1  1  0  1  4
10   1  1  1  0  1  4
11   1  1  1  0  1  4
12   1  1  1  0  1  4
13   1  1  1  0  1  4
14   1  1  1  0  0  3
15   1  1  1  0  1  4
16   1  1  1  0  1  4
17   1  1  1  0  1  4
18   1  0  0  0  1  2
19   1  1  1  0  0  3
20   1  1  1  0  0  3
21   1  1  1  0  1  4
22   1  1  1  0  1  4
23   1  1  1  0  1  4
24   1  1  1  0  0  3

    24 23 23  0 18 88
```

Appendix F - Techinical Efficiency Effects Model

Output from the program FRONTIER (Version 4.1c)

instruction file = PostLM.ins
data file =   PostLM.dta

 Tech. Eff. Effects Frontier (see B&C 1993)
 The model is a production function
 The dependent variable is logged

the ols estimates are :

              coefficient   standard-error   t-ratio

 beta 0   0.45196422E+01 0.88726413E+00 0.50939084E+01
 beta 1   0.51014675E+00 0.60700774E-01 0.84042874E+01
 beta 2   0.31814141E+00 0.73918569E-01 0.43039444E+01
 sigma-squared 0.38076334E+00

log likelihood function = -0.80855025E+02

the estimates after the grid search were :

 beta 0   0.46296048E+01
 beta 1   0.51014675E+00
 beta 2   0.31814141E+00
 delta 1   0.00000000E+00
 delta 2   0.00000000E+00
 sigma-squared 0.37987455E+00
 gamma   0.50000000E-01

 iteration =   0 func evals =   20 llf = -0.80905933E+02
    0.46296048E+01 0.51014675E+00 0.31814141E+00 0.00000000E+00 0.00000000E+00
    0.37987455E+00 0.50000000E-01
 gradient step
 iteration =   5 func evals =   46 llf = -0.79912416E+02
    0.46277200E+01 0.52531190E+00 0.29434527E+00 0.82470024E-03-0.24234342E-04
    0.38117308E+00 0.34006271E-01
 iteration =   10 func evals =   101 llf = -0.76886393E+02
    0.40497484E+01 0.56060460E+00 0.29504622E+00 0.13406546E-02-0.60831137E-04
    0.34483863E+00 0.10000000E-07
 pt better than entering pt cannot be found
 iteration =   13 func evals =   143 llf = -0.76856334E+02
    0.40996757E+01 0.54468589E+00 0.31524269E+00 0.13411299E-02-0.63786323E-04
    0.33795805E+00 0.10000000E-07

the final mle estimates are :

              coefficient   standard-error   t-ratio

 beta 0   0.40996757E+01 0.90595449E+00 0.45252557E+01
 beta 1   0.54468589E+00 0.91089543E-01 0.59796752E+01

```
beta 2        0.31524269E+00  0.11790559E+00  0.26736875E+01
delta 1       0.13411299E-02  0.52233096E-03  0.25675864E+01
delta 2      -0.63786323E-04  0.28037510E-04 -0.22750352E+01
sigma-squared 0.33795805E+00  0.54855873E-01  0.61608361E+01
gamma         0.10000000E-07  0.18970842E-03  0.52712474E-04
```

log likelihood function = -0.76856334E+02

LR test of the one-sided error =   0.79973823E+01
with number of restrictions = 3
 [note that this statistic has a mixed chi-square distribution]

number of iterations =   13

(maximum number of iterations set at :   100)

number of cross-sections =   24

number of time periods =   5

total number of observations =   88

thus there are: 32 obsns not in the panel

covariance matrix :

```
 0.82075353E+00 -0.44058218E-01 -0.47796445E-02 -0.60479420E-04  0.16315903E-05
-0.75755710E-03  0.10091891E-04
-0.44058218E-01  0.82973049E-02 -0.88016344E-02  0.19473984E-04  0.15157229E-06
-0.13540738E-03  0.50138588E-05
-0.47796445E-02 -0.88016344E-02  0.13901727E-01 -0.22710279E-04 -0.46435174E-06
 0.31503301E-03 -0.85576572E-05
-0.60479420E-04  0.19473984E-04 -0.22710279E-04  0.27282963E-06 -0.11292729E-07
 0.26384348E-05  0.28388403E-07
 0.16315903E-05  0.15157229E-06 -0.46435174E-06 -0.11292729E-07  0.78610199E-09
-0.49773880E-07 -0.15083621E-08
-0.75755710E-03 -0.13540738E-03  0.31503301E-03  0.26384348E-05 -0.49773880E-07
 0.30091668E-02 -0.52523433E-06
 0.10091891E-04  0.50138588E-05 -0.85576572E-05  0.28388403E-07 -0.15083621E-08
-0.52523433E-06  0.35989284E-07
```


technical efficiency estimates :

firm	year	eff.-est.
1	1	0.84454851E+00
2	1	0.90370665E+00
3	1	0.88204460E+00
4	1	0.95238019E+00
5	1	0.83743116E+00
6	1	0.95584826E+00
7	1	0.84973938E+00
8	1	0.78906547E+00
9	1	0.78864315E+00
10	1	0.72611480E+00

11	1	0.81194524E+00
12	1	0.83704631E+00
13	1	0.54976922E+00
14	1	0.76594093E+00
15	1	0.81330547E+00
16	1	0.88268806E+00
17	1	0.98974613E+00
18	1	0.94044761E+00
19	1	0.85527070E+00
20	1	0.88592163E+00
21	1	0.68660782E+00
22	1	0.81628160E+00
23	1	0.75555152E+00
24	1	0.88264808E+00
1	2	0.85318641E+00
2	2	0.92008038E+00
3	2	0.93511157E+00
4	2	0.96891648E+00
5	2	0.88869728E+00
6	2	0.98093001E+00
7	2	0.90454530E+00
8	2	0.83882841E+00
9	2	0.79021996E+00
10	2	0.48931281E+00
11	2	0.84415813E+00
12	2	0.93270581E+00
13	2	0.32577951E+00
14	2	0.77800177E+00
15	2	0.84748952E+00
16	2	0.84225124E+00
17	2	0.94672487E+00
19	2	0.94085408E+00
20	2	0.95864040E+00
21	2	0.66576610E+00
22	2	0.83408638E+00
23	2	0.78305052E+00
24	2	0.94418795E+00
1	3	0.86743998E+00
2	3	0.95633168E+00
3	3	0.96933826E+00
4	3	0.97787214E+00
5	3	0.93386443E+00
6	3	0.94035678E+00
7	3	0.91998252E+00
8	3	0.85449549E+00
9	3	0.81248274E+00
10	3	0.77485500E+00
11	3	0.79802649E+00
12	3	0.88804472E+00
13	3	0.69228774E+00
14	3	0.74645747E+00
15	3	0.89757340E+00
16	3	0.90631768E+00
17	3	0.94719760E+00
19	3	0.98188176E+00
20	3	0.97059188E+00
21	3	0.74632372E+00

```
22   3        0.92838263E+00
23   3        0.93001007E+00
24   3        0.85593195E+00
 1   5        0.87244456E+00
 2   5        0.99385199E+00
 3   5        0.92416307E+00
 4   5        0.94077943E+00
 7   5        0.87608674E+00
 8   5        0.86337316E+00
 9   5        0.83533002E+00
10   5        0.10000000E+01
11   5        0.85930050E+00
12   5        0.91819325E+00
13   5        0.72704633E+00
15   5        0.89628431E+00
16   5        0.88782715E+00
17   5        0.99332597E+00
18   5        0.92340092E+00
21   5        0.75351400E+00
22   5        0.89398667E+00
23   5        0.94505478E+00
```

mean efficiency =   0.84963916E+00

summary of panel of observations:
(1 = observed, 0 = not observed)

```
 t:  1  2  3  4  5
 n
 1   1  1  1  0  1   4
 2   1  1  1  0  1   4
 3   1  1  1  0  1   4
 4   1  1  1  0  1   4
 5   1  1  1  0  0   3
 6   1  1  1  0  0   3
 7   1  1  1  0  1   4
 8   1  1  1  0  1   4
 9   1  1  1  0  1   4
10   1  1  1  0  1   4
11   1  1  1  0  1   4
12   1  1  1  0  1   4
13   1  1  1  0  1   4
14   1  1  1  0  0   3
15   1  1  1  0  1   4
16   1  1  1  0  1   4
17   1  1  1  0  1   4
18   1  0  0  0  1   2
19   1  1  1  0  0   3
20   1  1  1  0  0   3
21   1  1  1  0  1   4
22   1  1  1  0  1   4
23   1  1  1  0  1   4
24   1  1  1  0  0   3

    24 23 23  0 18  88
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<u>Table G-1</u>: Value Added at the industrial level

	Industry	1990	1991	1993	1996	1998	1999	2000	2002
1	Food and Beverages	127086381	106635416	156192078	183232011.4	162391802.4	96320522.46	102159302.6	169319404.1
2	Tobacco	41520767	47883097	25464954	30668864.5	688657.3	32190998.44	32917422.6	69751332.4
3	Textiles	180754595	51372604	84085319	46467258.6	44714336.8	53942427.62	58318598.9	49913611.4
4	Wearing Apparel	26857462	84141895	67127155	23666411.2	21418364.4	35779693.69	21588721.6	42236228.2
5	Leather and Products of Leather,	1569557	15392265	3324653	5078839.1	6310771.5	3189609.9	3594362.2	8306880.8
6	Footwear	1611955	7317173	7421903	8816797.1	8006977.9	6980110.75	11191752.1	10379216.3
7	Wood Products	5959281	10439171	7545267	14983080	5495630.1	8813392.07	8906999.1	20001097.6
8	Paper Products	194798	4097557	18932736	32120268.6	11700919	7528894.17	22476912.5	52563811.2
9	Publishing	5196640	565470048	42073238	30087252	8234578.4	17705230.14	13666655.2	26141197.8
10	Coke, Refined Petroleum Products and Nuclear Fuel	n/a	131471393	134764957	33038763.2	1157268.6	12843138.76	29131971.2	79538318.5
11	Chemical Products	11324607	46314379	18371602	58880444.1	28616126.9	44678157.31	47002183.1	81680357.5
12	Rubber and Plastic Products	34927076	31487210	33444891	63081690.7	43492217.9	53764236.94	46496489.6	71184017.2
13	Other Non-Metallic Mineral Products	74703835	84477920	61361502	65018376	57346525.9	35222261.76	48687592.5	55767996.5
14	Basic Metals	11266988	36888673	46455490	17821870.3	9966793.3	14805317.42	17572447.9	34981163
15	Fabricated Metal Products	15472720	27714470	13759449	35207502.7	21291163.7	22825161.72	31910796.4	69280265.6
16	Machinery and Equipment	49351053	172678466	71812692	38512619	34982976.8	23414663.99	28994265.3	66655764
17	Office and Computing Machinery	8919	1563444	2915253	28023746.7	20339202.1	21209022.4	41925931.6	61038634.4
18	Electrical Machinery and Apparatus	24917531	25020389	15923318	40072948.1	18873188.6	21992089.85	38682872.1	29289664.4
19	Communication Equipment	39634272	93417839	33267777	47977429.1	42345219.8	28945697.74	72898227.1	166763128.3
20	Medical, Precision and Optical Instruments	1491073	3218459	789662	11917626.9	4054296.7	4013718.74	5713098.7	8112617.7
21	Motor Vehicles	21521740	97374615	29768662	139673043.4	72278363.7	40309249.98	49929964.2	151731395.3
22	Other Transport Equipment	241471	3124704	15425366	6666653.7	3990628.8	2155589.95	4714112.2	22834994.7
23	Furniture	15946122	7027309	3770973	14424684.7	9154099.9	7644800.5	11697332	19564625.6
24	Jewellery	1361045	12303381	9814812	9183942.4	4473935.2	8229415.95	5817432.4	10761747.7

<u>Table G-2</u>: Book value of Capital at the industrial level

	Industry	1990	1991	1993	1996	1998	1999	2000	2002
1	Food and Beverages	77595791	75792933	110117088	417831531	215955891.4	163900780.7	270779114.1	242720681.7
2	Tobacco	6240783	241667	3993945	9490772	1087067.3	5477158.32	4570816.6	8337219.3
3	Textiles	51770169	59439108	77669033	286220320	93492362.8	74037646.86	280588060.9	98295289.5
4	Wearing Apparel	13078867	23466028	43995219	41875311.2	20089665	25742831.53	10153378.7	45352135.6
5	Leather and Products of Leather,	877507	23161789	n/a	8649309	5359736.9	5151581.7	3527633.5	-91508387.9
6	Footwear	913294	2494667	2567877	16269173.2	9099820.2	3896821.51	9700195.3	-973559174.4
7	Wood Products	24491533	6530644	6904152	38801386.8	13704595.2	13034508.46	16183704.8	31927933.1
8	Paper Products	n/a	4485961	26425696	108265807.4	37621695.4	39858527.82	48657144.3	106377917.6
9	Publishing	5544875	5221123	4315452	49576582.4	13868844.9	35200536.43	24091706.2	22975674.9
10	Coke, Refined Petroleum Products and Nuclear Fuel	n/a	14338040	n/a	322123549.8	1481916.6	120895114.8	265634931.4	216640567.4
11	Chemical Products	8845343	58604340	32054619	293874557.6	150931877.5	145664781.6	127259608.6	247325677.2
12	Rubber and Plastic Products	35896182	37460539	20645441	189758674	80160777.2	77274423.67	85192173.1	97571041.5
13	Other Non-Metallic Mineral Products	56022513	90161021	153692381	300629715.4	185856562.9	181590256.7	59302496.9	195117780.9
14	Basic Metals	7141772	35405193	72723726	64065445.6	84349380.3	90204728.28	103180076.1	-125025013.2
15	Fabricated Metal Products	20172551	18920595	25152178	194666249.2	55698688.6	51874712	48718376.7	86012211.6
16	Machinery and Equipment	25379662	18441900	18036709	159338110.8	83388692.2	51911426.65	55079731.9	107473858.1
17	Office and Computing Machinery	1149	479141	829132	48247863.2	22125532.4	12398709.88	18391770.9	29540546.9
18	Electrical Machinery and Apparatus	n/a	16385869	16274801	113107614	39655700.1	-3770073.87	-106103454.9	51393951.1
19	Communication Equipment	11223609	9665952	60779554	272308124	85749148	31516813.83	47830779.5	-7656664.8
20	Medical, Precision and Optical Instruments	512917	n/a	2970813	18550162.6	8053888.3	6286082.66	10634081.1	-90613135.7
21	Motor Vehicles	4507867	28330337	22802186	259413944.2	114591156.4	172496262.7	154708833.7	117422513.5
22	Other Transport Equipment	1303780	2835933	18092533	15300198.8	12354361.5	5476460.48	7319809.2	12267252.4
23	Furniture	20385639	5095489	4480132	30467557.6	19408497.3	20076939.81	12316358.1	23613236.3
24	Jewellery	815770	4355639	n/a	94707408.8	5555857.6	3546584.03	7297653.4	-202483229

Table G-3: Number of Employees at the industrial level

	Industry	1990	1991	1993	1996	1998	1999	2000	2002
1	Food and Beverages	299745	240137	333079	399195	376787	386021	388805	698158
2	Tobacco	31708	22485	23863	17150	8344	13295	11883	14206
3	Textiles	411204	276472	335330	224860	200519	225586	232594	309785
4	Wearing Apparel	300134	227349	546636	173702	138851	178098	144450	302140
5	Leather and Products of Leather,	12112	13400	16598	10107	21839	17754	21965	34566
6	Footwear	17762	63262	55074	62118	55946	65553	83909	85660
7	Wood Products	27659	44336	48187	58580	40741	56442	51965	110778
8	Paper Products	784	17391	21495	43207	28493	36191	44093	55707
9	Publishing	25526	32362	24021	47570	30923	48197	44221	55843
10	Coke, Refined Petroleum Products and Nuclear Fuel	0	2610	13965	7413	1579	3505	7986	6718
11	Chemical Products	33666	52197	57901	93274	61158	74431	86013	119056
12	Rubber and Plastic Products	58556	80953	100831	192242	174182	180362	189278	237329
13	Other Non-Metallic Mineral Products	107262	115271	86894	153973	128200	109351	128442	169393
14	Basic Metals	30701	47751	61387	43171	31369	38521	38177	55858
15	Fabricated Metal Products	53364	64629	74081	129347	105852	98930	102915	175143
16	Machinery and Equipment	65951	57707	62459	113280	94020	71559	82990	124969
17	Office and Computing Machinery	112	1283	2105	78661	34951	42123	60686	27433
18	Electrical Machinery and Apparatus	49276	38223	39472	84860	85854	103371	112965	78927
19	Communication Equipment	35657	35384	86174	113328	126503	102182	153417	275253
20	Medical, Precision and Optical Instruments	5472	10396	7076	25068	12643	18806	28180	33934
21	Motor Vehicles	40870	72036	53340	107222	78142	96485	101617	105348
22	Other Transport Equipment	3102	6072	30343	22296	16636	13496	24509	29110
23	Furniture	32015	28578	30288	86636	72321	71732	73010	136592
24	Jewellery	8043	33398	24040	30945	23254	33217	28479	49629

Table G-4: Book value of Land at the industrial level

	Industry	1998	1999	2000	2002
1	Food and Beverages	37046372	48942637	49566397	77732992
2	Tobacco	639853.9	994674.9	552365.4	383407.1
3	Textiles	21467422	13962271	17081357	21368406
4	Wearing Apparel	5507178	4914814	2573588	14287032
5	Leather and Products of Leather,	1164814	1633406	1169663	5096772
6	Footwear	2090927	1086586	4044809	3651702
7	Wood Products	5160306	4436809	3633458	13252977
8	Paper Products	3800274	6028758	7181979	10338176
9	Publishing	3045590	9428560	7420480	8049962
10	Coke, Refined Petroleum Products and Nuclear Fuel	412283.7	6402891	10040493	6705845
11	Chemical Products	9991806	14657450	19168110	23577648
12	Rubber and Plastic Products	10740496	11985951	19117986	17750844
13	Other Non-Metallic Mineral Products	53609545	94333837	40123379	45631671
14	Basic Metals	8295307	9987567	12116655	11401758
15	Fabricated Metal Products	8751608	13440397	9643859	23686718
16	Machinery and Equipment	11259166	10544253	7789321	14579315
17	Office and Computing Machinery	1164773	2078808	2964079	1340686
18	Electrical Machinery and Apparatus	5113802	5849001	7197734	6410311
19	Communication Equipment	7345257	5677568	4993570	14039044
20	Medical, Precision and Optical Instruments	1410003	727184.9	855828.7	1726981
21	Motor Vehicles	24998527	34227371	27241989	26585585
22	Other Transport Equipment	2814419	1908494	1544175	2773735
23	Furniture	8630142	13202252	4149481	6281328
24	Jewellery	2200084	1506835	3345168	4086328

Table G-5: Book value of Machinery and Equipments at the industrial level

	Industry	1998	1999	2000	2002
1	Food and Beverages	121317861	68150830.81	175326319	140814903
2	Tobacco	222878	3552344.25	3295561.8	6687798.8
3	Textiles	57154253.9	56293922.22	245584923	66253617
4	Wearing Apparel	9581481.2	15169821.36	3437260.5	11227422.4
5	Leather and Products of Leather,	2405470.6	1499718.34	1030570.4	6259297.1
6	Footwear	4448520.6	3058401.46	4147468.8	3582762
7	Wood Products	4498829.7	4513699.71	8450503.4	8793134
8	Paper Products	27468216.1	27040459.54	42306932.8	89063236.1
9	Publishing	6855023	20337146.04	12053803.4	11731406.1
10	Coke, Refined Petroleum Products and Nuclear Fuel	745795.1	95347989.37	179169144	210749786.2
11	Chemical Products	121809128	110490499.3	98786562.8	212701407.4
12	Rubber and Plastic Products	48323152.2	55023030.66	49636383.6	55666676.5
13	Other Non-Metallic Mineral Products	99710988.1	60718480.22	103088767	112899190.3
14	Basic Metals	55985584.9	58395490.4	79741521	112184083.4
15	Fabricated Metal Products	33879428	25941266.19	28417283.6	39751662.7
16	Machinery and Equipment	53133154	29100038.4	35793672.7	73435286.9
17	Office and Computing Machinery	18847804.8	7554185.36	10709931.8	25308428.7
18	Electrical Machinery and Apparatus	24892591.8	23626998.71	31896029.5	36171175.9
19	Communication Equipment	63890530.9	21706912.53	61014480.9	100601528.1
20	Medical, Precision and Optical Instruments	5637438.2	2836002.19	4807095.8	14545025.3
21	Motor Vehicles	64990467	104279785.3	106642523	69497309.2
22	Other Transport Equipment	6263086.1	1742020.27	3913735.4	7176200.4
23	Furniture	4568645.8	2560035.57	4192073.3	11051550.8
24	Jewellery	770525.5	1774804.15	877711.9	1536854.8

Table G-6: Book value of Office Appliances at the industrial level

	Industry	1998	1999	2000	2002
1	Food and Beverages	3303215	3546433	4949362	5858375
2	Tobacco	5675.2	75358.46	74656.1	85180.7
3	Textiles	1489444	765958.8	1609499	1293920
4	Wearing Apparel	1721153	2125797	1289827	1940660
5	Leather and Products of Leather,	135259.4	91295.07	115708.9	245170.9
6	Footwear	702017.3	659192.4	249554	372632
7	Wood Products	290814.2	226364.3	261504.5	303623.9
8	Paper Products	454346	867482.4	860445.7	1767618
9	Publishing	674459	818942.3	788670	1286579
10	Coke, Refined Petroleum Products and Nuclear Fuel	26902.2	2028558	1789970	246398.9
11	Chemical Products	2245841	2907675	4540424	3190010
12	Rubber and Plastic Products	4855236	1764922	2219099	2592334
13	Other Non-Metallic Mineral Products	5967916	1804387	1507459	2466865
14	Basic Metals	980112.5	732343.3	1366359	2071466
15	Fabricated Metal Products	1604216	861144.9	1022274	2361101
16	Machinery and Equipment	2065362	1483121	3098511	4864354
17	Office and Computing Machinery	290402	545298.2	706057.2	869513.8
18	Electrical Machinery and Apparatus	1944769	1748946	1466660	1981113
19	Communication Equipment	4011885	1289503	3504601	3733799
20	Medical, Precision and Optical Instruments	418979	165747.8	805149.1	1436469
21	Motor Vehicles	5597253	8496112	6059710	10172919
22	Other Transport Equipment	246557.3	387677.4	296717.7	241726.3
23	Furniture	510065.8	293195.1	366602	539072.9
24	Jewellery	342836.7	159910.4	723428.3	807990.8