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Curtin Business School

Liberalization Reform and Productivity Growth in Indonesia: Firm Level Evidence

Bernadetta Dwi Suatmi

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Declaration

To the best of my knowledge and belief, this thesis contains no material previously published by any other person except where due acknowledgement has been made.

This thesis contains no material that has been accepted for the award of any other degree or diploma in any university.

The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee (EC00262), Approval Number#E&F-07-12

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List of Abbreviations and Acronyms

AE	Allocative efficiency
AFTA	ASEAN Free Trade Area
APEC	Asia-Pacific Economic Cooperation
ASEAN	The Association of Southeast Asian Nations
BULOG	*Badan urusan logistic* (national logistic agency)
B-P	Breusch Pagan
BPPC	*Badan Penyangga dan Pemasaran Cengkeh* (cloves distributor)
BPS	Indonesian Central Board of Statistics
COLS	Corrected ordinary least square
CRS	Constant return to scale
DEA	Data envelopment analysis
DFAT	Department of Foreign Affairs and Trade
ERA	Effective rate of assistance
ERP	Effective rate of protection
FDI	Foreign direct investments
FEM	Fixed effect model
FTA	Free trade agreement
FOB	Free on board
GDP	Gross domestic product
GLS	Generalised least squared
IMF	International Monetary Fund
IRTS	Increasing returns to scale
ISIC	International Standard Industrial Classification
IO	Input-output

LDC	Less developed country
LM	Lagrange multiplier
LP	Linear programming
MLE	Maximum likelihood estimation
MPI	Malmquist productivity index
n.e.c	not elsewhere classified
NRP	Nominal rate of protection
NTBs	Non-tariff barriers
OLS	Ordinary least squares
COLS	Corrected ordinary least square
OME	Output-oriented mix efficiency
OTE	Output-oriented technical efficiency
OSE	Output-oriented scale efficiency
OSME	Output-oriented scale mix efficiency
PCR	Productive capacity realization
PLN	The state energy company (*Perusahaan Listrik Negara*)
PSID	Firm specific identification code
RE	Random effect
RME	Residual mix efficiency
ROSE	Output-oriented residual scale efficiency
RTS	Returns to scale
SVFA	Stochastic varying frontier approach
SFA	Stochastic frontier approach
SI	Annual statistics of large and medium industries (*Statistik Industri*)
SOEs	State owned enterprises
SFA	Stochastic frontier approach

SPF	Stochastic production frontier
TC	Technical change
TE	Technical efficiency
TFP	Total factor productivity
TP	Technical progress
UNIDO	United Nations Industrial Development Organization
VRS	Variable returns to scale
WPI	Wholesale price index
WTO	World Trade Organization

Abstract

This thesis examines the effects of trade liberalization on firm-level efficiency and productivity growth in four selected Indonesian manufacturing industries. The key hypothesis is that trade reform at the industrial level generates firm-level productivity gains. Although trade reform policies have been implemented in the Indonesian manufacturing industry over the past four decades, determining their effects on firm-level efficiency and productivity remains a controversial issue, and the number of empirical studies of these effects is limited.

Two productivity methods are used to investigate the effects of trade reform on firm efficiency and productivity, while considering the firm characteristics of each sector of the selected manufacturing industries. The stochastic production frontier (SPF) approach is applied to examine the effects of trade reform on firms' technical efficiency levels. Subsequently, the Färe-Primont productivity index is employed to measure productivity growth and its components, and the econometric estimation that uses panel data is applied to investigate the effects of trade reform on productivity growth.

The first analysis investigates the effects of trade reform on firms' technical efficiency levels in four selected Indonesian manufacturing industries by using firm-level panel data from 1981 to 2000. The results show the effects of trade reform on technical efficiency vary across industries and sub-periods. Further, there is a change in the direction of trade reform effects on technical efficiency from pre-crisis to post-crisis. This finding suggests that the crisis interfered with the impact of trade reform on efficiency.

The second analysis focuses on the decomposition of productivity growth. The results reveal that at the two-digit and three-digit industries, technical change is generally the main source of productivity growth over the total observed period.

The last analysis is performed to examine the effects of trade reform on productivity growth and its components. This study finds there is no strong evidence that trade reform affect total factor productivity (TFP) growth across the four selected industries. However, the findings show that trade reform variables have effects on the components of TFP growth. The effects of trade reform on the components of

TFP are mixed across the four selected industries in the different periods in terms of their signs and significance.

Several policy implications follow from the above findings. First, this study finds that the effects of trade reform on technical efficiency vary across industries and sub-periods. Therefore, the government of Indonesia has to continue to deregulate trade policies. However, the government needs to consider that the economic crisis interferes with the effects of both trade reform variables (effective rate of protection and the ratio of imports) on technical inefficiency, such as in the case of the Indonesian food industry (ISIC 31). In this industry, both variables switch to opposite signs in the post-crisis. Second, the outcomes of the productivity analysis show that there is no strong evidence that trade reform consistently affect TFP growth across the four selected industries. The government may need to consider the characteristics of firms in each industry when formulating trade reform policies. In an industry where trade reform increases TFP growth, such as food products (ISIC 31) and textile (ISIC 32) industries, the government should continue to reduce protection for these industries. The government, however, should consider other industries that need protection rather than trade reform, such as the Indonesian metal products industry (ISIC 38). Third, the results from productivity analysis show that the effects of trade reform can be channelled through technological progress, technical efficiency and scale mix efficiency. However, the effects vary across TFP components and sub-periods. The government should continue the reform process in industries where the positive trade reform effects occur through technical efficiency, technological progress and scale mix efficiency. The government has to be aware that protection is needed in several industries in the early phases of development because it provides positive effects to TFP components.

Key words: technical efficiency, productivity growth, stochastic production frontier, panel data

JEL classification: F14, F63, O47

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Chapter 1
Introduction

1.1 Background of the Study

Over the last four decades, market-oriented economic reforms have been implemented by many developing countries in Latin America, Africa and Asia. Trade and investment agreements among developing and developed countries are examples of the reforms. It is widely believed that opening an economy to trade and investment is one of the means to increase a country's economic performance, particularly in terms of productivity growth.

There are a growing number of theoretical studies that provide arguments in support of the effects of trade liberalization on productivity growth. These studies identify several channels where trade liberalization can positively affect productivity growth. First, trade reform increases the possibility of gaining greater access to imported capital goods and technological advances from leading nations (Romer 1986, Lucas 1988). The increased availability of these goods creates insights for domestic researchers who use and/or study them. This increase in knowledge leads to greater technical efficiency. Second, trade reform can increase industrial productivity through the pressure of international competition. To compete with international producers, domestic producers must adopt newer and more efficient technologies or employ previously used technologies with less X-inefficiency to reduce costs (Nishimizu and Page 1982). Third, trade reform can increase productivity and efficiency through technical knowledge spillovers (Grossman and Helpman 1991), which may occur through suggestions from foreign buyers that improve the manufacturing process. All these studies present optimistic arguments regarding positive effects of trade liberalization on productivity growth.

Empirical studies, however, provide mixed evidence regarding the effects of trade reform on productivity growth. Although some studies identify positive effects of trade reform on productivity growth (Nishimizu and Robinson 1984, Urata and Yokota 1994, İşcan 1998, Njikam and Cockburn 2011, Topalova and Khandewal 2011), other studies find no effect from trade reform (Jenkins 1995, Balakrishnan *et al.* 2000, Sharma *et al.* 2000). Thus, the relationship between trade reform and productivity growth remains an issue for further empirical examination.

Despite significant attempts to investigate the effects of trade liberalization on productivity growth, empirical studies tend to lag behind evolving theoretical arguments. Three gaps are worth mentioning. First, many empirical studies that examine productivity gains from trade reform focus only on technological progress. However, theoretical arguments indicate that productivity gains can also lead to efficiency improvement. Broadly considered, trade reform policies facilitate firms' improvement of technical efficiency through technology, knowledge spillovers and competition pressure. Thus, the traditional approach of treating productivity gains from trade liberalization as synonymous with technological progress tends to underestimate the real effects of trade reform on total factor productivity (TFP) growth.

Second, very few empirical studies have considered scale efficiency as another source of productivity gain from trade reform effects, mainly because of the limitation that methodology cannot identify sources of productivity growth other than from technological progress and pure technical efficiency. Trade reform can improve scale efficiency as domestic producers respond to changes in relative prices and market opportunities. Given the theoretical argument that the effects of trade reform may improve scale efficiency, a systematic analysis of the effects of trade reform must include this component. Therefore, this thesis investigates the effects of trade reform on firm productivity growth using a methodology to capture the sources of productivity benefits that can be obtained not only from technological progress and pure technical efficiency but also from scale efficiency.

Finally, the majority of empirical studies that examine the decomposition of productivity growth have concentrated on the aggregated manufacturing level without providing an analysis of the disaggregated sub-sectoral level. Focusing on the aggregated manufacturing level offers a general picture regarding the effects of trade reform. However, to provide more detailed decomposition analysis, the disaggregated sub-sectoral levels decomposition is required. This analysis captures the link between the aggregated and disaggregated manufacturing sectors and provides more comprehensive analysis of the effects of trade reform on firm productivity growth.

This thesis attempts to enrich the research on the effects of trade reform and productivity growth by conducting analyse that have not been conducted in previous studies, specifically in the case of Indonesia. Three approaches are used to achieve the goals of the study. First, a stochastic production frontier (SPF) is applied to investigate the effects of trade liberalization on firm technical efficiency. Second, the Färe-Primont productivity index is used to decompose productivity growth and technical efficiency. In general, different policies have different effects on various components of productivity growth, and this decomposition analysis allows the different impact of policies to be identified. Finally, through an econometric model that uses panel data, the estimates of productivity growth and technical efficiency from the second approach are used to empirically test the effects of trade reform on productivity growth and technical efficiency.

1.2 Research Objectives

The main objective of this thesis is to analyse the effects of trade reform on productivity growth and its components in four selected Indonesian manufacturing firms. The specific objectives are as follows:

1. To examine the impact of trade reform on the technical efficiency in four selected Indonesian manufacturing industries both pre-crisis and post-crisis;
2. To investigate the sources of productivity growth in four selected Indonesian manufacturing at the two-digit and three-digit levels;
3. To decompose productivity growth into technical progress, technical efficiency and scale mix efficiency both pre-crisis and post-crisis and then to examine the effects of trade reform on the components; and
4. To recommend policies to maximize the effects of trade reform in four selected Indonesian manufacturing.

Similar to other developing countries, Indonesia has undertaken economic reforms. Industrialization policies, both import substitution and export-oriented, have been applied. Reform measures related to these policies have been undertaken, such as reducing tariff rates, simplifying import and export procedures and introducing various incentives to attract foreign direct investments (FDI). At the same time, devaluation of the domestic currency, a reduced reliance on state-owned enterprises (SOEs), improvements in financial supervision and the launching of privatization programmes have been implemented. Indonesia was also affected by the Asian financial crisis 1997, which caused the Indonesian government to more deeply integrate into the world market and to accelerate trade liberalization. Therefore, an examination of the performance of manufacturing industries and comparisons between pre- and post-reform periods and pre- and post-economic crisis should yield useful information regarding the effectiveness of policy reform and guide the direction of further policy reforms.

Despite the important role of manufacturing sectors in the Indonesian economy, the effects of trade reform on these sectors have remained insufficiently studied. Osada (1994) and Aswicahyono *et al.* (1996) were the first studies that investigate the effects of trade reform on total factor productivity (TFP) growth. After these pioneering studies, several studies conducted in this area through 2007, including Aswicahyono and Hill (2002), Amiti and Konings (2007) and Ikhsan (2007). All these studies, however, have focused only on the effects of trade reform on productivity and little attention has been paid to technical and scale efficiencies as the components of productivity growth.

1.3 Methods of Research

To achieve the research objectives above, this thesis employs the time-varying stochastic production frontier (SPF) for panel data proposed by Battese and Coelli (1995), the Färe-Primont productivity index proposed by O'Donnell (2012) and an econometric model that uses a panel data framework. The stochastic production frontier is used to estimate the effects of trade reform on firm-level technical efficiency. The Färe-Primont productivity index is used to compute and decompose total factor productivity growth into technological progress, technical efficiency growth and scale mix efficiency growth.

In the SPF, trade reform variables are included in the technical efficiency function, along with other contributing variables, namely age, capital intensity, the ratio of non-production workers to all workers and ownership status. Furthermore, to analyse the effect of the economic crisis, the samples are divided into two sub-periods pre- and post-crisis.

In the Färe-Primont productivity index, the total factor productivity growth of firms is decomposed into three main components: technological progress, technical efficiency growth and scale mix efficiency growth. The growth pattern of each component is analysed for the four selected manufacturing sector, before proceeding to estimate trade reform effects on TFP growth and on each component of TFP growth.

The Färe-Primont productivity index proposed by O'Donnell (2012) is one of the most up-to-date approaches available and allows the decomposition of productivity into broader components, unlike conventional productivity measurements. This index also satisfies all economically relevant axioms and tests from index number theory, including transitivity and identity tests, and is a reliable measure to compare multi-temporal (many periods) and/or multilateral (many firms) indices of TFP and efficiency (O'Donnell 2012). The possibility of decomposing TFP growth into broader components offers more extensive insights into productivity growth, in both aggregated and disaggregated industries.

Finally, the results of TFP growth and its components from the Färe-Primont productivity index are used to examine the effects of trade reform on TFP growth and its components using the econometric panel data framework. Other variables that represent firm characteristics, as mentioned above, are also included in this analysis.

1.4 Significance of the Research

This thesis contributes to the literature of trade liberalization and productivity growth in Indonesia in four significant ways. First, this thesis represents the first attempt to examine the effects of trade reform using the stochastic production frontier method, which enables identification of the effects of trade reform on firms' technical efficiency levels. Generally, previous studies on Indonesian manufacturing sectors have used a conventional production function approach, which assumes full efficiency, complete capacity utilization and constant returns to scale. Thus, this study extends the previous studies by considering the technical efficiency effects.

Second, the use of the Färe-Primont productivity index as proposed by O'Donnell (2012) allows the decomposition of productivity growth into broader components. Six components of productivity growth can be derived from this index, unlike conventional indices such as the Divisia index and Malmquist productivity index that decompose total factor productivity growth into three main components of technical change, scale efficiency change and technical efficiency change.[1] Therefore, a deeper analysis can be conducted using these decomposition results. In addition, the effects of trade reform on these three main components are investigated.

Third, this thesis utilizes long series data from 1981 to 2000, which include a period after the 1997 economic crisis. To the author's knowledge, none of the previous studies used data from 1997 onwards. The inclusion of more recent data allows this study to investigate the changes in magnitude of the effects of trade liberalization between the period before and after the economic crisis. Thus, this thesis has greater coverage than previous studies.

Finally, this thesis enriches the literature on the relationship between trade liberalization and productivity growth, specifically in the case of Indonesia, where there have been few previous studies. The results of this thesis offer important guidance to the government in formulating trade reform and industrial policies.

1.5 Structure of the Thesis

This thesis comprises eight chapters. The first chapter provides an introduction to the study's subject matter. The research background, objectives and significance of the study are presented. Chapter 2 surveys trade liberalization policies in Indonesia since early 1966, when the New Order Government began these policies. General achievements and the changes in trade reform policies from both the pre-and post-crisis periods are discussed.

Chapter 3 presents a review of various methods of measuring and estimating TFP growth along with empirical evidence on the impact of trade reform on TFP growth. In addition, this chapter also discusses the effect of trade reform on technical efficiency. Previous empirical studies on this effect are also discussed. Both international and Indonesian empirical studies are reviewed and summarized to emphasize the mixed evidence that exists regarding the effects of trade reform on firm productivity growth and its components.

[1] The Färe-Primont productivity index as proposed by O'Donnell (2012) decomposes productivity growth into six components, where one of the components is the result of multiplication of the other components. For the decomposition of productivity growth that uses output-oriented approach, for example, the TFP growth can be decomposed into ΔTFP* (technological progress/technical change), ΔTFPE (TFP efficiency change), ΔOTE (pure technical change), ΔOSE (scale efficiency change), ΔOME (mix efficiency change) and ΔOSME (scale mix efficiency change). The letter O in each component means "output-oriented".

Chapter 4 provides an analytical framework to examine the impact of trade reform on the productivity of the four chosen Indonesian manufacturing firms. Two productivity analysis methods are discussed: the SPF and the Färe-Primont productivity index. The discussion on the SPF method includes a review of this method, the panel data SPF with exogenous variables and the chosen model. The discussion the Färe-Primont productivity index involves its decomposition and estimation procedures by using Data Envelopment Analysis (DEA).

The empirical analysis in this thesis comprises three chapters. Chapter 5 investigates the effects of trade reform on firms' technical efficiency levels. This is performed by simultaneously estimating the stochastic production frontier and the inefficiency function under the one-stage procedure of Battese and Coelli (1995) model, which allows for testing the effects of trade reform on technical efficiency. To evaluate the impact of the 1997 economic crisis on the magnitude of trade reform, the samples are divided into two periods (pre- and post-crisis), and the SPF estimations are performed.

Chapter 6 provides an analysis of the decomposition of total factor productivity growth. Following O'Donnell (2012), the decomposition is computed using the Färe-Primont productivity index with the assumption that production technology exhibits variable returns to scale (VRS). Three sources of productivity growth are discussed, namely technical change, technical efficiency change and scale mix efficiency change. The decomposition of TFP growth is performed in four selected manufacturing industries, in terms of three-digit and two-digit levels, by using data from 1981 to 2000.

Chapter 7 is the third empirical chapter. This chapter analyses the effects of trade reform on firms' productivity growth using the results from Chapter 6. Panel data OLS regressions are applied to test the effects of trade reform on productivity growth and on each productivity growth component. Three panel data models are employed: pooled ordinary least square (OLS), fixed effect within transformation model (or FEM within) and random effect model (or Generalised Least Squares, GLS). To choose which model is appropriate for representing the dataset, the *Chow* test, the *Hausman* test and the *Breusch-Pagan* (BP) test are performed.

Finally, Chapter 8 concludes the study and discussing the key findings and policy implications. Chapter 8 also presents the limitations of the study and makes suggestions for further research.

Chapter 2
Trade Reform and the Indonesian Manufacturing Industry

2.1 Introduction

Indonesia has been implementing various trade and industrial policies since 1970s. The changes in trade and industrial policies have been driven by the fluctuation in oil prices and the economic crisis. During the period of increased oil price ("oil boom") from the 1970s to the mid-1980s, Indonesia pursued a strategy of import substitution for industrialization. Consequently, a very high level of protection in terms of tariff and non-tariff barriers was given to state-owned enterprises (SOEs) to reduce the impact of foreign competition. This strategy was implemented until the 1980s, when oil price declined. Since then, the government has shifted from a protective regime to more liberal regime. The government has reduced both tariff and non-tariff barriers and has begun to undertake an export promotion strategy. Hit by the Asian financial and economic crisis in 1997, the government accelerated trade liberalization and committed to several trade and investment organizations, such as World Trade Organization (WTO), ASEAN Free Trade Agreement (AFTA) and Asia-Pacific Economic Cooperation (APEC). Despite the increased trend of liberalization undertaken by the government, to the same extent, it has also been protecting some sectors through non-tariff measures.

The purpose of this chapter is to analyse Indonesian manufacturing industry, specifically trade reform policies and manufacturing performance. The rest of this chapter is organized as follows: Section 2.2 discusses the sequence of trade reform in Indonesia. This section includes the following eight main periods of reform: the stabilization period (1966-1970); the inward-looking strategies (1971-1981); the adjustment to the lower oil prices (1982-1988); the non-oil led economic recovery (1988-1992); the continued deregulation and some ambivalence (1993-1996); the economic crisis and recovery (1997-2004); the recovery of demand and the start of proactive industrial policy (2005-2007); and the current trade policy (2008-present). Section 2.3 briefly discusses the structural transformation from the agricultural sector to industrial manufacturing. Section 2.4 analyses the impact of trade reform on the manufacturing sector in terms of various indicators and is followed by Section 2.5, which compares trade reform between Indonesia and other East Asian economies. Finally, Section 2.6 provides the conclusion.

2.2 The Sequence of Trade Reform Policies in the Indonesian Manufacturing Industry

2.2.1 The Stabilization Period (1966–1970)

After power was transferred from the first president of Indonesia, Soekarno, in 1966, President Soeharto's 'New Order' had to address hyperinflation, multiple exchange rates and direct controls over its capital account (Fane 1996). The New Order introduced a macroeconomic programme and began to liberalize trade and investment policies based on the trilogy development ("Trilogi Pembangunan), which consisted of stability, growth and equity. The two most notable policies implemented in this period were the openness of capital account and the establishment of a law that guaranteed foreign investors the right to repatriate both capital and profits (Fane 1996, Widodo 2008).

The New Order moved to a more market-oriented regime. Reforms in trade policies and investment law were introduced. In 1967, foreign exchange was liberalized, and the import licensing system was dismantled. The government also simplified the import licensing system and introduced a new 'export bonus' scheme in 1967 and 1968, respectively. In addition, the government undertook a reform of investments. Investment law was introduced in 1967. This law opened the oil industry, the consumer sector and heavy industries to foreign direct investment (FDI), which had previously been banned.

In addition to the reforms in FDI, the government introduced a domestic investment law in 1969. In 1970, further trade reforms were implemented, including devaluation, the unification of a multiple exchange rate system, the simplification of export and import procedures and the elimination of international capital controls. In addition to the reforms on trade and investment policies, physical infrastructure that had been neglected for years was rehabilitated. All these policies resulted in strong investment responses.

2.2.2 The Inward-Looking Strategies (1971–1981)

The period from 1971 to 1981 was dominated by the fact that the increase in the price of oil (1973–1974 and 1979–1981) and non-oil commodities (1975–1979) had raised the government revenue (Fane 1996, Widodo 2008). By the late 1970s, the government became increasingly inward-looking, especially in the area of industrial policy. Protection was increased, and an import substitution strategy was adopted.

There were at least four main channels through which the government intervened during this period (Aswicahyono and Feridhanusetyawan 2004, Vanzetti *et al.* 2005):

- The government used some of the oil revenue to accelerate the process of industrialization through extensive public investment and state-owned enterprises (SOEs), mainly in capital-intensive import substituting industries such as the steel, cement, fertilizer, aeronautics and petrochemical.
- A new import system was introduced that controlled imports through quantitative restrictions, especially for heavy industries.
- The government dominated the market through direct state-owned banks that provided subsidized credit for favoured clients.
- The government established complex regulations to promote various industrial policy objectives, such as spatial dispersion, small industry development (in 1973, special treatment was implemented for indigenous borrowers) and indigenous business development (in 1980, Presidential Decree 14A was released and supported indigenous enterprises in government procurements).

2.2.3 The Adjustment to the Lower Oil Prices (1982–1988)

The period from 1982 to 1988 was dominated by the implementation of broad-based economic reforms because of a decrease in oil prices. The price of oil declined gradually in 1982 and continued on the decline from US$28 to $10 per barrel in 1986. The decrease in oil price reduced government revenue significantly and affected the ability of the government to fund heavy industries (Fane 1996, Aswicahyono 1998, Widodo 2008). This period was often referred as the ambivalent period because on the macroeconomic side, the policy responses were prompt but on the microeconomic side, the reforms occurred at a slower pace (Aswicahyono and Feridhanusetyawan 2004).

On the macroeconomic side, various measures were used by the government to minimize the balance of payment deficits due to the decrease in oil price. The government began with the devaluation of the rupiah in March 1983 and again in

September 1986, followed by tightening fiscal policy measures, such as the reduction or removal subsidies on domestic fuel, agricultural sector and SOEs. In addition, various capital industry projects were rescheduled.

On the microeconomic side, reforms were implemented at a slower pace, and external policies became more protectionist (Fane 1996, Aswicahyono and Feridhanusetyawan 2004). The following reforms related to trade and industrial policies were enacted during this period:

- In 1982, a system called the approved importers system was introduced by the government (*Tata Niaga Impor*). This system became an instrument for quantitative restrictions on imports. Under this system, licences to import were given to specific firms appointed by the government. In addition, to promote domestic industries, the government also established Junior Minister for Promotion of the Use of Domestic Products.
- In March 1985, tariff ceilings of 60% were introduced. These ceilings resulted in a reduction the level of nominal tariffs. The range was reduced from 0-225% to 0-60%, and most tariff rates ranged from 15-25%.
- In April 1985, reforms were undertaken in customs. Domestic and foreign shipping procedures were streamlined and simplified.
- In October 1986, many approved importer licenses were eliminated and converted to tariff equivalents.

2.2.4 Economic Recovery Led by Non-oil (1989–1992)

This period continued the reforms undertaken of the previous period. The government shifted further to an outward-oriented economy. Deregulation was extended to provide more opportunities to private sectors in the economy.

The following are the trade and industrial policies enacted by the government during this period:

- In November 1988, the import monopoly for plastic and steel was removed.
- In 1989, the import monopoly for cotton (the raw material input for the textile industry) was removed, and a more transparent quota allocation system for textile was introduced.

- In May 1990, more non-tariff barriers (NTBs) were removed. Consumer electronics and electronics components could be imported under the non-restrictive general importer licence.
- In June 1991, the first major trade and investment reforms were undertaken. The NTBs were reduced and replaced with tariff and export taxes. Several business areas, which were previously included on the negative lists, were reopened to new domestic and foreign investment. The removal of NTBs included the abolition of import bans on cold-rolled steel and sheets in addition to tin plates. The reforms also abolished export bans on copra and palm oil as well as the exclusive rights of several companies to export palm-oil-based products.

Concerning regional trade and investment integration, at the fourth ASEAN (the Association of Southeast Asian Nations) summit in 1992, Indonesia strongly supported the ASEAN free trade area (AFTA). The aim of AFTA was to achieve free trade among the ASEAN members by reducing intra-ASEAN tariffs between 0 - 5% and removing NTBs by 2002.

The trade reform trend, in terms of policy measures, can be monitored through two types of measures, i.e., tariff reductions and reduction in NTBs (Osada 1994). Table 2.1 shows the progress of trade liberalization reform in Indonesia regarding the reduction of nominal tariff rate (from pre-1985 to 1996), coverage of NTBs (from 1986 to 1993), and effective rates of protection (ERP) (from 1971 to 2003). These three measures generally tended to decline during the observed periods.

The estimates nominal tariff rate in Table 2.1A show the declining trend of the average unweighted and output weight rates. The exception is for the average of import weight rates, where there was a slight increase in 1988 but a tendency to decrease again in 1990 and 1992. The effects of tariff reduction since pre-1985 show that unweighted nominal tariff rates tended to decrease from 37% to 13% in 1996.[2]

[2] As noted by Osada (1994), the tariff rates for some manufactured goods were first reduced in 1985 to promote more competition in the domestic market. The tariff reductions up to 1988 were directed only at intermediate and capital goods to improve exports capability.

Table 2.1: Estimates of Nominal Tariff Rate, Coverage of Non-Tariff Barriers (NTBs) and Effective Rates of Protection (ERP)

A. Nominal Tariff Rate (%)

	Pre-1985	1985	1988	1990	1992	1993	1996
Average rate:							
Unweighted	37	27	24	22	20	19	13
Import weight	22	13	15	11	9	n.a	n.a
Output weight	29	19	18	17	13	n.a	n.a
Effective rate	n.a	4.9	5.1	6.2	4.8	n.a	n.a

B. Coverage ratio of NTB (%)

	1986	1987	1988	1989	1990	1992	1993
Output value coverage	41	38	29	28	25	22	22
Manufacturing	68	58	45	38	33	31	31
Agriculture	54	53	41	40	38	30	30
Import value coverage	43	25	21	17	15	13	13

C. Effective rate of protection (%)

	Sectors			All tradable sectors
	Manufacturing (excluding oil & gas)	Manufacturing (including oil & gas)	Agriculture	
1971	n.a	n.a	n.a	33
1975	n.a	n.a	n.a	30
1980	n.a	n.a	n.a	56
1984	n.a	n.a	n.a	133
1987	86	48	24	18
1994	29	23	14	9
1995	24	20	12	8
2003	16	13	9	4

Note: The nominal tariff includes surcharges and the effective rate is defined as the ratio of tariff revenue to non-oil imports. The weight for coverage ratio of NTB is based on 1985 output for 1986. The 1987 output weight is applied to other years.
Source: Osada (1994, p.484) and Hill (2000, p. 117) for the nominal tariff rate and the coverage ratio of NTB; Pangestu and Boediono (1986, p. 25-26), Fane and Phillips (1991, p. 118), Fane and Condon (1996, p. 39-40), Fane (1996, p.343) and Hill (2000, p. 114) for ERP.

NTBs, which were dominated by the import licensing system, have been gradually replaced with tariffs. As shown in Table 2.1B, for manufactured goods, the output value coverage was 68% in 1986 but decreased almost half by 1993. Over the same period, for agricultural goods, the output value coverage was 54% and continued on the decrease to 30% in 1993. These numbers show the efforts of the Indonesian government to improve efficiency by minimizing NTBs and reducing tariffs.

According to the estimates in Table 2.1C, the average ERP for the entire manufacturing sector, excluding natural gas and oil refining, fell from 86% in 1987 to 16% in 2003. Over the same period, the average ERP for agriculture decreased from 24% in 1987 to 9% in 2003. It can be observed that similar to the reduction of the number of NTB, the reforms in manufacturing sector were more pronounced than in agriculture. Nonetheless, these show how the government of Indonesia tried to reform both sectors.

2.2.5 Continued Deregulation and Some Ambivalence (1993–1996)

The government continued reforms during this period. Several business areas continued on the reopen. From 1986 to 1994, foreign and domestic direct investments were deregulated by allowing 95% ownership of export-oriented FDI (foreign direct investment), opening previously closed sectors and including several sectors on the positive lists.

Internationally, in 1994, Indonesia promoted the Bogor Declaration at APEC (Asia Pacific Economic Integration), which paved the way for involvement in regional economic integration. Building on Indonesia's APEC commitments, for the first time in 1995, for the first time, the government committed to a schedule of tariff reductions to a maximum tariff rate of 10% by 2003, excluding automotive-related products, and decreasing most items to between 0 and 5%. The reforms undertaken by the government could reduce non-tariffs barriers, and by 1995, tariffs covered 65% of items (DFAT 2000).

After the commitment at APEC, on 1 January 1995, Indonesia became a member of WTO (World Trade Organization). The government committed to reduce all bound tariffs to 40% or less over a ten-year period starting in 1995 that were subject to an exclusion list of products for which this commitment did not apply. Motor vehicles and components and the basic iron and steel industries were on the exclusion list (Amiti and Konings 2007).

Some studies, such as DFAT (2000), Aswicahyono and Feridhanusetyawan (2004), Vanzetti *et al.* (2005) and Widodo (2008), however, consider this period (1993 – 1996) to be deregulation fatigue or deregulation with some ambivalence. They argue that reform were too slow and did not include various sensitive agricultural commodities or several important manufacturing commodities. Among controversial cases were the increase in tariff surcharge on propylene and ethylene tariffs in 1993; the exemption for the national car, the Timor, from the 35% luxury tax; the protection of giving Timor extensive non-tariff and tariff barriers; and the clove trading monopoly.

2.2.6 Economic Crisis and Recovery (1997–2004)

The financial and economic crisis in 1997 had a severe impact on the Indonesian economy. Although the economic crisis began in mid-1997, the full effect of the economic crisis was felt in 1998, when the economic growth declined by 13%. Table 2.2 shows that in 1998, all sectors were affected negatively by the economic crisis except electricity, gas and water supply.

Table 2.2: Real GDP (Gross Domestic Product) Growth at 1993 Constant Price by Industrial Origin, 1997-2004 (%)

Industrial Origin	1997	1998	1999	2000	2001	2002	2003	2004
1. Agriculture, Livestock, Forestry, and Fishery	1.0	-1.3	2.2	1.9	1.7	2.0	2.5	2.8
2. Mining and Quarrying	2.1	-2.8	-1.6	5.5	1.3	2.5	0.5	-4.5
3. Manufacturing Industry	5.3	-11.4	3.9	6.0	3.1	3.4	3.5	6.4
4. Electricity, Gas, and Water Supply	12.4	3.0	8.3	7.6	8.2	6.0	6.8	5.3
5. Construction	7.4	-36.4	-1.9	5.6	4.4	4.9	6.7	7.5
6. Trade, Hotel, & Restaurant	5.8	-18.2	-0.1	5.7	3.7	3.8	3.7	5.7
7. Transport and Communication	7.0	-15.1	-0.8	8.6	7.8	8.0	10.7	13.4
8. Financial, Ownership, and Business Services	5.9	-26.6	-7.2	4.6	5.4	5.7	6.3	7.7
9. Services	3.6	-3.8	1.9	2.3	3.1	2.1	3.4	5.4
GDP	4.7	-13.1	0.8	4.9	3.5	3.7	4.1	5.0
GDP (Non-oil and gas)	5.2	-14.2	1.0	5.3	4.2	4.1	4.6	5.9

Source: Gross Domestic Product (GDP) by Industrial Origin, Statistics Indonesia, various publications.

The Indonesian manufacturing industry contracted by 11.4% in 1998. Table 2.3 shows that in 1998, all the non-oil and gas manufacturing industries recorded negative growth rates. Among these industries, the worst affected by the economic crisis was the transport equipment, machinery and apparatus (metal products) industries (52.3%), followed by other manufacturing industries (36%), cement and non-metallic mineral products industries (29.8%) and iron and basic steels (basic metal) (26.9%) industries.

Table 2.3: Growth of Indonesia's Manufacturing (%)

Sub-sector	1997	1998	1999	2000	2001	2002	2003	2004
I. Oil and Gas Manufacturing	-2.0	3.7	6.8	-1.7	-3.5	1.2	0.6	-1.9
II. Non-oil and Gas Manufacturing	6.1	-13.1	3.5	7.0	3.9	3.7	3.8	7.5
1. Food, Beverage, & Tobacco	12.3	-0.2	4.6	3.6	2.3	2.6	2.1	1.4
2. Textile, Leather Products, & Footwear	-3.8	-14.9	8.5	8.0	4.3	4.5	3.7	4.1
3. Wood Products								
4. Paper & Printing	-2.9	-25.5	-13.5	6.9	-0.3	0.0	1.9	-2.1
5. Fertilizers, Chemical, &	8.4	-4.0	2.3	2.6	-5.7	2.9	7.9	7.6
Rubber Products	3.5	-16.0	10.3	7.1	5.0	7.0	10.4	9.0
6. Cement & Non-metallic Mineral Products	3.5	-29.8	5.2	5.5	12.3	10.1	6.3	9.5
7. Iron & Basic Steel								
8. Transport Equipment,	-0.5	-26.9	-0.2	13.1	-0.3	3.2	-1.6	-2.6
Machinery, & Apparatus	-1.1	-52.3	-10.3	43.5	20.3	4.8	4.3	17.7
9. Other Manufacturing								
	6.8	-36.0	-1.5	12.8	21.0	10.2	7.9	12.8
Manufacturing Industry	5.3	-11.4	3.9	6.0	3.1	3.4	3.5	6.4

Source: Gross Domestic Product (GDP) by Industrial Origin, Statistics Indonesia, various publications.

Wie (2000) provides an explanation how the manufacturing industries affected by the financial crisis. The effect of financial crisis on the manufacturing industries was transmitted through two channels. The first channel was through substantial capital outflow, depreciation of rupiah and the contractionary effects of fiscal and monetary policies on GDP and various sectors of the GDP. The second channel was through the increased prices of manufactured products because of the depreciation of rupiah in early 1998, which reduced the demand of tradable goods, including manufactured products.

To address the economic crisis, the Indonesian government adopted deeper integration with the world market by accelerating trade liberalization. Trade reforms were intensified when the government of Indonesia committed to the IMF (International Monetary Fund) programme, with conditions included the dismantling of almost all remaining NTBs and special privileges, such as the clove monopoly and the national car (Fane 1999, Vanzetti *et al.* 2005).

To analyse the process of trade reform, two measures are used, namely, tariff reductions and reduction in NTBs (Osada 1994). Concerning tariff reductions, consistent with the commitments to the WTO, APEC and the IMF, the government continued on the reduce tariffs. Table 2.4 reveals that in 1997, 51% of Indonesian tariff codes were within the 0 to 5% range, and 63% were at 10% less. This number continued on the decrease by 1999, when tariff codes were 59% within the 0 to 5% range and 72% at 10% less.

Table 2.4: Indonesia's Import Tariff Structure, 1997–1999

Tariff	0 to 5%	0 to 10%	0 to 20%	25 to 35%	40% or higher	Total tariff lines
July 1997						
Total tariff lines	3,688	4,563	6,151	1,032	80	7,263
Per cent	51	63	85	14	1	100
July 1997						
Total tariff lines	4,266	5,188	6,973	167	72	7,212
Per cent	59	71	96	2	1	99
1999						
Total tariff lines	4,289	5,266	7,055	135	69	7,259
Per cent	59	72	97	2	1	100

Source: DFAT (2000, p. 60)

In terms of non-tariff barriers, the Indonesian government committed to removing all remaining NTBs by 2002, especially exclusive licences for importers of agricultural products and several important manufacturing commodities (DFAT 2000). In early 1998, the government agreed to liberalize import licences for cloves and propylene and ethylene, which previously only state-owned producers could import.

The import licensing requirements controlled by national logistic agency, BULOG (*Badan Urusan Logistik*), were removed after November 1997. This deregulation opened import competition for wheat, wheat flour, soy beans and garlic. In addition, this deregulation also created competition for the sale and distribution of flour, and the importing and marketing of sugar.

In 1998, the government opened rice imports to competition and dismantled controls on wood panel export and shipments and on dairy imports. The monopoly of the domestic marketing and distribution of cloves by BPPC (*Badan Penyangga dan Pemasaran Cengkeh*) was ended. Internal and external trade restrictions in cements were eliminated to allow traders to buy and distribute all cement brands in all provinces and to export under the General Exporter licence (Soesastro and Basri 2005b).

As a part of liberalization in the automotive trade, in June 1999, the government permitted general importers to import completely finished vehicles. Special tax, customs and credit concessions for the national car project, Timor, were abolished. In addition, the government agreed to phase out the motor vehicle local content programme that gave preferential tariff rates to manufacturers that used a high percentage of local parts.

The liberalization reforms were continued by implementing the government's commitments to AFTA and APEC. NTBs were reduced, import licencing was simplified, and customs and other procedures were harmonized to facilitate trade.[3]

2.2.7 Recovery of Demand and the Start of a Proactive Industrial Policy (2005–2007)

After being hit by the Asian economic crisis in 1997-1998, Indonesia recovered and continued on the open its economy by removing constraints to trade, investment and production and by simplifying procedures at the borders. International commitments to WTO, APEC, and ASEAN were also continuously undertaken.

Concerning tariffs, the government committed to decrease and simplify tariff rates. In February 2006, the government announced a medium-term tariff harmonization programme, which aimed to move towards a low and uniform tariff rate and specified a tariff reduction schedule between 2005 and 2010. The government planned for 94% of all tariff lines to have rates at or below 10% by 2010 and the remaining 6% to be reduced to 10% within a longer time-frame.

Table 2.5 shows the decreasing trend of Indonesia's simple average tariffs. From 2005 to 2007, although the tariff rates for manufactured and primary products were stagnant from 2005 to 2006, tariff rates decreased in 2007. In addition, the government continued on the reduce the number of products subject to import restrictions, prohibitions and special licencing requirements. During this period, tariff lines were down from 1,112 in 1990 to 141 in 2006.

[3] A summary of Indonesia-AFTA tariff reduction schedule and Indonesia's APEC individual action plan are provided in Table 4.5 and 4.6 (DFAT, 2000).

Table 2.5: Indonesia Simple Average Tariffs, 1989–2013 (%)

Year	Manufactured Products	Primary Products	All Products
1989	18.91	17.66	18.74
1990	16.88	16.48	16.83
1993	16.89	15.92	16.74
1995	14.32	12.28	14.01
1996	10.60	11.73	10.76
1999	9.72	10.75	9.86
2000	8.09	6.02	7.78
2001	6.07	6.07	6.07
2002	6.26	7.67	6.45
2003	5.73	7.34	5.95
2004	5.90	7.24	6.07
2005	5.90	6.64	6.00
2006	5.90	6.64	5.99
2007	5.78	6.62	5.88
2009	5.19	5.67	5.24
2010	5.03	3.21	4.79
2011	5.24	3.39	5.02
2013	5.23	3.39	5.03

Source: World Bank (2014)

Table 2.6 shows that the ERP in the manufacturing industry decreased from 1991 to 2005. The range of ERP went from a low of 30.8% to a high of 78.9% in 1991. This range decreased in 2005, where the lowest ERP was 4% and the highest ERP was 15.4%. On average, the ERPs in manufacturing were down from 57% in 1991 to 10.2% in 2005.

Table 2.6: Effective Rates of Protection by ISIC 2-digit Industry (%)

ISIC	Industry/Sectors	Effective Rates of Protection			
		1991	1995	2001	2005
31	Food	52.6	61.7	43.3	15.4
32	Textile clothing	78.9	55.1	17.5	13.7
33	Wood	53.4	53.2	16.0	10.7
34	Paper	49.4	25.4	6.6	4.0
35	Chemical	48.0	33.6	13.6	9.5
36	Metal	67.3	29.2	12.2	9.0
37	Machinery	30.8	20.1	8.6	7.7
38	Electrical	57.9	47.1	10.8	6.8
39	Other	74.9	56.2	19.6	15.0
	All	57.0	42.4	16.5	10.2

Source: Widodo (2008, p.171)

In terms of NTBs, the government committed to reform customs procedure. The changes in procedures were expected to take effect in 2007. This reform attempted to reduce the time and cost of clearing customs and limit smuggling and custom fraud.

2.2.8 Current Trade Policy (2008–Present)

Unlike the previous periods in which the government tended to open its industrial policies and trade, in this period, there has been concern regarding the impact of increasing import competition on domestic industries. This may be one of the impacts of the implementation of previous trade reform, especially related to Free Trade Agreement (FTA) (Tijaja and Faisal 2014). The new Industrial Bill 2014 specifically mentioned that imports from China were one of the factors that caused a drop in Indonesia's competitiveness. As indicated by Patunru and Rahardja (2015), Indonesia's manufacturing products, especially labour-intensive products such as footwear, garments, and other light manufacturing, compete directly with China's manufacturing.

To protect domestic industry from competition, the government reverted to protectionism. Several policy measures were launched in terms of tariffs and NTBs. Concerning tariffs, in 2009 and 2010, the tariffs on many goods were increased by the government, especially for goods that directly competed with locally manufactured product such as chemical, electronic products, medicines and many of agricultural products. Export taxes were also used by the government to ensure the sufficiency of domestic input supply to support downstream domestic industries such as export taxes on cocoa, rattan, crude palm oil and mineral ores.

In terms of NTBs, regulations have been in place since 2009. The government applied tighter regulation to import machines, the verification of foreign raw materials in textile and approval of used capital goods, as well as additional requirements on the importation of certain products. In addition, local content requirement regulations have been enforced, in the textile, clothing, footwear and automotive industries.[4]

2.3 Structural Changes in the Economy

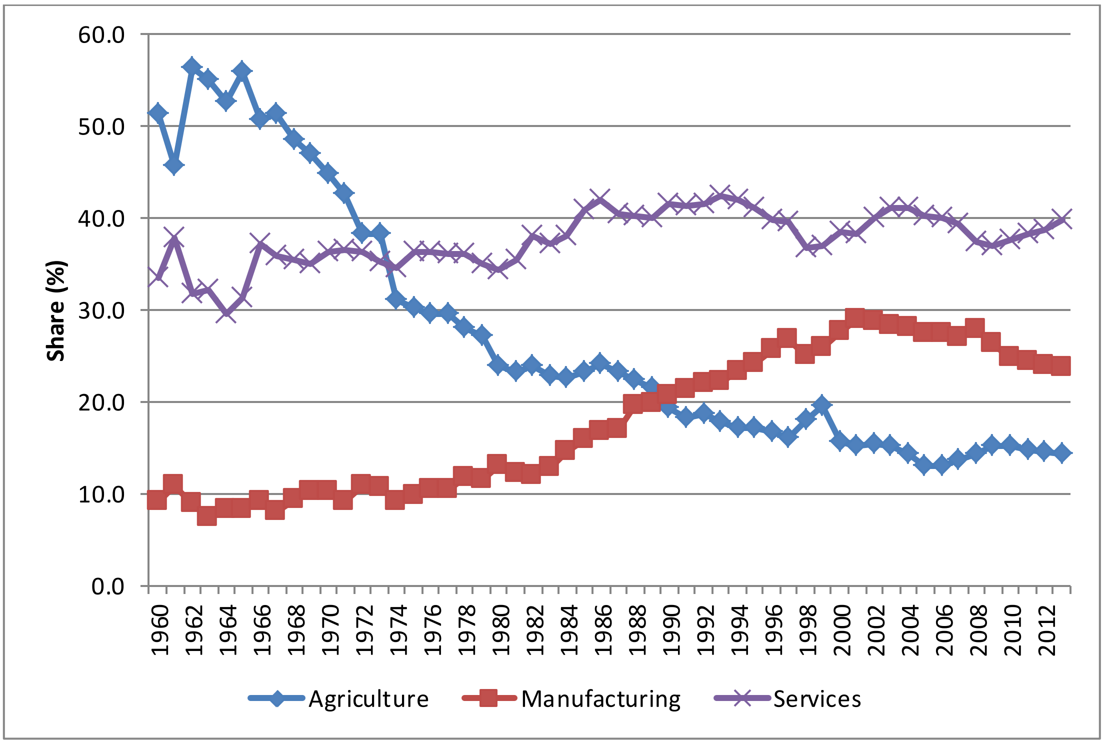
The previous section briefly discussed the major trade reform implemented from 1966 to 2015 in Indonesia. The impact of these reforms has influenced the manufacturing industries in many ways, including, but not limited to, the structural changes in the Indonesian economy. The structural changes in the economy can be

[4] More detailed lists on tariffs and NTBs during this period are provided by Tijaja and Faisal (2014) and Patunru and Rahardja (2015).

analysed in terms of the share of manufacturing industry to GDP, the share of employment in the manufacturing industry to national employment and the share of manufacturing exports to total exports.

Figure 2.1 shows the structural changes in the Indonesian economy regarding the share of manufacturing industries to GDP from 1960 to 2013. In a relatively short period, Indonesia transformed from economy dominated by agricultural sector to economy dominated by manufacturing sector just before the economic crisis.

Figure 2.1: The Share of Manufacturing Industry to Gross Domestic Product (GDP), 1960–2013 (%)

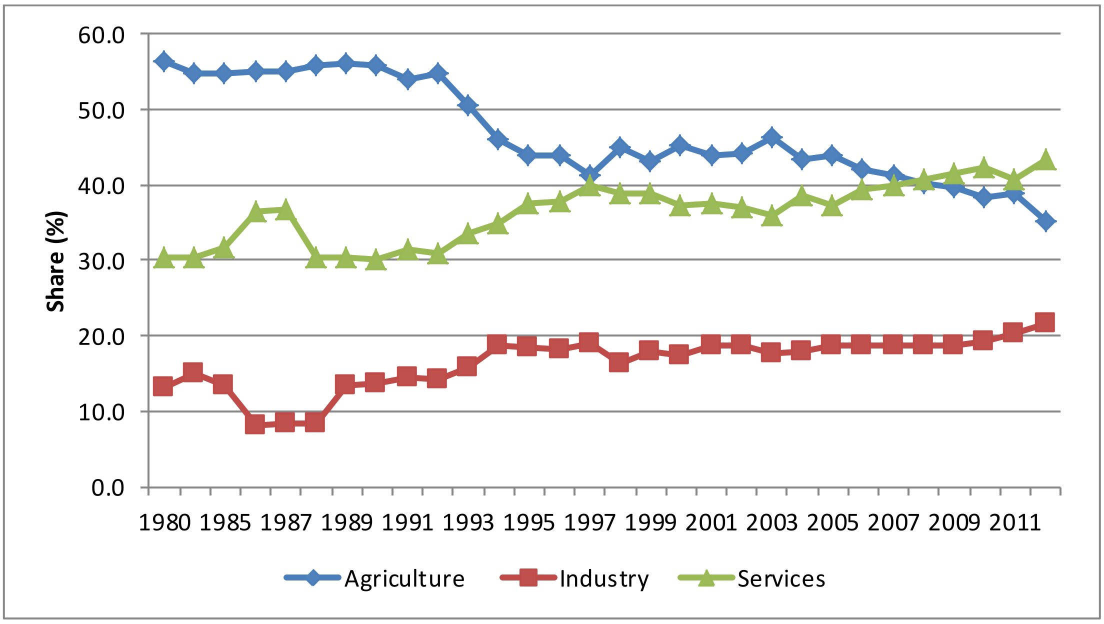


Source: World Development Indicators (World Bank 2014)
Note: The services sector consists of government and private services; finance, real estate and business services; transport and communication; and trade, hotel, and restaurants.

The manufacturing sector has surpassed the share of agricultural sector in the economy since 1990. The role of agricultural sector declined from 51.5% to 16.1% in 1997, a third of its 1960 share. Conversely, the share of manufacturing sector in the economy increase continuously. In 1960, its share was only 9.2% of the GDP and increased to 27% in 1997, three times its 1960 share. The share of the manufacturing sector to GDP was relatively stable at 26% on average until 2013. Meanwhile, the contribution of the services sector was the highest and tended to be consistent at approximately 37% per year.

The second indicator that reflects the structural transformation in the Indonesian economy is the share of labour to total employment. Figure 2.2 shows the change in the contribution of manufacturing to national employment. The share of manufacturing employment to national employment increased from 13.1% in 1980 to 21.7% in 2012. Simultaneously, the share of agricultural sector employment to national employment decreased from 56.4% in 1980 to 35.1% in 2012.

Figure 2.2: The Share of Manufacturing Industry to National Employment, 1980–2012 (%)

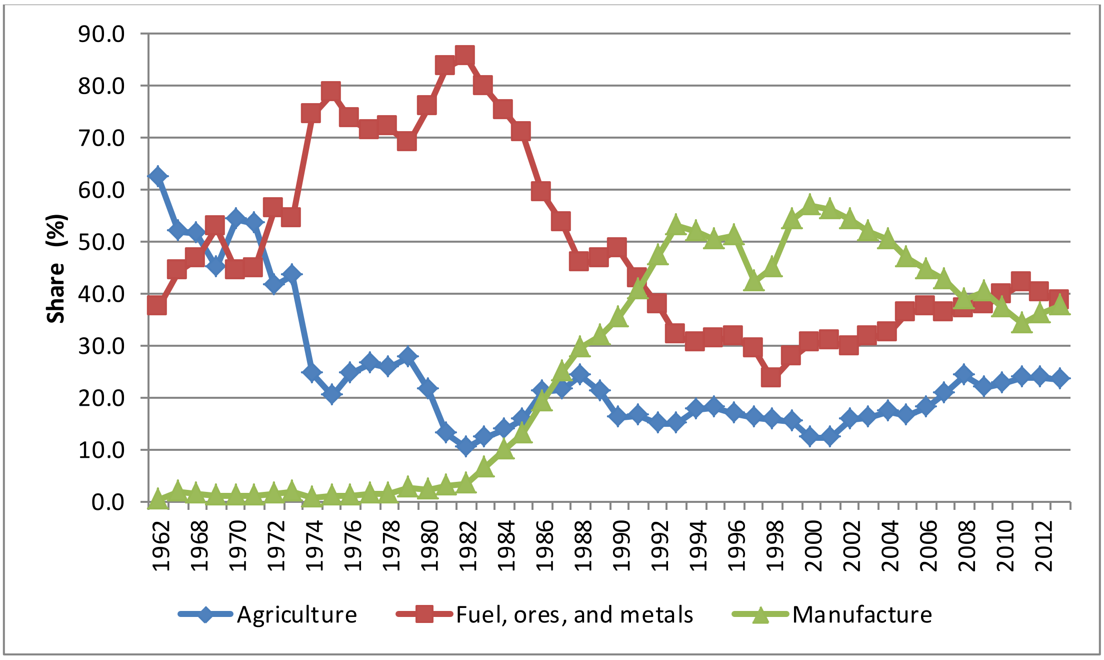


Source: as in Figure 2.1.
Note: The services sector consists of the government and private services; finance, real estate, and business services; transport and communication; and trade, hotel, and restaurants.

Despite a structural transformation in terms of the share of national employment, the smaller change in the share of manufacturing employment to national employment than the share of manufacturing to GDP indicates that the labour productivity of the manufacturing industry is higher than the labour productivity of the agricultural sector. This phenomenon is consistent with the hypothesis that labour movement occurs when there is a rapid transformation during industrialization. In Indonesia, however, the labour movement from the agricultural sector to the manufacturing sector should be carefully interpreted because there are different labour qualifications between the agricultural and manufacturing sector. In Indonesia, un-skilled labour dominates the agricultural sector. Unlike the agricultural sector, the manufacturing sector requires more skilled labour. As a result, the labour availability from the agricultural sector is unsuitable to the demand of labour in the manufacturing industry.

The third indicator of structural change in the economy is the share of manufacturing exports to total exports. Figure 2.3 depicts the pattern of Indonesia's exports since 1962. Until the early 1980s, the contribution of manufacturing exports to total exports was less than 4%. In 1987, the share of manufacturing exports overtook the share of agricultural exports, and in 1992, it surpassed the share of fuel, ore and metal exports. This consistent increase in manufacturing exports to total exports occurred in the period of outward-oriented strategies

Figure 2.3: The Composition of Exports, 1962–2013 (%)



Source: as in Figure 2.1.

Several factors may explain the consistent increase in manufacturing exports from the early 1980s to 1992 (Hill 1996). First, there was a commitment by the government towards moderately low inflation, which facilitated the devaluations of the 1980s. Second, trade reforms were introduced starting in the mid-1980s. Finally, various microeconomic efficiency-promoting reforms began to take effect.

The share of manufacturing exports to total exports tended to increase until 1993. However, in 1994, just three years before the economic crisis, the contribution of manufacturing exports began to decrease until 1998. The contribution of manufacturing exports recovered in 1999 to more than 50% of total exports and reached a peak of 57.1% in 2000, then decreased again from 2000 to 2013. The contribution of manufacturing exports to total exports from 2000 to 2013 was less than the contribution of fuel, ore and metal to total exports.

Many factors contributed to the slow-down of the share of manufacturing exports to total exports (Dhanani 2000). First, manufacturing development relied on a limited number of export products and markets. Second, many industries, even labour-intensive industries such as the textile, garment and leather and footwear industries, relied heavily on imported raw materials because of the lack of domestic suppliers and support industries and weak domestic industrial linkages. Third, the Indonesian manufacturing sector specialized in relatively low technology segments and did not improve its technology status overtime compared with other fast-growing economies.[5] In addition, Wie (2000) notes that manufacturing firms responded to the rapidly and effectively changing demands in export markets with low efficiency and a lack of dynamism.

2.4 The Impact of Trade Reform Policies on Indonesian Manufacturing Industry

This section expands the analysis of the performance indicators and structure of manufacturing industries in the two previous sections. The analysis focuses on the comparison of key indicators the periods of trade reform.

2.4.1 Share of Value Added by Industry

After examining the general trends in the share of manufacturing industry to GDP, the discussion now turns to the path of structural transformation within the manufacturing industry. Table 2.7 shows that among the nine two-digit industries, food (ISIC 31), textile (ISIC 32), chemical (ISIC 35) and metal products (ISIC 38) are the four main largest industry groups in terms of value added. The yearly fluctuation of these four industries is shown in Figure 2.4.

The structural change within the manufacturing industry is shown in Table 2.7. The value added share for food industry declined consistently from 39.7% in 1975-1981 to 20.5% in 1993-1996, which is a loss of over one-third of its 1975-1981 share but

[5] Using UNIDO System of Industrial Development Indicators data 1985 and 1997, Dhanani (2000) shows that the share of higher technology industries remained at approximately 17 %, ranked among the lowest countries listed, and was half of the share of higher technology industries in the Philippines and India.

increased again in the next three periods of trade reform. Although there was a declining trend in the share of food industry to total manufacturing industry, the contribution of food industry was still the highest.

The high contribution of food industry to total manufacturing industry in the early trade reform periods may have occurred because the government focused on this industry as a policy target of self-sufficiency. Realizing that adequate supply of food is an important factor in economic development, the government prioritized this industry by regulating and protecting it.

The second highest contributor to total value added in manufacturing industry is textile. Similar to the Indonesian food industry, the government prioritized the textile industry to reach self-sufficiency for domestic demand. Table 2.7 shows that textile industry reached a peak of 20.1% in the period 1993-1996. Aswicahyono (1998) indicates that the increasing trend of value added in the textile industry was due to the rising demand in the domestic market in the late 1970s and the increased export opportunities in the early 1980s. Several factors can explain the increase export opportunities for the textile industry. Among these factors are sluggish domestic demand following the end oil boom, the relatively low labour cost in Indonesia, under-utilized export quotas and attractive incentives given by the government, such as export subsidies (*Subsidi Ekspor*), interest rate subsidies for export credits and an under-valued real exchange rate (Pangestu 1997).

The share of value added in textile to total manufacturing has declined continously since 1994,as shown in Table 2.7. Pangestu (1997), Dhanani (2000) and Patunru and Rahardja (2015) provide explanations for the decreased share of textile industry. First, intense competition emerged from other low-cost Asian producers, such as China, India and Bangladesh. Second, there was a reduction in Indonesia's relative competitiveness because of changes in the government's minimum wage policy and increased uncertainty in the regulatory environment after the Asian crisis.

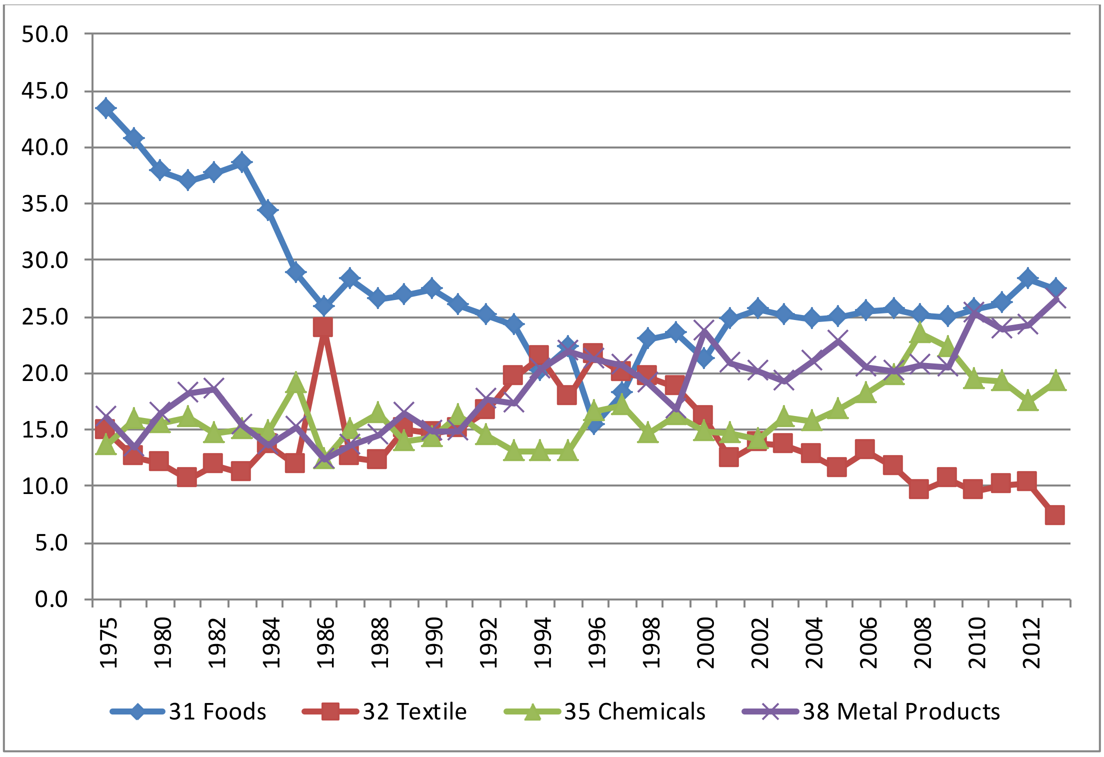
Table 2.7: The Average Share of Value Added in Indonesia's Manufacturing Industries, 1975-2013 (%)

Industries	1975-1981 Inward Looking (IL)	1982-1988 IL	1989-1992 Early Reform (Outward-oriented Strategies)	1993-1996 Further Reform (Outward-oriented Strategies)	1997-2004 Economic Crisis and Recovery	2005-2007*) Recovery Demand and Proactive Industrial Policy	2008-2013*) Current Trade Policy (Growing IL)	Average 1975-2013
31 Food	39.7	31.4	26.4	20.5	23.3	25.4	26.2	27.4
32 Textile	12.5	13.9	14.7	20.1	15.8	12.1	9.5	14.1
33 Wood and Products	5.0	8.8	11.6	8.9	6.7	3.3	1.8	6.6
34 Paper and Products	2.8	2.9	4.6	5.1	6.8	7.1	6.1	5.1
35 Chemical	15.3	15.4	15.1	13.9	15.4	18.2	20.2	16.2
36 Non-Metal and Minerals	6.0	4.9	3.8	4.2	4.1	4.2	3.7	4.4
37 Basic Metal	2.4	7.7	7.6	6.2	5.8	6.2	7.1	6.3
38 Metal Products	16.0	14.7	15.7	20.2	20.2	21.1	23.5	18.8
39 Others	0.3	0.4	0.6	0.8	1.9	2.3	1.9	1.2

Source: Author's calculation from the Annual Survey of Large and Medium Manufacturing Industries, the Indonesian Central Bureau of Statistics/BPS (Badan Pusat Statistik), various issues.

*) During the periods 1975-2013, there have been four revisions in the industrial code as follows: (1) from 1975 to 1990, (2) from 1991 to 1999, (3) from 2000 to 2007, and (4) from 2008 to present. In the first period, the BPS adopted ISIC revision 1. ISIC revision 2, 3 and 4 were used in the second, third and fourth periods, respectively. To obtain comparable and consistent figures, the industrial codes were adjusted to the code of 1990 (ISIC revision 2) by using the special map provided by the BPS.

Figure 2.4: The Share of Value Added in Selected Medium and Large Manufacturing Industries, 1975–2013 (% of Total)



Source: as in Table 2.7.

The decrease in the contribution of value added by the Indonesian food and textile industries to total manufacturing industry were replaced by new emerging industries, such as chemical and metal products. Table 2.7 and Figure 2.4 clearly show the structural transformation of manufacturing in Indonesia. From 1975-2013, the Indonesian manufacturing industry shifted from light labour-intensive industries to heavy capital-intensive industries.

Table 2.7 shows the share of value added by chemical industry to manufacturing industry. This share was approximately 15% in the early periods of industrialization and became one of the highest contributor of value added to Indonesian manufacturing industry. This contribution occurred because the government prioritized this industry as a policy target to reach self-sufficiency in the production of rice,[6] to reduce import dependence on petrochemical products and to increase the domestic value added of oil- and gas-based products.

[6] One sub-sector in the chemical industry is fertilizer. This sub-sector was designated a strategic industry by the government because fertilizer is an important material in the production of rice. Accordingly, the government imposed strict controls on the production and distribution of fertilizer.

Similar to the Indonesian chemical industry, the Indonesian metal products industry was one of the highest contributors of value added to the total manufacturing industry. One possible explanation for the high contribution of metal products may be because the government selected this sector as a policy target of self-sufficiency in the capital goods industry. By implementing import substitution, the government provided high protection and various NTBs to this industry.

2.4.2 Share of Employment by Industry

Table 2.8 describes the employment share in the manufacturing industries from period 1975-2013. Similar to the highest contributors of value added in the manufacturing industries, food (ISIC 31), textile (ISIC 32), chemical (ISIC 35) and metal products (ISIC 38) were the four highest contributors of labour absorption in the Indonesian manufacturing industry. The yearly fluctuation of employment absorption in manufacturing industry is shown in Figure 2.5

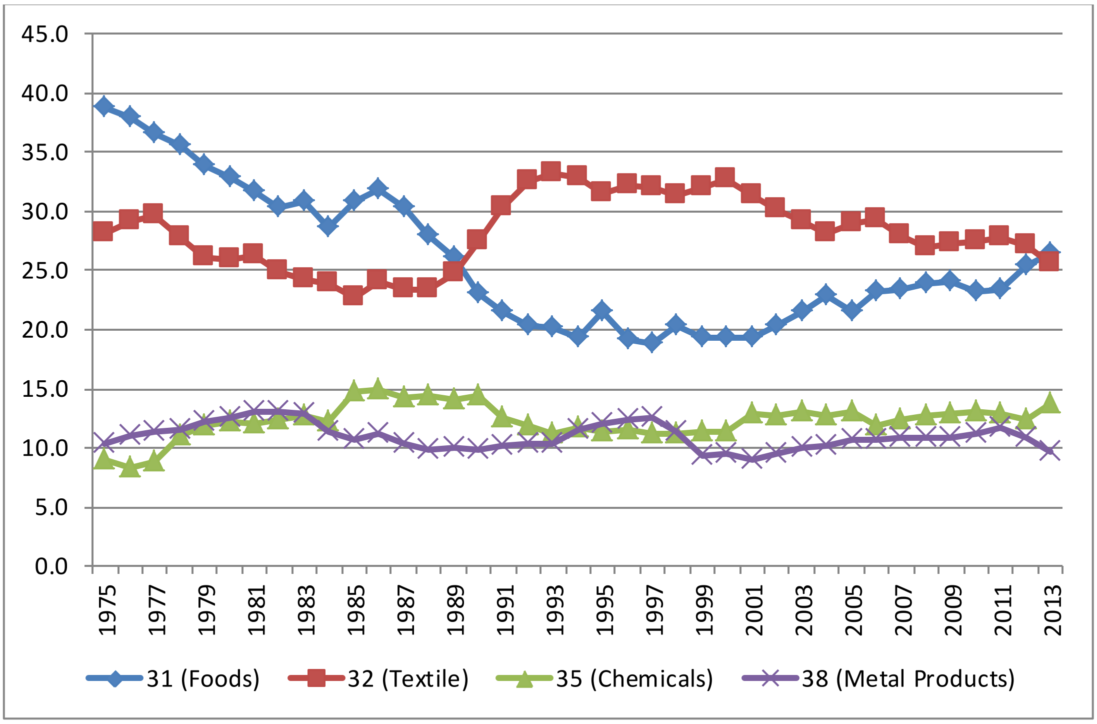
Two specific characteristics of labour absorption are worth mentioning. First, employment share in the manufacturing industry was dominated by labour-intensive industries, which were the food and textile industries. In the first-two periods of trade reforms, food industry (ISIC 31) absorbed the highest share of total employment in manufacturing industry. The food industry reached a peak of 35.3% in the first period of trade reform (inward-looking) and decreased to 24.4% from 2008-2013. Although the share of employment in food industry tended to decrease during the observed periods, the share of employment in textile industry (ISIC 32) increased from 27.6% in 1975-1981 and reached a peak of 32.4% in 1993-1996. The share of employment in this industry, however, started to decrease from 1997-2004 and from 2008-2013, its share was 27% of total manufacturing industry, which is approximately the same as its share in the first period of trade reform.

Table 2.8: The Average Share of Employment in Indonesia's Manufacturing Industry, 1975–2013 (% of Total)

Industries	1975-1981 Inward Looking (IL)	1982-1988 IL	1989-1992 Early Reform	1993-1996 Further Reform	1997-2004 Economic Crisis and Recovery	2005-2007 Recovery Demand and Proactive Industrial Policy	2008-2013 Current Trade Policy (Growing IL)	Average 1975-2013
31 Food	35.3	30.1	22.7	20.1	20.2	22.7	24.4	25.8
32 Textile	27.6	23.8	28.8	32.4	30.8	28.8	27.0	28.2
33 Wood and Products	5.6	11.0	14.9	13.5	10.1	6.6	4.9	9.2
34 Paper and Products	3.3	3.4	3.4	3.6	3.9	4.1	3.9	3.6
35 Chemical	10.5	13.7	13.2	11.4	12.1	12.4	13.0	12.3
36 Non-metal and Minerals	4.7	4.9	4.4	4.3	4.0	3.9	3.9	4.3
37 Basic Metal	0.6	1.0	1.2	1.2	3.3	4.1	4.6	2.2
38 Metal Products	11.7	11.4	10.1	11.5	10.2	10.8	10.9	10.9
39 Others	0.6	0.8	1.3	1.9	5.3	6.7	7.4	3.3

Source: as in Table 2.7.

Figure 2.5: The Share of Employment in Selected Medium and Large Manufacturing Industry, 1975–2013 (% of Total)



Source: as in Table 2.7.

Second, two capital-intensive industries contributed a relatively high share to employment: chemical (ISIC 35) and metal products (ISIC 38). The shares of employment to total employment were 13% for the chemical industry and 10.9% for the metal products industry from 2008-2013. However, their shares to total employment during the observed periods were smaller than their share of total value added in manufacturing industry. This finding indicates that these sectors had relatively higher labour productivity compared with other industries.

2.5 Comparisons of Trade Reform across Countries

After this discussion of the trade reform policies' impact on the Indonesian manufacturing industry, this section continues with comparisons of the trade reform policies in manufacturing industries across countries. Table 2.9 provides some comparisons between the ERP estimates for Indonesian manufacturing industry and these available estimates of six major East Asian economies. A consistent comparison of ERP estimates across countries is difficult to compile because of significant differences in ERP estimates concerning the coverage given the various elements of trade reform policies in each country. However, based on the trend of magnitude, it can be inferred that the trend of protection in Indonesia is consistent with the other countries in the region. From 1969-2005, there was a substantial decrease in the ERP in Indonesia, Malaysia, Philippines, Thailand and Vietnam.

As shown in Table 2.9, by the end 1980s, the ERPs were 70%, 23%, and 51% in Indonesia, Malaysia and Thailand, respectively. This result means that compared with Malaysia and Thailand, the protection rate in Indonesia was higher. By the early 2000s the ERPs were 23.4%, 10.4%, 25.2% and 44% in Indonesia, Malaysia, Thailand and Vietnam, respectively. Thus, the protection rate in Indonesia was lower than the protection rate in Thailand and Vietnam but still higher than in Malaysia. The Philippines had faster reform process because its ERP within seven years decreased, from 32% in 1992 to 10% in 1999.

Table 2.9: ERP Manufacturing Industry in Selected East Asian Countries

Country	Year	ERP (%)	Source
Indonesia	1975	74	World Bank (1993)**
	1987	70	Fane and Condon (1996)**
	1990	59	World Bank (1993)**
	1991	51[a], 55.6[b]	Widodo (2008)
	1995	25[c], 42.4[a,d], 45.6[b,d]	[c]Fane and Condon (1996)**; [d]Widodo (2008)
	2000	25.7	Soesastro and Basri (2005a)
	2001	16.5[a], 23.4[b]	Widodo (2008)
	2005	10.2[a], 11.6[b]	Widodo (2008)
South Korea	1970	40	World Bank (1993)
	1975	55	World Bank (1993)
	1980	67	World Bank (1993)
	1985	80	World Bank (1993)
	1988	28	Paganariya (1994)
Malaysia	1969	45	Shalleh and Meyanathan (1993)
	1979/1980	31	Shalleh and Meyanathan (1993)
	1988	23	Paganariya (1994)
	2003	16	Athukorala (2005a)
Philippines	1992	32	Paganariya (1994)
	1999	10	WTO (1999)
Thailand	1981	74	World Bank (1993)
	1988	51	Paganariya (1994)
	2002	25.2	Athukorala *et al*. (2004)
	2004	22.7	Athukorala *et al*. (2004)
Vietnam	1997	121	Athukorala (2002)
	2002	95	Athukorala (2002)
	2003	44	Athukorala (2005b)

Note: * is calculated as the weighted average of estimates by industry reported in the given source. Weighting was performed by using value added data from UNIDO (United Nations Industrial Development Organization).

** Estimates for non-oil manufacturing

a. The simple average of ERP industry ISIC taken from Table 3, Widodo (2008)

b. The simple average of ERP industry IO-codes taken from Table 4, Widodo (2008)

Source: Table 5, Widodo (2008)

Table 2.10: ERP by IO (Input-Output) Code Industry (%)

IO Code	Industry	ERP					
		Indonesia				Malaysia[a]	Vietnam[b]
		1991	1995	2001	2005	2003	2003
27	Food manufacture industry	-18.8	65.5	49.6	29.4	3.6	43.9
28	Oil and fat industry	48.0	59.5	38.7	12.3	5.8	18.5
29	Rice milling industry	178.0	117.5	82.9	17.8	11.4	123.2
30	Flour industry	57.8	61.6	31.9	10.2	11.4	34.0
31	Sugar industry	26.1	45.7	58.6	11.7	3.8	34.0
32	Other food industry	48.7	56.8	35.9	11.7	3.8	34.0
33	Beverage industry	43.8	51.2	25.7	15.3	24.3	55.4
34	Tobacco	37.5	35.7	23.3	14.5	5.3	55.3
35	Knitting industry	63.7	49.3	17.3	13.5	13.9	71.0
36	Textile, clothes, & leather industry	94.2	61.0	17.7	13.9	28.6	43.0
37	Bamboo, wood, & rattan industry	53.4	53.2	16.0	10.7	21.0	1.2
38	Paper & paper products industry	49.4	25.4	6.6	4.0	7.8	17.1
39	Fertilizer & pesticide industry	54.4	40.6	16.5	11.5	4.1	-1.7
40	Chemical industry	46.9	34.8	12.0	7.9	1.6	-4.0
41	Refined petroleum industry	40.7	27.5	11.3	7.8	4.1	-
42	Rubber & plastic products industry	59.5	40.9	13.0	9.7	17.5	21.8
43	Non-metallic mineral products	34.1	26.9	12.2	8.6	15.8	47.8
44	Cement industry	52.3	30.6	16.8	11.5	7.2	49.7
45	Iron & steel industry	58.6	23.4	11.8	9.4	6.6	-20.9
46	Non-ferrous metal industry	74.4	35.3	15.0	9.1	18.0	0.8
47	Metallic products industry	68.9	28.9	9.7	8.4	4.9	-
48	Machinery and electrics equipment industry	57.9	47.1	10.8	6.8	2.4	2.0
49	Transportation equipment industry	30.8	20.1	8.6	7.7	21.7	46.6
50	Other manufacturing products	74.9	56.2	19.6	15.0	4.0	34.6
	Maximum (Max)	178.0	117.5	82.9	29.4	28.6	123.2
	Minimum (Min)	-18.8	20.1	6.6	4.0	1.6	-20.9
	Range (Max-Min)	196.8	97.4	76.3	25.4	27.0	144.1
	Simple Average	55.6	45.6	23.4	11.6	10.4	32.2
	Standard Deviation	33.5	20.5	18.3	4.9	7.9	31.3
	Coefficient of Variation	0.6	0.5	0.8	0.4	0.8	1.0

Note: a. Taken from Athukorala (2005a)

b. Taken from Athukorala (2005b). Some figures in the cases Malaysia and Vietnam are the simple averages of the ERP of some industries (IO Codes) because of different classifications of the sectors in the IO table among countries

Source: Table 4, Widodo (2008)

The empirical studies conducted by Athukorala (2005a), Athukorala (2005b) and Widodo (2008) show the ERP in terms of the industry IO code in Malaysia, Vietnam and Indonesia, which are shown in Table 2.10. Generally, the ERPs in Indonesia were lower than the ERPs in Vietnam but higher than in Malaysia. Regarding the simple averages, the average ERP in Indonesia in 2005 was still higher than in Malaysia in 2003 but lower than Vietnam in 2003. In addition, the value of coefficient of variation in Indonesia in 2001 was the same as this value in Malaysia in 2003. The coefficient of variation in Indonesia, however, declined to 0.4 in 2005. The decline of the coefficient of variation suggests that the protection rates in Indonesian industries were less dispersed in 2005 than in 2001. Furthermore, this table also reveals that in 2005, the food manufacturing industry was the most protected industry in Indonesia.

2.6 Conclusion

This chapter presents an overview of Indonesian manufacturing industry. It discusses the series of major trade reforms that have been introduced since the 1960s and their impacts on trends and structural changes in the Indonesian economy. The purpose of this chapter is to provide a background for the subsequent analysis of trade reform and its impact on productivity in Indonesian manufacturing. Since 1966, there have been at least eight major trade reform episodes. The changes in trade reform regimes have important effects on the trends and structural changes in manufacturing industry. There was a shift from an open economy that prioritized resources-based and labour-intensive industries, such as food and textile, to a more closed economy during the oil boom period that highly depended on implementing an import substitution strategy. The regime returned to a more open economy when oil prices declined and again, the economy was opened the economy by focusing on an export promotion strategy. However, the government tended to retreat to protectionism in the later period (2008-2013) because of a decrease in the prices of commodity exports and an increase in competition from other low-wage countries.

This chapter also finds that there are four important industries in the manufacturing sector, in terms of the share of value added to total value added in manufacturing sector and the share of employment absorption to total employment in the manufacturing sector. The four main industries are food (ISIC 31), textile (ISIC 32), chemical (ISIC 35) and metal products (ISIC 38).

The effects of the trade reform policies on the manufacturing sectors can be evaluated in various ways. As noted in the literature, trade reforms tend to have different effects across manufacturing industries and countries. Therefore, it is worth examining the effects of trade reforms on the productivity and efficiency growth in the Indonesian manufacturing industry. The next task of this thesis is to develop appropriate methods to investigate the effects of trade reforms on the Indonesian manufacturing industry, in terms of productivity and efficiency growth. However, first, there is a review of existing literature on the subject in the following chapter.

Chapter 3
Total Factor Productivity (TFP) Growth and Trade Reform: A Survey of the Literature

3.1 Introduction

This chapter reviews the methods of measuring total factor productivity (TFP) growth and the empirical literature on the impact of trade reform on industrial productivity growth and technical efficiency. The purpose of this review is to highlight some important issues for empirical analysis of the impact of trade reform on technical efficiency and productivity growth in selected Indonesian manufacturing industries provided in Chapters 5, 6 and 7.

This chapter is organized as follows: Section 3.2 discusses various methods of measuring and estimating TFP growth. This section is followed by a review of the empirical literature relating to the impact of trade reform on TFP growth in Section 3.3. Section 3.4 presents the empirical literature on the impact of trade liberalization on technical efficiency. Finally, Section 3.5 provides a conclusion and relates this chapter to the focus of the present study.

3.2 Total Factor Productivity (TFP): A Survey of Methodological Literature

The concept of TFP growth dates back to the works of Abramovitz (1956), Swan (1956), Solow (1957) and Griliches and Jorgenson (1966) among others. Since these early studies, a significant number studies have been done by researchers, such as Griliches (1960), Arrow *et al.* (1961), Kendrick (1961), Denison (1962), Jorgenson and Griliches (1967), Nadiri (1970, 1972) and Nelson (1981). According to these earliest contributions to TFP growth measurement, TFP growth is measured as the difference between the growth of output and the growth of inputs. Therefore, conceptually, TFP growth is the growth of output not attributable to the growth of inputs.

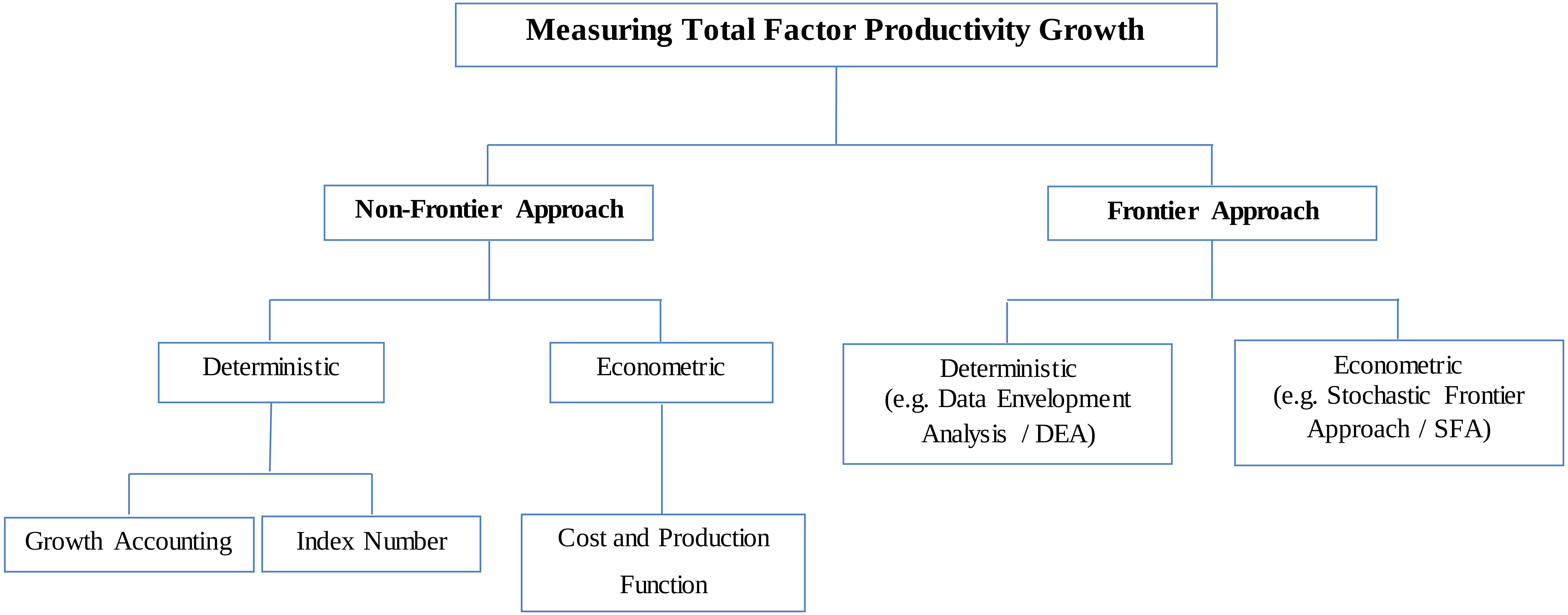
More recently, the analysis of productivity measurement has undergone significant development building on the introduction of the frontier approach by Farrell (1957). Under this approach, firms are considered to have an improvement in productivity arising from technical progress alone, if firms are operating on their production frontier. When firms are operating below the production frontier, any change in TFP growth may arise from not only technical change but also from changes in technical efficiency. A number of studies, including Nishimizu and Page (1982), Bauer (1990), Färe *et al.* (1994), Perelman (1995) among others, use this approach to TFP measurement.

Figure 3.1 shows that the literature on TFP growth measurement can be broadly categorized into two groups: (1) the non-frontier approach and (2) the frontier approach. The non-frontier and frontier classification is very important in the methodological categorization since the frontier approach explicitly incorporates the presence of technical inefficiency as a component of TFP growth. In contrast, the non-frontier approach assumes that firms are technically efficient, thus technical progress is the only component of TFP growth. Both groups, the non-frontier and the frontier methodologies, can be further divided into two groups: (a) the deterministic approach and (b) the econometric approach. The following sections provide an overview of this categorization of TFP measurement.

3.2.1 Non-Frontier Approach

Under the non-frontier approach, it is assumed that firms are always fully efficient. Thus, the observed output in every period of time is a best practice or frontier output and all firms are technically efficient in the sense of Farrell (1957). As noted above, the non-frontier approach can be divided into (a) deterministic methodologies and (b) econometric methodologies. Deterministic methodologies can also be divided into (i) the growth accounting approach and (ii) the index number approach. The econometric approach can be divided into (i) the production function and (ii) the cost function.

Figure 3.1: Measuring Total Factor Productivity Growth



Source : Author's schematization based on Salim (1999) and Gatto *et al.* (2009)

3.2.1.1 Deterministic Methodologies

3.2.1.1.1 Growth Accounting Approach

The original analysis of the growth accounting method was first introduced by Solow (1957). According to Solow, the aggregate production function can be written as:

$$Y = A(t)F(K, L) \tag{3.1}$$

where Y, K, and L are output, capital, and labour, respectively. $A(t)$ represents the technology which is a function of time. Taking logs of the production function and differentiating Equation 3.1 with respect to time yields:

$$\dot{Y} = A_t \dot{t} + F_K \dot{K} + F_L \dot{L} \tag{3.2}$$

where A_t is $\frac{\partial A(t)}{\partial t}$, F_K is $\frac{\partial F(K,L)}{\partial K}$ and F_L is $\frac{\partial F(K,L)}{\partial L}$.

Applying exactly the same technique as used in Equation 3.2 in deriving the expression for the growth rate of output yields:

$$g_y = \frac{A_t t}{Y} g_t + \frac{F_K K}{Y} g_K + \frac{F_L L}{Y} g_L \tag{3.3}$$

The growth of output is equal to a function of the growth rates of the technology factor, capital and labour. To obtain total factor productivity (TFP) growth it is assumed that labour and capital are traded in competitive markets and paid at their marginal products. This means that the marginal product of capital, $F_K(K, L) = r$, where r is the rental cost of capital in the economy and that the marginal product of labour, $F_L(K, L) = w$, where w is the real wage. Additionaly, it is defined that Solow Residual Growth (SRG henceforth) = $SRG = \frac{A_t t}{Y} g_t$. Equation 3.3 can be rewritten as follows:

$$g_y = SRG + \frac{rK}{Y} g_K + \frac{wL}{Y} g_L \tag{3.4}$$

Since $\sigma_K = \frac{rK}{Y}$ corresponds to the share of total income spent by the economy on payments to capital, it is usually called the capital share. Similarly, $\sigma_L = \frac{wL}{Y}$ corresponds to the share of of total income spent by the economy on payments to labour and is called the labour share. The expression of SRG, which is also called as TFP growth, can be expressed as:

$$TFP\ growth = SRG = g_y - \sigma_K g_K - \sigma_L g_L \tag{3.5}$$

It is clear from Equation 3.5 that TFP growth is the growth in output not accounted for by the growth in inputs. In the literature, this Solow productivity index is widely known as Solow's 'residual' approach. Given the assumptions of perfectly competitive equilibrium, TFP growth based on this approach is equivalent to technical change represented by vertical shifts in the production function.

When the production function is assumed as constant returns to scale (homogeneous of degree one), the sum of the capital and labour shares is one and TFP growth can be expressed as follows:

$$TFP\ growth = SRG = \ g_y - \ \sigma_K g_K - (1 - \sigma_K) g_L \qquad \textbf{3.6}$$

The Solow residual approach has both advantages and disadvantages. The advantage of this approach is mainly because of its characteristic that it is relatively simple to compute and has empirical appeal. However, there are several shortcomings. These shortcomings are due to the very strong assumption of perfect competitively equilibrium. In reality, these assumptions may not hold. So, measuring productivity growth using this approach may lead to unreliable results.

As shown by Gatto *et al.* (2009), relaxing the implicit assumption of constant returns to scale in the production function produces a difference between the estimated Solow's residual growth, $\widehat{SRG}$, and true productivity growth (SRG). For instance, in the case of increasing returns to scale and spillovers, the production function can be written as:

$$Y_i = AK_i^{\alpha} K_i^{\beta} L_i^{1-\alpha} \qquad \textbf{3.7}$$

Equation 3.7 shows that the production function of firm i depends not only on its inputs, K_i and L_i, but also on aggregate capital stock, K. If $0 < \alpha < 1$ and $\beta > 0$, it represents a production function with constant returns to scale (CRS) in its inputs and positive spillovers.

For simplicity, it is assumed that in equilibrium each firm has the same capital-labour ratio and aggregating across firms in the economy yields a production function as follows:

$$Y = AK^{\alpha+\beta} L^{1-\alpha} \qquad \textbf{3.8}$$

It can be shown that in this case, the estimated Solow's residual growth, $\widehat{SRG}$, would be biased upwards:

$$\widetilde{SRG} = \ SRG + \ \beta \frac{\dot{K}}{K} \qquad \textbf{3.9}$$

where SRG denotes the true TFP growth rate.

3.2.1.1.2 Index Number Approach

Another way to measure productivity growth besides the growth accounting approach is by using an index number approach. Unlike the growth accounting approach that starts with an aggregate production function, the index number approach starts with an index number. There are four index numbers used to measure productivity, namely, the Laspeyres, Paasche, Fisher and Törnqvist (Diewert and Lawrence 1999, Carlaw and Lipsey 2003). These index numbers show that productivity growth can be measured as the ratio of output index to an index of all inputs assigned with appropriate weights.

Suppose that a firm produces *M* outputs and uses *N* inputs in each time period t. The quantity of output *m* produced in period *t* is represented by y_m^t for m = 1, . . . , *M* and the quantity of input *n* used in period *t* is denoted by x_n^t for n = 1, . . . , *N*. The output revenue share is defined as:

$$s_m^t \equiv \frac{p_m^t y_m^t}{\sum_{i=1}^{m} p_i^t y_i^t} \qquad \textbf{3.10}$$

Equation 3.10 is used as a weight of individual output growth rates, where p_m^t is the average selling price for output *m* in period t.

The Laspeyres, Paasche, Fisher and Törnqvist output quantity indices for periods 0 and 1 are defined, respectively, as follows:

$$Q_L(p^0, p^1, y^0, y^1) \equiv \frac{(p^0 y^1)}{(p^0 y^0)} = \sum_{m=1}^{M} s_m^0 \left(\frac{y_m^1}{y_m^0}\right) \qquad \textbf{3.11}$$

$$Q_P(p^0, p^1, y^0, y^1) \equiv \frac{(p^1 y^1)}{(p^1 y^0)} = \left[\sum_{m=1}^{M} s_m^1 \left(\frac{y_m^1}{y_m^0}\right)^{-1}\right]^{-1} \qquad \textbf{3.12}$$

$$Q_F(p^0, p^1, y^0, y^1) \equiv [Q_L(p^0, p^1, y^0, y^1) Q_P(p^0, p^1, y^0, y^1)]^{0.5} \qquad \textbf{3.13}$$

$$Q_T(p^0, p^1, y^0, y^1) \equiv \prod_{m=1}^{M} \left(\frac{y_m^1}{y_m^0}\right)^{0.5(s_m^0 + s_m^1)} \qquad \textbf{3.14}$$

Similarly, the Laspeyres, Paasche, Fisher, and Törnqvist output quantity indices for periods 0 and 1 are defined, respectively, as follows:

$$I_L(w^0, w^1, x^0, x^1) \equiv \frac{(w^0 x^1)}{(w^0 x^0)} = \sum_{n=1}^{N} s_n^0 \left(\frac{x_n^1}{x_n^0}\right) \qquad \textbf{3.15}$$

$$I_P(w^0, w^1, x^0, x^1) \equiv \frac{(w^1 x^1)}{(w^1 x^0)} = \left[\sum_{n=1}^{N} s_n^1 \left(\frac{x_n^1}{x_n^0}\right)^{-1}\right]^{-1} \qquad \textbf{3.16}$$

$$I_F(w^0, w^1, x^0, x^1) \equiv [I_L(w^0, w^1, x^0, x^1) I_P(w^0, w^1, x^0, x^1)]^{0.5} \qquad \textbf{3.17}$$

$$I_T(w^0, w^1, x^0, x^1) \equiv \prod_{n=1}^{N} \left(\frac{x_n^1}{x_n^0}\right)^{0.5(s_n^0 + s_n^1)} \qquad \textbf{3.18}$$

where the period t cost share for input n is defined as:

$$s_n^t \equiv \frac{w_n^t x_n^t}{\sum_{n=1}^{N} w_n^t x_n^t} \qquad \textbf{3.19}$$

Using the output and input quantity indices as defined in Equations 3.11 to 3.18 above, a productivity index is now formulated as an output quantity index $Q(p^0, p^1, y^0, y^1)$ divided by an input quantity index $I(w^0, w^1, x^0, x^1)$.

The Laspeyres and Paasche indices are the most frequently used (Diewert 1992, Salim 1999). As can be seen from Equations 3.11 and 3.15, the Laspeyres index is the value of output/input quantities in period 1 relative to those in period 0 measured using prices of period 0. The Paasche index measures the relative output/input quantities in the two periods using period current year prices (period 1) in its calculation of weights.

The popularity of Laspeyres and Paasche indices for measuring TFP is mainly because of their computational ease. However, the use of these indices has diminished recently. The Laspeyres index is criticized because of the assumption imposed regarding the production function (Christensen 1975). It is implicitly assumed that the underlying production function is linear, which implies that all factors of production are perfect substitutes. The linearity of the production function implies that marginal productivities remain constant irrespective of the growth rate of an input in relation to the other input (Yotopulous and Nugent 1976).

The Paasche index is also criticized because of a tendency of upward bias in measuring output per unit of input (Ruttan 1960). Furthermore, Diewert and Lawrence (1999) show that these index numbers do not satisfy the properties outlined in the axiomatic approach to index numbers.[7] Hence, measuring the productivity index by using these index numbers may lead to misleading results.

Another commonly used index number which is 'ideal' in measuring the productivity index is the Fisher index (Fisher 1922). Diewert and Lawrence (1999) show that this index is ideal because it satisfies a maximum number of standard tests.[8] Fisher's productivity index, as shown in Equations 3.13 and 3.17, is equal to the square root of the product of the Laspeyres and Paasche indices. Diewert (1976, 1978) shows

[7] Diewert and Lawrence (1999) list the desired properties of the axiomatic approach and discuss which index number satisfies all the properties.
[8] Some of tests in this approach are the product test, the identity test, the commensurability test, the proportionality test and time reversal test.

that the Fisher index is the best choice for measuring the productivity index because it does not depend on any assumptions about optimizing behaviour on the part of firms and it passes all the standard tests.

In recent economic research, another commonly used index number for measuring productivity is the Törnqvist (1936) index number. The Törnqvist index geometrically weights the output of the two periods using an average of the two period share weights. Based on Equations 3.14 and 3.18, the Törnqvist productivity growth rate is the difference between the successive (say, *t* and *t-1*) total output less the weighted average of differences between successive total input shares, all expressed as logarithm, as follows:

$$TP = \left[[lnY_t - lnY_{t-1}] - \sum_i \frac{1}{2}[S_{i,t} + S_{i,t-1}][lnX_{i,t} + lnX_{i,t-1}]\right] \qquad \textbf{3.20}$$

where *TP* denotes the Törnqvist productivity index , $[lnY_t - lnY_{t-1}] = \sum_i \frac{1}{2}[R_{i,t} + R_{i,t-1}][lnY_{i,t} + lnY_{i,t-1}]$, R_i represents the revenue share of the *i*th output in total revenue, Y and X stand for output and inputs, respectively; and S_i represents the input shares to output measured as $S_i = \frac{p_{ix_i}}{\sum_i p_{ix_i}}$ where input prices are given by p_i.

The Törnqvist productivity index, as given in Equation 3.20, is also known as a translog productivity index because Diewert (1976) relates this index to a translog production function. This index requires three restrictive assumptions, they are: (i) price taking revenue maximizing behaviour on the part of the producer; (ii) price taking cost minimizing behaviour and (iii) a translog technology. Christensen *et al.* (1971, 1973) show that this index is ‘exact’ for the homogenous translog technology. Furthermore, Christensen *et al.(*1971, 1973) argue that the translog production function can provide a second-order approximation to an arbitrary twice differentiable homogenous production function. Diewert (1975) uses the term ‘superlative’ for the ‘exact’ index number. This production function is referred to as a ‘flexible’ production function since it can approximate a production function with arbitrary substitution possibilities. This translog production function does not require inputs to have perfect substitution. If there is a change in relative prices of inputs, firms can adjust the use of inputs until all marginal productivities are proportional to the new price.

Poole and Bernard (1984) show that the Törnqvist productivity index is computationally simple because it does not have an econometric estimation problem of a cost function and factor share demands, and the production function approach is still attractive even if the market is imperfect. However, the Törnqvist index has a shortcoming in certain circumstances. As shown by Fuss (1994), if the assumption of price equal marginal costs does not hold, the estimates of TFP using the Törnqvist formula are theoretically incorrect.

Using Canadian telecommunication firms' data, Fuss shows that this assumption does not hold due to the characteristics of the regulatory environment. The prices of toll services tend to be above marginal cost, whereas the prices of basic local services are set below marginal costs by regulators. In such circumstances, where the prices are not set proportional to marginal costs, the use of the conventional Törnqvist formula leads to biased results. Empirically, Fuss calculates the productivity growth in the two largest Canadian telephone companies, namely, Bell Canada and B.C. Tel. For Bell Canada, the conventional Törnqvist formula leads upwards bias to be approximately 75% over the period 1980-1989 and 80% over the period 1985-1989. For B.C. Tel, the use of this index yields an upward bias as well. The upward bias for B.C. Tel is approximately 37% over the period 1980-1989 and 48% over the period 1985-1989. In these circumstances, Fuss demonstrates that the conventional Törnqvist formula needs to be replaced by a formula which uses cost elasticity weights. Thus, the revenue share (R) in $[lnY_t - lnY_{t-1}]$ in Equation 3.20 is replaced by $[lnY_t - lnY_{t-1}] = \sum_i \frac{1}{2}[M_{i,t} + M_{i,t-1}][lnY_{i,t} + lnY_{i,t-1}]$, where $M_{i,t}$ is the cost elasticity of the *i*th output divided by the sum of the cost elasticities, summed over all outputs.

3.2.1.2 Econometric Approach: Estimation of Production or Cost Function

Having reviewed the method of measuring TFP by using deterministic methodologies, attention now is given to another method of measuring TFP growth. The method is an econometric approach that can measure TFP growth by estimating a production or cost function. Under an econometric estimation of production or cost functions, technological change is defined by the shift in the production or cost function if scale and efficiency effects are assumed to be constant (Salim 1999).

Suppose a production function has time as an argument:

$$y_t = f\ (x_t, t) + \ \varepsilon \qquad \textbf{3.21}$$

where y and x denote output and inputs, respectively. ε is disturbance term. Time, t, is an argument, and t = 1, 2, 3 …, T. Parameters of the production function in Equation 3.21 can be estimated by ordinary least square (OLS) or maximum likelihood method. The first partial differentiation of the input set with respect to time is technical change, that is $\frac{\delta f(x_t)}{\delta t}$. Assuming firms, industries and sectors are operating under full efficiency, then technical change is equivalent to TFP growth.

As shown by Ohta (1975), technical change can also be formulated by using cost functions. Following Grosskopf (1993), the cost function which is dual to the production function in Equation 3.23 can be written as follows:

$$C_t = C\left(y_t w_t, t\right) = \sum_{n=1}^{N} w_t^n\, x_t^n \qquad \textbf{3.22}$$

where x_t^n are chosen to minimize cost at t given outputs $y_t\ \in\ \Re_+^M$, input prices w_t^n and technology. Assuming there is no technical inefficiency and no allocative inefficiency, technology exhibits constant returns to scale and technical change is Hicks neutral, the cost function in Equation 3.22 can be rewritten as:

$$C_t = B(t)C\left(w_t\right)y_t \qquad \textbf{3.23}$$

where $B(t)$ is the function which captures technical change. Totally differentiating Equation 3.23 and using Shephard's lemma yields:

$$\frac{\dot{C}}{C} = \frac{\dot{y}}{y} + \frac{\dot{B(t)}}{B(t)} + \ \sum_{n=1}^{N} s^n \left(\frac{\dot{w}^n}{w^n}\right) \qquad \textbf{3.24}$$

or

$$\frac{\dot{B}(t)}{B(t)} = \frac{\dot{C}}{C} - \ \frac{\dot{y}}{y} - \sum_{n=1}^{N} s^n \left(\frac{\dot{w}^n}{w^n}\right) \qquad \textbf{3.25}$$

Equation 3.25 shows that technical change is the residual change in average cost $\left(\frac{\dot{C}}{C} - \ \frac{\dot{y}}{y}\right)$ which is not accounted for by the change in the index of input prices. It is clear that under constant returns to scale $\frac{\dot{B}(t)}{B(t)} = A_t \dot{t}$ (from Equation 3.2). In this case, when there is no technical or allocative inefficiency, technical change is again synonymous with TFP growth.

3.2.2 Frontier Approach

Another approach in measuring TFP is the frontier approach. Under the frontier approach, actual output and potential output may differ because of the presence of technical inefficiency. This presence implies that TFP growth now explicitly consists of not only technological change but also efficiency change. Technological change reflects the frontier shift – how far the efficient frontier shifts over time due to the use of better technology and equipment, while efficiency change indicates the catching up effect – how far a firm moves towards the efficient frontier due to a better use of technology and equipment (Mahadevan 2003).

The presence of technical inefficiency leads to a discrepancy between observed output and maximum obtainable output given a set of inputs and available technology. Consider a panel of *i (i=1, . . ., N)* firms observed in *t (t=1, . . ., T)* periods, the presence of technical efficiency can be expressed as:

$$Y_{i,t} < A_{i,t}F(X_{i,t}) \qquad \textbf{3.26}$$

$$Y_{i,t+1} < A_{i,t+1}F\ (X_{i,t+1}) \qquad \textbf{3.27}$$

where $Y_{i,t}$is output of firm i at time t, $X_{i,t}$ inputs of firm i at time t and $A_{i,t}$ is how much output can be produced from a certain amount of inputs of firm i at time t, given the technological level.

To bring the idea of technical inefficiency in the production function, Malmquist (1953) and Shephard (1970) introduce the concept of distance function. The panel of firms i observed in t *(t=1, . . ., T)* periods transform input vectors $X_{i,t} = \left(X_{i,t}^1, \dots, X_{i,t}^N\right) \in \Re_+^N$ into output vectors $Y_{i,t} = \left(Y_{i,t}^1, \dots, Y_{i,t}^M\right) \in \Re_+^M$. Given this information, technology can be represented by the production possibility set of feasible input-output combinations:

$$S_t = \{(X_t,\ Y_t);\ X_t \in \Re_+^N\ can\ produce\ Y_t \in \Re_+^M\}, t = 1, \dots, T \qquad \textbf{3.28}$$

The output distance function, D_t^O, is given by:

$$D_t^O\left(X_{i,t}, Y_{i,t}\right) = \inf\{\theta > 0: \left(X_{i,t}, Y_{i,t}/\theta\right) \in S_t\} = \left(sup\{\theta: \left(X_{i,t}, \theta Y_{i,t}\right) \in S_t\}\right)^{-1} \textbf{3.29}$$

Equation 3.29 shows that the output distance function is defined as the reciprocal of the maximum expansion in output vector, given available inputs, such that production is still feasible, i.e., $\left(X_{i,t}, \theta Y_{i,t}\right) \in S_t$.

The technology in Equation 3.28 is assumed linearly homogenous of degree one in Y and non-increasing in X. For any period of time t, a complete characterization of the technology of a firm is expressed as:

$$D_t^O\left(X_{i,t}, Y_{i,t}\right) \leq 1 \text{ if and only if } \left(X_{i,t}, \theta Y_{i,t}\right) \in S_t \qquad \textbf{3.30}$$

Equation 3.30 serves as a method for measuring the relative distance from the frontier of the technology set to any point of input-output combination inside the frontier. According to Shephard (1970), the maximum feasible expansion of the output vector with the input vector held fixed is $D_t^O(X_{i,t}, Y_{i,t}) = 1$. Under this condition, a firm is said to be technically efficient, which is represented by the subset of isoquant $S_t(X_{i,t}, Y_{i,t}) = \{(X_{i,t}, Y_{i,t}) : D_t^O(X_{i,t}, Y_{i,t}) = 1\}$. In contrast, a firm is said to be technically inefficient if $D_t^O(X_{i,t}, Y_{i,t}) < 1$.

Based on the concept of the distance function, Equations 3.26 and 3.27 can be rewritten as the following:

$$D_t^O(X_{i,t}, Y_{i,t}) = \frac{Y_{i,t}}{A_{i,t}F(X_{i,t})} \quad \textbf{3.31}$$

$$D_{t+1}^O(X_{i,t+1}, Y_{i,t+1}) = \frac{Y_{i,t+1}}{A_{i,t+1}F\,(X_{i,t+1})} \quad \textbf{3.32}$$

where at each moment in time t, in the presence of technical inefficiency, maximum potential output $A_t\,F\,(X_t)$ is equal to the observed output, Y_t, corrected for the output distance function $D_t^O(X_t, Y_t)$.

The TFP indices at time *t* and *t+1* are expressed as the following:

$$TFP_{i,t} = \frac{Y_{i,t}}{F(X_t^i)} = A_{i,t}D_t^O(X_{i,t}, Y_{i,t}) \quad \textbf{3.33}$$

$$TFP_{i,t+1} = \frac{Y_{i,t+1}}{F(X_{i,t+1})} = A_{i,t+1}D_{t+1}^O(X_{i,t+1}, Y_{i,t+1}) \quad \textbf{3.34}$$

Equations 3.33 and 3.34 yield the following expression for the TFP growth index between the two periods:

$$\frac{TFP_{i,t+1}}{TFP_{i,t}} = \frac{A_{i,t+1}}{A_{i,t}} \frac{D_{t+1}^O(X_{i,t+1}, Y_{i,t+1})}{D_t^O(X_{i,t}, Y_{i,t})} \quad \textbf{3.35}$$

Equation 3.35 shows that in the presence of technical inefficiency, the components of TFP growth consists of technological change—shown as the first ratio on the right-hand side of Equation 3.35 —and technical efficiency change—shown as the second ratio on the right-hand side of Equation 3.35. The absence of technical efficiency means that TFP change can be explained solely in terms of technological change. In the presence of technical inefficiency, however, measuring TFP growth based on non-frontier methods as explained previously leads to misleading results.

There are two methodologies that are commonly use to estimate TFP growth based on the frontier approach, namely, the deterministic and econometric approaches. The most common method used in the deterministic approach is data envelopment analysis (DEA), while the most widely used method in the econometric approach is the stochastic frontier approach (SFA). The following sub-sections explain how the DEA and SFA measure TFP growth.

3.2.2.1 Deterministic Approach: DEA

This section focuses on the DEA non-parametric approach to TFP measurement which explicitly takes into account technical inefficiency. This section explains the Malmquist productivity index. This index is constructed based on the distance function, which allows for the calculation and isolation of changes in technical efficiency. Since this index is based on distance function, it does not require price or share data. Therefore, TFP growth based on this index only needs output and input data.

On the basis of the output distance function as in Equations 3.31 and 3.32, Caves *et al.* (1982a) introduce the Malmquist productivity index to measure TFP growth. Suppose that firm *i*'s technology is observed in two periods, $t = t, t+1$. The technology for these two periods is represented by $(X_{i,t}, Y_{i,t})$ and $(X_{i,t+1}, Y_{i,t+1})$. The output oriented Malmquist productivity index under constant returns to scale, as introduced by Caves *et al.* (1982b), can be defined as:

$$M_{t,t+1}^{O}\left(X_{i,t}, Y_{i,t}, X_{i,t+1}, Y_{i,t+1}\right) = \left(\frac{D_t^O(X_{i,t+1}, Y_{i,t+1})}{D_t^O(X_{i,t}, Y_{i,t})} \times \frac{D_{t+1}^O(X_{i,t+1}, Y_{i,t+1})}{D_{t+1}^O(X_{i,t}, Y_{i,t})}\right)^{\frac{1}{2}} \qquad \textbf{3.36}$$

where $M_{t,t+1}^{O}\left(X_{i,t}, Y_{i,t}, X_{i,t+1}, Y_{i,t+1}\right)$ is a Malmquist productivity index for the period $t = t, t+1$. $D_t^O\left(X_{i,t+1}, Y_{i,t+1}\right)$ represents a distance function that compares a firm's technology in period $t+1$ and t, $D_t^O\left(X_{i,t}, Y_{i,t}\right)$ is a distance function for firm *i* at technological period *t*, $D_{t+1}^O\left(X_{i,t+1}, Y_{i,t+1}\right)$ denotes a distance function for firm *i* at technological period $t+1$, $D_t^O\left(X_{i,t}, Y_{i,t}\right)$ is a distance function that compares a firm in period *t* and $t+1$, X_i is the input of firm *i* and Y_i is the output of firm *i*.

The right-hand side of Equation 3.36 can be rewritten as:

$$M_{t,t+1}^{O}\left(X_{i,t}, Y_{i,t}, X_{i,t+1}, Y_{i,t+1}\right) = \left(\frac{D_t^O(X_{i,t}, Y_{i,t})}{D_{t+1}^O(X_{i,t}, Y_{i,t})} \times \frac{D_t^O(X_{i,t+1}, Y_{i,t+1})}{D_{t+1}^O(X_{i,t}, Y_{i,t})}\right)^{\frac{1}{2}} \times \left(\frac{D_{t+1}^O(X_{i,t+1}, Y_{i,t+1})}{D_t^O(X_{i,t}, Y_{i,t})}\right) \qquad \textbf{3.37}$$

where the first part of the right-hand side of Equation 3.37 measures the geometric mean of the technological change (TC) between periods *t* and *t+1* and the second part measures the change in the output-oriented measure of Farrell (1957) technical efficiency (TE) between period t and $t+1$. Equation 3.37 can be rewritten as the following:

$$M^O_{t,t+1} = TC^O_{t,t+1}(X_{i,t}, Y_{i,t}, X_{i,t+1}, Y_{i,t+1}) \times TE^O_{t,t+1}(X_{i,t}, Y_{i,t}, X_{i,t+1}, Y_{i,t+1}) \quad \textbf{3.38}$$

where

$$TC^O_{t,t+1}(X_{i,t}, Y_{i,t}, X_{i,t+1}, Y_{i,t+1}) = \left(\frac{D^O_t(X_{i,t}, Y_{i,t})}{D^O_{t+1}(X_{i,t}, Y_{i,t})} \times \frac{D^O_t(X_{i,t+1}, Y_{i,t+1})}{D^O_{t+1}(X_{i,t}, Y_{i,t})}\right)^{\frac{1}{2}} \quad \textbf{3.39}$$

and

$$TE^O_{t,t+1}(X_{i,t}, Y_{i,t}, X_{i,t+1}, Y_{i,t+1}) = \frac{D^O_{t+1}(X_{i,t+1}, Y_{i,t+1})}{D^O_t(X_{i,t}, Y_{i,t})} \quad \textbf{3.40}$$

If M^O is greater than 1, it indicates that productivity has increased between period t and $t+1$ and this increase can be explained in terms of technological progress and/or technical efficiency improvement. If M^O takes a value smaller than 1, it indicates technological regress or a decrease in technical efficiency between the two periods.

3.2.2.2 Econometric Approach: Stochastic Frontier Approach (SFA)

Under the econometric approach, one approach most commonly used in estimating productivity growth is the SFA. Unlike the DEA which lumps noise and technical inefficiency together as technical inefficiency, the SFA separates noise due to random shocks beyond the control of firms and technical inefficiency of firms. In addition, the decomposition of TFP growth through the SFA approach provides three components of growth (*i.e.*, technical change, technical efficiency change and scale economies), which can be obtained from the parameters of the SFA.

Following Kumbhakar and Lovell (2000), the stochastic frontier model starts with the production function as the following:

$$Y_{i,t} = f\,(X_{i,t}, t)\exp(-u_{i,t}) \quad \textbf{3.41}$$

where $Y_{i,t}$ is output of the ith firm ($i = 1, \ldots, N$) in period t ($t = 1, \ldots, T$), $f(.)$ is the frontier output, X is a vector of J inputs, t is the time trend variable and $u \geq 0$ is a measure of output-oriented technical inefficiency. Technical efficiency is introduced in this model to capture shortfall $Y_{i,t}$ from $f(X_{i,t}, t)$.

Totally differentiating $lnY_{i,t}$ with respect to time yields:

$$\frac{dlnY_{i,t}}{dt} = \frac{dln(X_{i,t}, t)}{dt} - \frac{\partial u_{i,t}}{\partial t} \quad \textbf{3.42}$$

Totally differentiating $ln(X_{i,t}, t)$ with respect to time gives:

$$\frac{dln(X_{i,t},t)}{dt} = \frac{\partial ln(X_{i,t},t)}{\partial t} + \sum_j \frac{\partial f\ (X_{i,t},t)}{\partial X_j} \cdot \frac{dX_j}{dt}$$

$$= \frac{\partial ln(X_{i,t},t)}{\partial t} + \sum_j \epsilon_j \cdot \dot{X}_J \qquad \textbf{3.43}$$

To obtain the decomposition of output growth, substitute Equation 3.43 into Equation 3.42 to yield:

$$\dot{y} = \frac{\partial ln(X_{i,t},t)}{\partial t} + \sum_j \epsilon_j \cdot \dot{X}_J - \frac{\partial u_{i,t}}{\partial t} \qquad \textbf{3.44}$$

Equation 3.44 shows that output growth consists of three components, namely, $\frac{\partial ln(X_{i,t},t)}{\partial t}$, $\sum_j \epsilon_j \cdot \dot{X}_J$ and $\frac{\partial u_{i,t}}{\partial t}$ that represent technical change (TC), change in input use and technical efficiency change (TEC), respectively. TC shifts the production frontier upward if it takes a value > 0, while it shifts downward if it takes a value < 0. TEC represents the rate at which an inefficient producer moves towards the production frontier. If TEC < 0, it means that technical efficiency declines over time. $\sum_j \epsilon_j \cdot \dot{X}_J$ is the effect of change in input use.

Omitting the subscripts *i* and *t* to avoid notational clutter, the rate of growth of TFP can be defined as:

$$\dot{TFP} = TC - \frac{\partial u_{i,t}}{\partial t} + \sum_j (\epsilon_j - s_j)\dot{X}_J \qquad \textbf{3.45}$$

the sum of technical change, the rate of technical inefficiency change and the growth of inputs weighted by their respective output elasticities. Using the measure of returns to scale $RTS = \sum_j \epsilon_j$ and defining $\lambda_j = \frac{f_j x_j}{\sum_k f_k x_k} = \epsilon_j / RTS$ where f_j is the marginal product of input X_j. Equation 3.45 can be rewritten as follows:

$$\dot{TFP} = TC - \frac{\partial u_{i,t}}{\partial t} + \sum_j (RTS - 1)\lambda_j \dot{X}_J + \sum_j (\lambda_j - s_j)\dot{X}_J \qquad \textbf{3.46}$$

It is clear from the Equation 3.46 that the rate of growth of TFP can be decomposed into technical change (TC), technical efficiency change $\left(\frac{\partial u_{i,t}}{\partial t}\right)$, scale component $((RTS - 1)\lambda_j \dot{X}_J)$ and price effects $\left(\sum_j (\lambda_j - s_j)\dot{X}_J\right)$. If RTS =1 (*i.e.*, the assumption of constant returns to scale (CRS) holds), the third term at the right-hand side of Equation 3.46 cancels out. On the other hand, if $RTS \neq 1$, a share of TFP change can be attributed to changes in the scale of production. For example: in the case of decreasing returns to scale, an increase in the amounts of inputs contributes negatively to TFP growth, whereas in the case increasing returns to scale, an increase in the amounts of inputs contributes positively to TFP growth. The price effects represent the contribution of changes in allocative efficiency to TFP growth. It captures either deviations of input prices from the value of marginal products, or departure of marginal rate substitution from the ratio of input prices.

Equation 3.41 can be estimated by using the corrected ordinary least square (COLS) or the maximum likelihood estimation (MLE) methods. Once Equation 3.41 has been estimated, the TFP growth and its components can be obtained.

Total factor productivity growth can also be estimated by using a cost function. Bauer (1990) starts with the conventional Divisia index of TFP growth in a continuous time as follows:

$$\dot{T}FP = \dot{y} - \left(\dot{F}\right) \quad \textbf{3.47}$$

where the dots are time derivatives and F is an index of input usage, where F is usually proxied by $\dot{F} = \sum_{n=1}^{N}\left(\frac{w_n x_n}{C}\right)\dot{x}_n$ and C is total cost. However, the TFP decomposition as expressed in Equation 3.47 leads to a biased measure of TFP if allocative or technical inefficiency exist. To incorporate both types of inefficiency, Bauer starts with the Farrell (1957) measure of cost efficiency. The single-product cost frontier can be represented as follows:

$$C = C\,(y, w, t) \quad \textbf{3.48}$$

where C is the total cost given (y, w, t). Following Farrell (1957), an input-based overall measure of cost efficiency can be defined:

$$CE = \frac{C(y,w,t)}{C} \quad \textbf{3.49}$$

where $0 \leq CE \leq 1$. CE can be decomposed into $CE = TE \times AE$ or $\dot{CE} = \dot{TE} + \dot{AE}$ where TE and AE are Farrell input-based measures of technical and allocative efficiency, respectively. Totally differentiating Equation 3.48 and some substitution yields the following decomposition of TFP:

$$T\dot{F}P = \left[1 - \epsilon_{cy}(y,w,t)\right]\dot{y} + \dot{TE} + \dot{AE} - \dot{C}(y,w,t) + \sum_{n=1}^{N}[s_n - s_n(y,w,t)]\dot{x}_n \quad \textbf{3.50}$$

where $\dot{C}(y,w,t)$ is technical progress, ϵ_{cy} is output cost elasticity, s_n is the observed output cost share and $s_n(y,w,t)$ is the minimal cost share of the nth input.

Clearly, Equation 3.50 shows that TFP based on the cost function can be decomposed into five components, namely, returns to scale, changes in technical efficiency, changes in allocative efficiency, technological progress and a residual price effect. The price effect component exists when the aggregate measure of input usage is biased since the firm is allocatively inefficient. If the firm is allocatively efficient, $s_n = s_n(y, w, t)$ and the price effect term is equal to zero. Similarly, this term is also equal to zero when input prices change at the same rate since $\sum_{n=1}^{N}[s_n - s_n(y, w, t)]\dot{x}_n = 0$.

To calculate Equation 3.50, Bauer uses translog cost and input share equations, estimated as frontiers:

$$ln C = ln\, C\,(y, w, t) + u + v \qquad \textbf{3.51}$$

$$s_n = s_n(y, w) + w_n \quad n = 1, \dots, N \qquad \textbf{3.52}$$

where u is a one-sided disturbance term which incorporates both allocative and technical inefficiency, v is a two-sided noise disturbance and w_n is a two-sided disturbance which allows for noise as well as allocative inefficiency.

More recently, a significant method of TFP estimation and decomposition has been proposed by O'Donnell *et al.* (2008). Under the Frontier approach, O'Donnell has shown that TFP can be estimated by using an index numbers formula. The index numbers proposed by him satisfy all economically relevant tests from index theory. There are three index numbers which are reliable for multi-lateral and multi-temporal comparisons, namely, the Lowe, Färe-Primont and Geometric Young indexes. He also has shown that these indices number can be further decomposed into technical change, technical efficiency change, mix efficiency change and scale efficiency change. Thus, compared to the growth accounting approach, traditional index numbers formula and the conventional frontier approach, the TFP decomposition proposed by O'Donnell provides more detailed components of TFP growth. Furthermore, because the index number formulae satisfy all economically relevant tests from index theory, these proposed index numbers have more reliable results than other methods.

With the assumption of full efficiency relaxed, this thesis adopts the frontier approach for analysing the impact of trade reform on technical efficiency and productivity. The SFA is used in analysing the impact of trade reform on technical efficiency, while the O'Donnell approach on the decomposition of productivity is used for analysing the impact of trade reform on productivity. These approaches are explained in the next chapter.

3.3 Trade Reform and Industrial TFP Growth: Empirical Evidence

Having reviewed the various methods of estimating, measuring and decomposing TFP growth, a review is now undertaken of the various studies that attempt to empirically explain the impact of trade reform on TFP growth. This section consists of two sub-sections. The first sub-section covers empirical studies which examine the impact of trade reform on TFP growth in selected countries not including Indonesia. The second sub-section summarizes the empirical studies on TFP growth which have been done in Indonesia.

3.3.1 International Literature

Researchers commonly examine the link between trade liberalization and TFP growth using two main procedures. The first procedure is to estimate industry or firm productivity and the second procedure is to relate productivity to various measures of trade liberalization and other variables in regression equations with different specifications and estimation methods. Table 3.1 summarizes selected empirical studies relevant to this thesis. The main findings of each empirical study are explained in the following passages.

The first study which tests empirically the link between TFP growth and the trade regime is conducted by Nishimizu and Robinson (1984). Utilizing 16 manufacturing industries data from the late 1950s to the late 1970s from four countries (Japan, Korea, Turkey and Yugoslavia) and applying a translog index number to obtain TFP growth, they find that there are significant and strong differences in the impact of export expansion versus import substitution of trade orientation on TFP growth. Export expansion leads to higher TFP growth, whereas the increase of import substitution (import liberalization) leads to lower (higher) TFP growth.

Applying a different method of TFP growth to that used by Nishimizu and Robinson (1984), Bonelli (1992) investigates the link between TFP change and variables related to trade orientation in Chile from the mid-1970s to the mid-1980s. In his research, he uses the growth accounting method to obtain TFP growth. Bonelli finds that there is a positive association between export expansion and TFP growth.

Using the growth accounting method, Urata and Yokota (1994) examine the impact of trade reform on productivity in Thailand's manufacturing industry over the period 1976 to 1988. They find that trade liberalization—measured by the effective rate of protection (ERP)—leads to an improvement in production efficiency. They conclude that policies taken to liberalize trade and foreign investment are important to increase productivity growth.

İşcan (1998) examines the impact of trade reform on industrial TFP growth in Mexico over the period 1973–1990. He uses the Solow growth model to estimate industrial TFP growth and ERP as a variable to represent trade reform. When the level of ERP is used as a trade reform variable, the estimated coefficient of ERP is found to be statistically insignificant. However, when the level of ERP is changed into ERP change, ERP change is found to be statistically significant in all specifications. These results indicate that trade reform has a significant productivity effect on the manufacturing industry and sectors with larger reductions in protection rates have higher increases in productivity. Based on this study, it appears that the specification of the trade reform variable may influence the results of the estimation.

Using a translog index number to obtain TFP growth, Kim (2000) investigates the relationship between trade liberalization and productivity in Korean manufacturing industries over the period 1966–1988. To examine the impact of trade reform on industrial TFP growth, Kim (2000) utilizes two models: (i) the first model assumes constant returns to scale and perfect competition and (ii) the second model assumes non-constant returns to scale and imperfect competition. In his models, there are two variables used as proxies of trade reform, namely, quota restrictions (QR) and nominal protection (NP). The result shows that when the first model is applied, none of trade reform measures are significantly related to TFP growth. However, when the second model is applied, both QR and NP have a significant and negative impact on TFP growth. This second result means that trade protection is negatively correlated with productivity growth. In other words, this result supports a claim that trade liberalization positively correlates with productivity growth.

Despite the significant effect of trade reform on TFP growth, Kim (2000) finds that the contribution of TFP in Korea's output growth was very small. During the 1966–1988, the sectoral TFP growth rates were about 0.5% per annum, explaining only 3 percentage points of 17.9% output growth in Korean manufacturing industries. In light of this finding, Kim concludes that the small contribution of TFP growth in output growth does not mean that the link between trade reform and productivity can be ignored. Rather, it suggests trade reform policies have not been substantial enough to increase productivity.

Unlike previous studies that use the growth accounting method, translog index numbers and the Solow growth model to obtain industrial TFP growth, Paus *et al.* (2003) use labour productivity growth to represent industrial TFP growth. Trade variables are represented by export growth, import growth and a commercial reform index. Paus *et al.* (2003) show that trade opening variables have a significant positive effect on productivity growth. They investigate the relationship between these trade variables and productivity growth at the level of three-digit manufacturing industries for seven Latin American countries during 1970–1998. Their results suggest that trade liberalization is associated with higher levels of manufacturing productivity growth for these countries. Paus *et al.* (2003) interpret this finding as compatible with the hypothesis that the impact of trade opening occurs through import competition, capital goods imports and export effects.

Using a translog index number to obtain industry TFP growth, Goldar and Kumari (2003) estimate the impact of trade liberalization on the Indian manufacturing sector over the period 1981–1998. ERP, real effective exchange rate, non-tariff barriers on imports and a dummy for liberalization are used as trade reform variables. The estimate of ERP shows that the coefficient of ERP is consistently negative and significant, which means that reduction in ERP increases productivity. The coefficient of the real effective exchange rate is found to be positive and statistically significant. The coefficient of non-tariff barriers is found to be positive but statistically insignificant. The dummy for liberalization is found to be positive but statistically insignificant. By comparing the results of the regressions, they conclude that import liberalization increases productivity growth in Indian manufacturing.

Using the Levinsohn and Petrin (2003) methodology to measure TFP growth, Topalova and Khandewal (2011) assess the impact of trade reform on industrial productivity growth in India over the period 1989–2001. Input and output tariffs are used as trade reform measures. They find that reductions in trade protection through input tariffs and output tariffs increased productivity among Indian firms.

Furthermore, their estimation shows that the reduction of input tariffs has a larger impact in driving the productivity gains compared to the reduction of output tariffs.

The Levinsohn and Petrin (2003) methodology used by Topalova and Khandewal (2011) is also used by Njikam and Cockburn (2011). They examine the impact of trade liberalization on TFP growth in Cameroon over the period 1988–2002. Using an effective rate of assistance (ERA) as a proxy variable for trade reform, they find that there is a negative and significant relationship between ERA and firm productivity growth. This implies that trade reform positively affects firm productivity growth.

Employing a non-parametric data envelopment analysis (DEA) and applying a Malmquist TFP index method, Hassan *et al.* (2010) calculate indices of TFP change for 82 manufacturing firms in Bangladesh between 1993 and 1998. Their results suggest that during trade reform the majority of Bangladeshi manufacturing experienced positive TFP growth, averaging 29% over a five-year period. By classifying firms into export-oriented and import-oriented firms, they find that export-oriented firms performed better than import-oriented firms.

Using a political economy model of trade policy proposed by Grossman and Helpman (1994), Karacaovali (2011) examines the impact of trade reform on productivity in Colombia. Unlike previous studies which do not take into account potential endogeneity problems[9], Karacaovali (2011) estimates his model by controlling the endogeneity bias. He finds that in Colombia, trade reform has a significant positive impact on productivity and the impact on productivity is higher after correcting for the endogeneity bias. The finding suggests that it may happen in different countries as well and researchers may underestimate the positive effect of reform on productivity if they do not take into account the endogeneity problems.

Using Olley and Pakes (1996) and Levinsohn and Petrin (2003) methodology, Maiti (2013) examines the effect of trade reform on productivity growth in India. After controlling the market imperfections in the product and labour markets, Maiti (2013) finds that trade openness has positive effects on productivity growth as it increases competition in domestic and export markets. Maiti (2013) inteprets the improvement

[9] It is usually assumed that trade reform is independently determined of productivity, and hence exogenous. However, there might be an endogeneity which in that productivity might directly affect trade policy.

of productivity growth takes place through the increased technology transfers, technical diffusion and other spill-over effects in the economy.

In contrast to the empirical studies mentioned above, a number empirical studies show mixed evidence of the impact of trade reform on productivity growth. Studies finding no evidence of the positive impact of trade reform include Balakrishnan *et al.* (2000) for India and Jenkins (1995) for Bolivia. A negative impact or no clear evidence of trade reform on productivity growth are identified by Sharma *et al.* (2000) for India and Weiss and Jayanthakumaran (1995). No substantial effect of economic reform on the contribution of capacity realization to TFP growth is shown by Salim (2003) for Bangladesh's food manufacturing industry.

The main implication of the various findings in the empirical studies is that the impact of trade reform varies among countries. Even within a country, the impact of trade reform varies between industries. Drawing on the arguments developed by Havrylyshyn (1990), it may be inferred that the theoretical foundation for the linkages between trade reform and productivity growth is not yet solid and needs further empirical examination.

Table 3.1: Summary of Selected Empirical Studies on Trade Liberalization and TFP Growth not Including Indonesia

No	Author (s)	Period of Data	Countries	TFP Measure	Results
Studies that provide evidence of positive effect of trade reform on TFP Growth					
1	Nishimizu and Robinson (1984)	1955–1973 1960–1977 1963–1976 1965–1978 (Industry)	Japan Korea Turkey Yugoslavia	Translog Index Number	There are significant and strong differences in the impact of export expansion versus import substitution. Export expansion led to higher TFP growth, through economies of scale and/or through competitive incentives. Increased import substitution (import liberalization) leads to lower (higher) TFP growth.
2	Bonelli (1992)	1975–1985 (Industry)	Brazil	Growth Accounting Method	There is a positive association between export expansion and rates of productivity.
3	Urata and Yokota (1994)	1976–1988 (Industry)	Thailand	Growth Accounting Method	There is strong evidence of an increase in TFP due to trade reform. The degree of trade reform, initial ERP, scale effect and the strength of domestic competitive pressure are used to represent trade reform.
4	Işcan (1998)	1973–1990 (47 sectors)	Mexico	Modified Solow Growth Model	Reduction in ERP has a significant effect on sectoral productivity levels.
5	Kim (2000)	1966–1988 (Industry)	Korea	Translog Index Number	Even though trade liberalization is found to have a positive impact on productivity performance, the productivity increase was not significant because the extent of trade liberalization is not substantial enough in Korea. During the 1966–1988 period, the sectoral TFP growth rates are about 0.5% per annum, explaining only 3 percentage points of 17.9% output growth in Korean manufacturing industries.
6	Paus *et al.* (2003)	1970–1998 (Industry)	Latin America	Labour Productivity Growth	Trade variables—measured by export growth, import growth and a commercial reform index—have significant positive effects on productivity growth.
7	Goldar and Kumari (2003)	1981/82–1997/98 (Industry)	India	Translog Index Number	Trade reform variables—measured by ERP, nontariff barriers on imports and real effective exchange rate—have significant favourable effects on industrial productivity growth.
8	Topalova and Khandewal (2011)	1989–2001 (Firms)	India	Levinsohn and Petrin (2003) Methodology	Reductions in trade protection lead to higher levels of productivity. Lowering input tariffs has a larger impact in driving productivity gains compared to lowering output tariffs.

Table 3.1 continued on the next page.

Table 3.1: Summary of Selected Empirical Studies on Trade Liberalization and TFP Growth not Including Indonesia (continued from the previous page)

No	Author (s)	Period of Data	Countries	TFP Measure	Results
9	Hassan *et al.* (2010)	1993–1998 (Firms)	Bangladesh	DEA Malmquist Index	Trade liberalization improves TFP growth of all firms with export-oriented firms performing better than import-oriented firms in improving productivity.
10	Karacaovali (2011)	1983–1998 (Firms)	Colombia	Political Economy Model of Trade Policy	By controlling potential endogeneity problems, it is found that the positive impact of trade liberalization—measured by ERP—was higher by 17 per cent than the result when endogeneity problems were not accounted for.
11	Njikam and Cockburn (2011)	1988/1989–2001/2002 (Firms)	Cameroon	Levinsohn and Petrin (2003) Methodology	Reductions in ERP and increases in export shares improve TFP.
12	Kim and Saravanakumar (2012)	2000–2006 (Firms)	India	SFA	Trade liberalization improves TFP growth in every industry except the non-metal industry.
9	Hassan *et al.* (2010)	1993–1998 (Firms)	Bangladesh	DEA Malmquist Index	Trade liberalization improves TFP growth of all firms with export-oriented firms performing better than import-oriented firms in improving productivity.
10	Karacaovali (2011)	1983–1998 (Firms)	Colombia	Political Economy Model of Trade Policy	By controlling potential endogeneity problems, it is found that the positive impact of trade liberalization—measured by ERP—was higher by 17 per cent than the result when endogeneity problems were not accounted for.
11	Njikam and Cockburn (2011)	1988/1989–2001/2002 (Firms)	Cameroon	Levinsohn and Petrin (2003) Methodology	Reductions in ERP and increases in export shares improve TFP.
12	Kim and Saravanakumar (2012)	2000–2006 (Firms)	India	SFA	Trade liberalization improves TFP growth in every industry except the non-metal industry.
13	Maiti (2013)	1998–2005 (Industry)	India	Olley and Pakes (1996) and Levinsohn and Petrin (2003)	The impact of openness—measured by the ratio of total trade (exports and imports) relative to total production— is positive on the productivity growth when the market imperfection due to the trade reform are controlled.
Studies that provide evidence of no or little effect of trade reform on TFP growth					
14	Weiss and Jayanthakumaran (1995)	1979–1989 1982–1989 (Industry)	Sri Lanka	Labour Productivity, Residual of Gross Value Added, and Price Cost Margin	The findings are not robust. Over the longer period no support is found for the trade liberalization and performance hypothesis. Over the short period, there is a link, albeit weak, between trade liberalization and performance.

Table 3.1 continued on the next page.

Table 3.1: Summary of Selected Empirical Studies on Trade Liberalization and TFP Growth not Including Indonesia (continued from the previous page)

No	Author (s)	Period of Data	Countries	TFP Measure	Results
15	Jenkins (1995)	1980–1991 (Industry)	Bolivia	Labour Productivity	There is no evidence that trade liberalization improves productivity performance.
16	Mulaga and Weiss (1996)	1987–1991 (Firms)	Malawi	Growth Accounting Method	The findings are not robust. When TFP growth is defined as real value added growth, ERP has a statistically significant effect on TFP growth. However, when TFP estimates are adjusted for change in capacity utilization, the authors do not find a link between TFP growth and fall in protection.
17	Sharma *et al.* (2000)	1972/73–1993/94 (Industry)	Nepal	Growth of Value Added and Gross Output	There are significant and strong differences in the impact of export expansion versus import substitution. Export expansion led to higher TFP growth through economies of scale and/or through competitive incentives. Increased import substitution (import liberalization) leads to lower (higher) TFP growth.
18	Balakrishnan *et al.* (2000)	1989/89–1997/98	India	Solow Growth Model	There is a positive association between export expansion and rates of productivity.
19	Salim (2003)	1986, 1992, 1997 (Firms in food manufacturing industry)	Bangladesh	Random Coefficient Stochastic Frontier	The relative contribution of capacity realization to TFP growth is not substantial in inhibiting the industry's high and sustained growth. Industry responded a little to the implementation of economic reform.

Source: Author's compilation

3.3.2 Indonesian Literature

Having discussed the most relevant empirical studies on the impact of trade reform on manufacturing productivity in the international literature, this section continues with a discussion about the impact of trade reform on productivity and technical efficiency in Indonesia. There are several studies which examine the performance of the manufacturing sector at sub-sectoral and firm level. However, only a very limited number of studies exist which have directly investigated the links between trade liberalization and productivity in the manufacturing sector in Indonesia. The empirical studies which have used Indonesian data are summarized in Table 3.2.

Studies on this topic have been conducted only since 1994. Osada (1994) makes the first attempt using time series data of eight manufacturing sectors from 1987 to 1990. He estimates the impact of trade liberalization on TFP growth. He uses the growth accounting method to obtain TFP growth. Using foreign direct investment (FDI) and effective rate of protection (ERP) as the independent variables and TFP growth as the dependent variable, he finds that both FDI and ERP have significant impacts on TFP growth. Furthermore, he shows that the impact of ERP reduction has more crucial impact on TFP growth than that of FDI increases.

Aswicahyono *et al.* (1996) estimate the TFP growth rate over the period 1976 to 1991. They apply the accounting growth methodology to calculate TFP growth during that period and divide the period into sub-periods based on various distinct policies. They find that TFP growth rates during the liberalization period are higher than TFP growth before the liberalization period.

Using the same method as used by Aswicahyono *et al.* (1996) to obtain TFP growth, Timmer (1999) estimates TFP growth over the period 1975 to 1995. Although he finds different TFP growth rates compared to the results of Aswicahyono *et al.* (1996) because of the different method of estimating capital stock, his results show that TFP growth rates during the liberalization period are higher than TFP growth before the liberalization. These results confirm the finding of Aswicahyono *et al.* (1996).

Using ordinary least squares (OLS) regression, Sjöholm (1999b) examines whether participation in international trade affects firm productivity. He uses imports and exports as international trade variables. His results show that exports have a positive effect on productivity growth, whereas imports do not affect the rate of productivity growth.

Another attempt to examine the links between trade liberalization and TFP growth is carried out by Aswicahyono and Hill (2002). They use the growth accounting method to estimate TFP growth. Export expansion, import substitution, and ERP are used as trade liberalization variables. Utilizing manufacturing data from 1976 to 1993, their results show that these variables significantly affect TFP growth. The finding that ERP has a significant impact on TFP growth is in line with Osada (1994).

Using two-digit industry data from 1976 to 1995, Vial (2006) estimates TFP growth of Indonesian manufacturing. TFP growth is estimated by using the growth accounting method. Similar to Aswicahyono *et al.* (1996) and Timmer (1999), she also divides the data into sub-periods based on distinct various policy reforms. She finds that TFP growth rates based on her estimation are higher than those of Aswicahyono *et al.* (1996) and Timmer (1999). Nevertheless, she shows that TFP growth rates during recovery and deregulation years are higher than TFP growth rates during the heavy regulation period. This is in line with Aswicahyono *et al.* (1996) and Timmer (1999).

Using tariffs on input and tariffs on output as international trade liberalization variables, Amiti and Konings (2007) examine the impact of these variables on TFP growth in Indonesian manufacturing industry from 1991-2001. TFP growth is estimated by using the growth accounting method. Their results show that the effect of reducing input tariffs significantly increases productivity and this effect on productivity is much higher than reducing output tariffs. This confirms the theoretical endogenous growth model by Ethier (1982), Markusen (1989) and Grossman and Helpman (1991) that lower input tariffs can lead to increased productivity from access to a greater variety of intermediate inputs, access to higher quality inputs and through learning effects.

Unlike studies mentioned above which use the growth accounting method to estimate TFP growth rates, Margono and Sharma (2006) and Ikhsan (2007) use the SFA production function to obtain TFP growth rates in the Indonesian manufacturing sector. [10] Margono and Sharma (2006) examine TFP growth in four manufacturing sectors in Indonesia; they are food, textile, chemical, and metal products. Using firm-level data from 1993 to 2000, their results show that on average TFP growth during this period for three sectors, food, textile and chemical, were negative. The chemical sector was the only sector which had positive TFP growth. Furthermore, they divide their analysis into two sub-periods: before the Asian crisis hit Indonesia (1994–1997) and after the Asian crisis hit Indonesia (1998–2000). Their results reveal that the Asian crisis affected TFP growth more in the textile, chemical and metal industry.

Ikhsan (2007) estimates TFP growth with SFA for the eight Indonesian manufacturing sectors over the period 1988–2000. He shows that TFP growth rates are higher during the liberalization period. This finding is in line with Aswicahyono *et al.* (1996), Timmer (1999) and Vial (2006). In addition, he also considers the impact of the economic crisis in 1997. His results reveal that the effect of the crisis differs across industries. This finding supports the findings of Margono and Sharma (2006).

[10] The growth accounting approach estimates TFP without distinguishing between components of TFP growth and in this approach TFP growth is often used synonymously with technological progress. In the SFA decomposition method, TFP growth is the sum of technological progress, improvement in technical efficiency and economies of scale.

Table 3.2: Summary of Empirical Studies on Trade Liberalization and TFP Growth in Indonesia

No	Author(s)	Period of Data	Method of Estimation	Dependent Variable	Measure of Trade Liberalization	Results
1	Osada (1994)	1987–1990	OLS Cross-industry Regression, Time Series	TFP (growth accounting method)	FDI (Foreign Direct Investment), ERP (Effective Rate of Protection)	The ratio of ERP reduction and the increase of FDI play important roles in TFP. The impact of ERP reduction is more crucial than the impact of FDI increase.
2	Aswicahyono *et al.* (1996)	1976–1991	Growth Accounting Method			The fastest TFP growth rates are during the reform period.
3	Timmer (1999)	1975–1995	Growth Accounting Method.			Performance varies greatly across industries. TFP growth rates increase considerably during policy reforms.
4	Sjöholm (1999b)	1980–1991	OLS	TFP (growth in value-added)	Import, Export	Export is the only variable that has a positive statistically significant effect on TFP growth.
5	Aswicahyono and Hill (2002)	1976–1993	OLS; Panel data	TFP (growth accounting method)	Trade orientation (export expansion and import substitution)	Trade orientation variables are positively related to TFPG and statistically significant. ERP is regressed separately on TFP growth and has a negative statistically significant impact on TFP growth.
6	Vial (2006)	1976–1995	OLS; Panel data; Cobb-Douglas	Growth Accounting Method with the Levinshon and Petrin methodology		TFP growth rates are higher during reform period.
7	Margono and Sharma (2006)	1993–2000	Panel data, Stochastic Frontier, Translog in four sectors (food, textile, chemical, metal products)	Gross Output		The chemical sector is the only sector which recorded positive TFP growth rate, other sectors have negative TFP growth rates.

Table 3.2 continued on the next page

Table 3.2: Summary of Empirical Studies on Trade Liberalization and TFP Growth in Indonesia (continued from the previous page)

No	Author(s)	Period of Data	Method of Estimation	Dependent Variable	Measure of Trade Liberalization	Results
8	Amiti and Konings (2007)	1991–2001	OLS with firm fixed effects, two-stage least squares, unbalanced panel data, Cobb-Douglas, Translog	Growth Accounting method with the Olley-Pakes methodology	Output tariff, input tariff, interacting variable (input tariff multiplied by importing firms), and imported inputs.	Output tariff, input tariff and interacting variable have negative statistically significant effects on TFP. Imported inputs have a positive statistically significant effect on TFP.
9	Ikhsan (2007)	1988–2000	Panel data, Stochastic Frontier, Translog	Gross Output		TFP growth rates are higher during reform period.

Source: Author's compilation.

Based on the empirical studies on the TFP growth in Indonesia discussed in this section, it can be seen that there are a few empirical studies on the impact of trade reform on TFP growth. Only four studies (Osada 1994, Sjoholm 1999, Aswicahyono and Hill 2002 and Amiti and Konings 2007) directly assess econometrically the impact of trade reform variables on TFP growth. These four empirical studies use the growth accounting method to obtain TFP growth.

The growth accounting method has limitations, especially related to the implicit assumptions that firms are efficient. In other words, all firms are assumed to be operating on the frontier. As firms are all operating on the frontier, the shift of production frontier measures technical change. Thus, technical change in the growth accounting method is used synonymously with TFP growth. This assumption is not realistic as firms may not operate efficiently. This unrealistic assumption can be relaxed by applying a more recent method of measuring productivity growth. Thus, there is a need to study the impact of trade reform on productivity growth by applying a more recent methodology of TFP growth measurement.

3.4 Trade Reform and Technical Efficiency: Empirical Evidence

Having reviewed the impact of trade reform on TFP growth, attention is now given to the empirical studies on the impact of trade reform on technical efficiency. This section summarizes empirical studies on the impact of trade reform on technical efficiency. This section consists of two sub-sections. The first sub-section covers empirical studies that examine the impact of trade reform on technical efficiency in selected countries not including Indonesia. The second sub-section summarizes the empirical studies on technical efficiency that have been done in Indonesia.

3.4.1 International Literature

There are a number of empirical studies on the impact of trade reform on technical efficiency. As shown in Table 3.3, findings of existing empirical studies show mixed results on the impact of trade reform on technical efficiency. Several studies such as Gökçekuş (1995), Alam and Morrison (2000), Driffield and Kambhampati (2003), Kalirajan and Bhide (2004) and Sheikh and Ahmed (2011) suggest that trade reform has a positive impact in increasing technical efficiency. On the other hand, empirical studies conducted by Handoussa *et al.* (1986), Salim (1999, 2007, 2008), Tybout *et al.* (1991), Parameswaran (2002) and Aedo (2011) show that trade liberalization has no or little impact on technical efficiency. The following passages explain the main findings of these studies.

An empirical study of the effect of trade reform on technical efficiency in Turkey is conducted by Gökçekuş (1995) using the Turkish rubber industry in the years 1980 and 1985 and employing the SFA in his estimation. Data from 1980 and 1985 are chosen to represent before and after liberalization periods. The findings show that trade reform has a significant effect on the technical efficiency level. The coefficient of trade reform is negative and statistically significant, which means that an increase in the rate of protection decreases the technical efficiency level.

Table 3.3: Summary of Selected Empirical Studies between Trade Liberalization and Technical Efficiency not Including Indonesia

No	Author(s)	Country	Period of Data	Method of Estimation	Result
Studies that provide evidence of a positive impact of trade reform on technical efficiency					
1	Gökçekuş (1995)	Turkey	1980, 1985 (Firms in Turkish Rubber Industry)	SFA	Technical efficiency improves significantly after trade reform.
2	Alam and Morrison (2000)	Peru	1988–1992 (Firms)	DEA	Peruvian reform package of 1990 leads to increased technical efficiency in Peru's manufacturing.
3	Driffield and Kambhampati (2003)	India	1987–1994 (Firms)	SFA	Trade reform increases technical efficiency in five out of six industry sectors.
4	Kalirajan and Bhide (2004)	India	1997–2000 (Firms in three manufacturing industries: Chemical Product, Electrical Machinery, Transport)	SVFA	The impact of trade reform varies across industries. Transport industry gains more technical efficiency.
5	Hossain and Karunaratne (2004)	Bangladesh	1978–1994 (Three-digit level industry)	SFA	Technical efficiency increases over time after trade reform. Trade liberalization—represented by export orientation and capital deepening—has a significant impact on the reduction of technical inefficiency.
6	Sheikh and Ahmed (2011)	Pakistan	1981-2006 (Three-digit level industrial classification on eleven agro-based industries)	SFA	Trade liberalization has a significant and favourable effect on technical efficiency of agro-based industries.

Table 3.3 continued on the next page.

Table 3.3: Summary of Selected Empirical Studies between Trade Liberalization and Technical Efficiency not Including Indonesia (continued from the previous page)

No	Author(s)	Country	Period of Data	Method of Estimation	Result
Studies that provide evidence of a decline or no significant impact of trade reform on technical efficiency					
7	Handoussa *et al.* (1986)	Egypt	1973–1979	Deterministic Frontier Production Function.	There is a deterioration in technical efficiency during the liberalization period.
8	Tybout *et al.* (1991)	Chile	1967, 1979 (Industry)	Cobb Douglas production function	Technical efficiency does not improve significantly between two census years. However, industries undergoing a large reduction in protection show improvement in technical efficiency relative to others.
9	Salim (1999)	Bangladesh	1981,1987,1991 (Firms: food processing and chemical industry)	Random Coefficient Production Frontier Approach	Trade and industrial policy reforms related variables (openness and ERA) do not have a significant effect on productive capacity realization.
10	Parameswaran (2002)	India	1989–1998 (Firms)	SFA	Trade policy environment has a positive significant effect on technical efficiency in all industries, except non-electrical machinery and electronics industries. However, the level of technical efficiency is lower in the post-liberalized period.
11	Salim (2007)	Bangladesh	1992–1994,1997–1999 (Firms: food manufacturing industry)	SVFA	Openness and ERA do not significantly affect technical efficiency.
12	Salim (2008)	Bangladesh	1992–1994, 1997–1999	SFA	Openness and ERA do not significantly affect technical efficiency.
13	Ali *et al.* (2009)	India	1980–2002 (Firms in Food Processing Industry)	Data Envelopment Analysis Malmquist Productivity Index	Technical efficiency declines during the post-liberalization period compared to the pre-liberalization period. The technical efficiency varies across food processing sectors.
14	Aedo (2011)	Chile	2001–2007 (Firms in Agro Processed Food Industry)	SFA	Trade liberalization—represented as share of exports—does not lead to higher efficiency.

Source: Author's compilation

Using the DEA as the method of estimation, Alam and Morrison (2000) study the impact of the effective rate of protection on firm level technical efficiency in Peruvian manufacturing industries. Their data cover 1988 to 1992, which represent two years before and two years after the implementation of trade reform. Their findings suggest that the degree of protection and level of technical efficiency is inversely related, which means that a high degree of protection decreases the level of technical efficiency. These findings are in line with the findings of Gökçekuş (1995).

Using the SFA, Driffield and Kambhampati (2003) test the effect of trade reform on technical efficiency in India. They incorporate three variables as the proxies for trade liberalization, export intensity, import intensity and a liberalization dummy. The liberalization dummy is used to capture trade reform effects which are not captured by export and import intensity, such as the effects of deregulation of entry, expansion and exit. Their findings show that in all sectors, except machine tools, average efficiency levels increased in the post-reform period. However, in analysing the determinants of efficiency, the three variables used as trade reform indicators show mixed results. Export intensity shows a negative effect on technical efficiency in machine tools and chemical industries, while in other sectors it increases technical efficiency. Import intensity shows a positive effect on technical efficiency in textile only, whereas in other industries it shows a negative effect on technical efficiency. The last variable of trade reform, the liberalization dummy, shows a positive impact on technical efficiency in all sectors except in the chemical sector. From this study, it can be concluded that the impact of trade reform on technical efficiency varies across industries.

Unlike earlier studies which use the DEA and the SFA to estimate the effect of trade reform on technical efficiency, Kalirajan and Bhide (2004) estimate the technical efficiency using the stochastic varying frontier approach (SVFA). In analysing the determinants of technical efficiency, they use variables, such as export intensity, imported raw material intensity and imported technology intensity as the proxy for trade reform. They analyse three industries in India, which are chemical products, electrical machinery and transport. The results reveal that the impact of trade liberalization varies across these three industries.

Kalirajan and Bhide (2004) find that export intensity does not have a significant impact on technical efficiency in the chemical industry, but the coefficient of export intensity has a positive and significant effect on technical efficiency in the electrical machinery and transport industry. Thus, in the electrical machinery and transport industry, when firms increase their export intensity, their technical efficiencies tend to improve. Comparing the magnitude of the coefficient of export intensity on technical efficiency, the impact of export intensity on technical efficiency is higher in the transport industry than in the electrical machinery.

Kalirajan and Bhide (2004) also find that the impact of imported raw material intensity varies across industries. This variable does not have a significant effect on technical efficiency in the electrical industry. However, it has a positive and significant effect on technical efficiency in the transport and chemical industries and the magnitude of the coefficient is higher in the transport industry than in the chemical industry. The positive and significant coefficient of imported raw materials intensity means that the use of imported raw materials tends to increase technical efficiency.

Finally, Kalirajan and Bhide (2004) find that imported technology intensity has a positive and significant impact on technical efficiency in all sectors but the magnitude of the coefficient in electrical machinery is the smallest compared to the other two sectors. Similar to the coefficient of imported raw materials, the use of imported technology appears to increase technical efficiency. The results of these findings confirm the findings of Driffield and Kambhampati (2003) that the trade reform effect varies across industries.

Empirical studies conducted by Hossain and Karunaratne (2004) in Bangladesh and Sheikh and Ahmed (2011) in Pakistan suggest that trade reform has a positive and significant impact on technical efficiency. Both of these studies use translog SFA in estimating the impact of trade reform on technical efficiency. Hossain and Karunaratne (2004) use export orientation and capital deepening as the proxies for trade reform variables, whereas Sheikh and Ahmed (2011) use effective tariff rates as a measure of trade reform. Their results confirm that trade reform has a positive effect in increasing technical efficiency.

In contrast to empirical studies mentioned above, several studies show that trade reform provides either no effect or negative effect on technical efficiency. Studies conducted by Tybout *et al.* (1991) in Chile and Ali *et al.* (2009) in India show that trade liberalization brought a little effect on technical efficiency. A negative effect of trade reform in technical efficiency is shown by Handoussa *et al.* (1986) in Egypt and Parameswaran (2002) in India. The following passages explain these empirical studies.

Using a Cobb-Douglas production function and maximum likelihood estimators, Tybout *et al.* (1991) study the effect of trade reform in technical efficiency. By comparing technical efficiency in 1967 and 1979—as pre- and post-liberalization period, respectively—they find that technical efficiency does not improve significantly after trade reform. However, by comparing the level of protection and technical efficiency in each manufacturing sector, they show that industries that undergo the greatest reduction in protection show the greatest productivity improvement.

Salim (1999, 2007, 2008) estimates the impact of trade reform in productive capacity realization, that is technical efficiency, in Bangladesh. Using different methods to estimate productive capacity realization (random coefficient production frontier, SVFA and SFA), he finds that trade reform does not have a significant impact on technical efficiency. He also shows that technical efficiency rates vary widely across firms and over time. Regarding the insignificance effect of trade reform variables (effective rate of assistance and openness) on technical efficiency, the author provides the following remark (Salim, 2007, p.1): "further reform of trade policies, in particular, focusing on reducing nominal and effective protection levels in order to enhance competition and competitiveness so that an efficient production can take a firmer root in the industrial sector of the economy".

Using data envelopment analysis (DEA) and a Malmquist productivity index (MPI), Ali *et al.* (2009) examine the impact of trade liberalization over the period 1980–2002 on the Indian food processing industry. Their findings show that technical efficiency scores for the food processing industry declined during the post-liberalization period and varied across sub-sectors. In addition, they also point out that although the food industry experienced positive TFP change, the positive gain in TFP is due to changes in technological progress, whereas the contribution of technical efficiency is very small. Using input slack analysis, they indicate that the reason for the decline of efficiency is that raw materials, capital, and energy are used excessively.

Handoussa *et al.* (1986) estimate the effect of trade reform on productivity change in the Egyptian manufacturing public sector over the period of 1973–1979. Using the decomposition methodology of TFP productivity measurement proposed by Nishimizu and Page (1982)[11], they find that there are high rates of technological change but these high rates of technological change are offset by deteriorating technical efficiency. Their interpretation is that the deterioration of technical efficiency is probably a consequence of the movement from highly centralized direction of public sector firms to a more liberalized environment of production.

The findings of Handoussa *et al.* (1986) as discussed above are similar to the empirical results conducted by Parameswaran (2002). Using selected Indian manufacturing sectors (electrical machinery, electronics machinery, non-electrical equipment and transport) over the period 1989–1998, Parameswaran (2002) finds that although the change in policy has a positive effect on technical efficiency in all selected manufacturing industries except non-electrical machinery, the level of efficiency is lower in the post-liberalized period. The decrease of technical efficiency takes place in the context of an increase in technological change. He interprets these findings as the failure of firms to catch up with a shifting of the frontier technology.

Using the share of exports to represent trade liberalization, Aedo (2011) examines the impact of trade liberalization on technical efficiency in the Chilean agro-processed food industry from 2001 to 2007. He finds that a higher share of exports does not lead to higher efficiency. This finding is not consistent with theoretical expectation that higher exports lead to higher technical efficiency. Regarding this finding, he explains that it may occur because of two reasons: (i) distributional problems, since the group of exporting firms consists of less than 10% of the sample; and (ii) the continuous depreciation of the US dollar since 2001.

It can be concluded from the empirical studies explained above that similar to the empirical studies of the impact of trade reform on TFP growth, the empirical studies of the impact of trade reform on technical efficiency also have various findings. Drawing on the arguments developed by Pack (1988), Havrylyshyn (1990), and

[11] Nishimizu and Page (1982) decompose TFP change into technological change and technical efficiency change. Technological change refers to the change in the best practice production frontier, while technical efficiency change refers to the movement within the best practice technology which may include learning by doing, new technological diffusion and improvement of managerial practice.

Deraniyagala and Fine (2001), it may be inferred that the empirical findings have not confirmed clearly as yet that trade reform leads to higher technical efficiency.

3.4.2 Indonesian Literature

There are several empirical studies of technical efficiency in Indonesian manufacturing as summarized in Table 3.4. They examine the determinants of technical efficiency in Indonesian manufacturing using SFA and incorporating several industry-specific variables and other variables which may influence firm technical efficiency. However, none of these studies investigate the impact of trade reform on technical efficiency. The findings of these studies are discussed in the following passages.

The first attempt to study the determinants of technical efficiency in Indonesian manufacturing was conducted by Pitt and Lee (1981). Using pooled data on 50 Indonesian weaving firms for the years 1972, 1973 and 1975 and applying a time-invariant efficiency model, they find that average mean efficiency for the Indonesian weaving industry is between 60% and 70%. They also investigate the sources of technical inefficiency in this industry and find that age, size and ownership significantly affect firm technical inefficiency. Their findings suggest that larger firms are more efficient than smaller firms, younger firms are more efficient than older firms and domestic firms are more efficient than foreign firms.

Following Pitt and Lee (1981), Hill and Kalirajan (1993) examine the determinants of technical efficiency in the Indonesian garment industry using data of the 1986 Census of Small Industry. Unlike the study conducted by Pitt and Lee, Hill and Kalirajan estimate both average technical efficiency and individual firm-specific technical efficiency. They also use different variables from the study of Pitt and Lee, except age, to investigate the determinants of technical efficiency. Using discriminant analysis, they find that export orientation, sources of finance and female participation of the workforce have a positive association with high levels of technical efficiency in firms, while the age of firms and the proportion of unpaid workers are positively associated with a lower level of technical efficiency in firms.[12]

[12] Hill and Kalirajan (1993) classify firms as highly technically efficient (HTE) if the firm had greater than 75 % efficiency level and classify firms with less than 50 % level of technical efficiency as highly technically inefficient (HTI)

Margono and Sharma (2006) study empirically the factors contributing to firm technical efficiency and the impact of the Asian economic crisis (1997–1998) on technical efficiency in four Indonesian manufacturing industries over the period 1993 to 2000. The four industries they choose are food, textile, chemical and metal products. The findings show that average technical efficiency in all four sectors is 55.87%, which means that firms in these four sectors are operating at only 55.87% of their potential output. Based on regression analysis, they note that in general larger firms are more efficient, except in the food sector. Private firms are more efficient than public firms, except in the textile sector. Both age of firms and regional location did not affect significantly the technical efficiency of firms. Regarding the impact of the Asian economic crisis on firm technical efficiency, they find that in all sectors, annual growth rates of technical efficiency were lower than annual growth rates before the Asian economic crisis.

Similar to Margono and Sharma (2006), Ikhsan (2007) examines the changes of technical efficiency in Indonesian manufacturing from 1988 to 2000. He finds that technical efficiency varies considerably across time and manufacturing industry. He also investigates the impact of the economic crisis in 1997 on technical efficiency. The findings show that the effect of the economic crisis differs across industries. However, unlike the earlier studies, Ikhsan (2007) does not investigate the determinants of technical efficiency.

Table 3.4: Summary of Selected Empirical Studies on Technical Efficiency in Indonesia

No.	Author(s)	Period of Data	Method of Estimation	Result
1	Pitt and Lee (1981)	1972, 1973, 1975 (50 Weaving Firms)	SFA	Age, size, and ownership have a significant effect on technical efficiency.
2	Hill and Kalirajan (1993)	1986 (Garment Small Industry)	Discriminant Analysis	Export orientation, sources of finance and female participation have positive effects on technical efficiency.
3	Margono and Sharma (2006)	1993–2000 (Firms: food, textile, chemical, and metal product)	SFA	On average, technical efficiency decreases after the Asian crisis hit Indonesia. The size coefficient for all sectors is negative and significant. The regional coefficient is significant in the textile sector and insignificant in the other three sectors. The ownership coefficients are significant and have negative signs except in the textile sector. However, in the chemical and the metal products, the ownership coefficient is significant but has different signs.
4	Ikhsan (2007)	1988–2000 (All Industry)	SFA	Technical efficiency varies across time and manufacturing industries. The effect of the crisis differs across industries.
5	Suyanto *et al.* (2009)	1988-2000 (Chemical and Pharmaceutical)	SFA-Malmquist index	The FDI spillovers do not contribute much to technical efficiency.
6	Suyanto *et al.* (2012)	1988-2000 (Garment and Electronics Manufacturing)	SFA-Malmquist index	FDI generates a positive effect on technical efficiency change in the garment industry. In contrast, FDI does not have a significant effect on technical efficiency change in the electronics industry.

Source: Author's compilation

Empirical study on technical efficiency in Indonesian chemical and pharmaceutical firms has been provided by Suyanto *et al.* (2009). They investigate the impact of FDI spillovers on technical efficiency in Indonesian chemical and pharmaceutical firms over the period 1988–2000. Their findings suggest that foreign firms have higher technical efficiency than domestic firms. They also find that a spillover variable, represented by the share of foreign firms' output in total output, has a negative and significant impact on technical inefficiency, which means that a higher foreign share leads domestic firms to use their resources more efficiently.

Another study on technical efficiency in garment and electronics manufacturing is examined by Suyanto *et al.* (2012). They study empirically the spillovers effects of FDI for firms in these industries. They find different spillovers effects of FDI in these different industries. FDI contributes a positive effect on technical efficiency change in the garment industry. In contrast, FDI generates a negative effect on technical efficiency change in the electronics industry. These findings suggest that the impact of FDI spillovers are not similar in these two selected industries.

Based on the empirical studies on technical efficiency in Indonesian manufacturing discussed in this section, it can be seen that until recently, there has been no systematic study of the impact of trade reform on technical efficiency in Indonesian manufacturing industry.

3.5 Conclusion

This chapter provides a review of methodology used in measuring TFP growth. The first section explains various approaches to measuring TFP growth rates. Each of these approaches has its advantages and disadvantages. The analysis provided shows that some of these disadvantages may lead to biased estimates and lead to incorrect policy formulation. The earliest methods of measuring TFP growth assume that all firms are operating on the frontier, which means that there is no technical inefficiency. This assumption is too strong and rarely applies in reality. Firms are usually operating under the frontier because of a combination of various factors. Therefore, this first section concludes that an alternative method, which relaxes this assumption in measuring TFP, is needed to improve these earlier methods.

This chapter also summarizes the empirical evidence on the impact of trade reform on industrial TFP growth. From the findings of the empirical studies in the international literature, not including Indonesia, it can be seen that there is still no consensus regarding the impact of trade reform on TFP growth. Several studies show that trade reform improves TFP growth, while other studies show that trade reform has a negative, or no impact on TFP growth. This thesis is aimed at helping reconcile controversy regarding the findings of previous studies. Concerning the empirical studies conducted in Indonesia on the impact of trade reform on TFP growth, it can be seen that trade reform has a positive impact on TFP growth. However, these studies use the growth accounting method to measure TFP growth. This method may lead to biased estimates. Research is needed in order to improve the method of measuring TFP used in the previous empirical studies. This study attempts to address this issue and fill this research gap.

After discussing the empirical studies on the impact of trade reform on TFP growth, this chapter summarizes some empirical studies on the impact of trade reform on technical efficiency. Similar to the findings of the impact of trade reform on TFP growth, the findings here show there is mixed evidence on their impact. Several studies show that trade reform improves technical efficiency, while other studies show that there is no evidence, little or no impact on technical efficiency. Regarding the empirical studies on this topic in Indonesia, there are a few empirical studies on technical efficiency in Indonesia. However, none of these studies assess the impact of trade reform variables on technical efficiency. Research is needed to analyse the impact of trade reform on technical efficiency. This study attempts to fill this gap.

Based on the identified research gaps as explained above, this chapter concludes there is a need for an alternative method to analyse the impact of trade reform on TFP growth and the empirical studies to analyse the impact of trade reform on technical efficiency in Indonesia. Two alternative methods to analyse these issues are discussed in the following chapter.

Chapter 4
The Analytical Framework

4.1 Introduction

Having reviewed the methodology of total factor productivity (TFP) measurement and provided an empirical survey of the impact of trade reform on productivity growth in Chapter 3, attention is now given to the analytical framework used in this thesis. The objective of this chapter is to describe the methodology used for measuring the impact of trade reform on technical efficiency and TFP in Indonesia.

As noted in Chapter 3, the commonly used framework for analysing the impact of trade reform on productivity is a conventional production function. Under the conventional production function, it is assumed that firms are technically efficient, the technology exhibits constant returns to scale, technical change is Hicks neutral, and firms are operating in perfect competition of input and output markets. However, as noted by Kalirajan and Shand (1999), in practice there is normally a gap between a firm's actual output and potential output. It is noted by O'Donnell (2008, p.20) that 'In any empirical application, the joint probability of meeting all these requirements may be near zero'. Drawing on the arguments developed by Kalirajan and Shand (1999) and O'Donnell (2008, p.20), this thesis applies methods of estimating productivity which relax the assumptions of the traditional production function.

There are two techniques applied in this thesis to measure technical efficiency and TFP. The first technique is the one-stage stochastic frontier approach (SFA) proposed by Battese and Coelli (1995). This technique is used to examine the impact of trade reform on technical efficiency. The second technique is the Färe-Primont TFP index proposed by O'Donnell (2011). This technique is used to measure TFP changes. The impact of trade reform on TFP changes is evaluated by relating the obtained Färe-Primont TFP changes to trade reform using panel data analysis. These two techniques allow for more realistic results of estimation of the effects of trade reform on technical efficiency and TFP changes than the conventional production function used in the earlier empirical studies.

This chapter consists of four sections. Section 4.2 discusses the stochastic frontier approach (SFA), which includes a brief overview of the SFA, a discussion about the model for panel data SFA with inefficiency effects and a description of the chosen SFA for this study. Section 4.3 presents the TFP index used to measure productivity, covering the discussion of O'Donnell's approach to TFP definition and decomposition of TFP, the components of efficiency and the decomposition of TFP change adopted in this study. The conclusion is presented in Section 4.4.

4.2 Measurement of Technical Efficiency: The Stochastic Frontier Approach (SFA)

The SFA was introduced independently by Aigner *et al.* (1977) and Meeusen and Broeck (1977). In their papers, they introduce an error term with two components in a stochastic production frontier framework. The first part of the composite error term represents stochastic (random) statistical noise beyond the firm's control, such as luck, unusual weather conditions, errors in measurement and omitted variables. The second part of composite error term accounts for the technical inefficiency of the firm.

The functional form of the SFA as proposed by Aigner *et al.* (1977) and Meeusen and Broeck (1977) can be written as:

$$Y_i = f\ (X_i; \alpha_0, \beta)\exp(\varepsilon_i) \qquad \textbf{4.1}$$

$$\varepsilon_i = v_i - u_i \qquad \textbf{4.2}$$

where Y_i is the scalar output of firm i *(i = 1,2, … , N)*, $f\ (X_i; \alpha_0, \beta)\exp(\varepsilon_i)$ is the deterministic frontier production function, X_i is a *(1*x*k)* vector of inputs used by firm *i*, β is a *(k*x*1)* vector of parameters, α_0 is the intercept of the production frontier, $\exp(\varepsilon_i)$ is the composite error term. The error term, ε_i, is composed of two components, one is v_i, a two-sided random statistical noise of firm i, with $iid\ N(0, \sigma_v^2)$, and the other is u_i, a one-sided error component representing technical inefficiency of firm i with $u_i \sim N^+(0, \sigma_u^2)$; v_i and u_i are distributed independently of each other and of the regressors.

In a log-linear format for firm *i*, Equations 4.1 and 4.2 can be rewritten as:

$$y_i = \alpha_0 + x_i\,\beta + v_i - u_i \qquad \textbf{4.3}$$

where y_{it} is the scalar of the logarithm of output for firm *i* $(i = 1, 2, \ldots, N)$, x_{it} is a $(1\text{x}k)$ vector of the logarithm inputs used by firm *i* and the other variables are as defined previously.

The motivation for introducing a composite error in the SFA model originates from the difference between the assumptions of neo-classical production theory and the observations of firms' production. An underlying assumption based on neoclassical production theory is that firms are producing at the full efficiency level using the best available technology and factor inputs are paid at their marginal product (Bartelsman and Doms 2000). However, these assumptions are too restrictive because in reality, firms may produce less than the maximum possible output. Taking into account the technical inefficiency of firms, the SFA includes a one-sided error term, u_i. Therefore, the objective of SFA model is not only to estimate the parameters of production technology β, as in the neo-classical production function, but also to measure the technical inefficiency by separating the two error components (v_i and u_i).

To estimate the SFA model, one can use the maximum likelihood estimation (MLE) or corrected ordinary least square (COLS) method (Schmidt 1985). These methods require a distribution for the two error components (v_i and u_i) and an assumption of non-correlation between both error terms and input variables (X_i). In dealing with the distributional assumption, in all stochastic frontier models to date, the errors representing random statistical noise are assumed to be independently and identically distributed (*iid*) normal. A number of distributions have been assumed for the one-sided errors representing inefficiency (u_i). Aigner *et al.* (1977) suggest a half-normal distribution, Meeusen and Broeck (1977) offer an exponential distribution, Greene (1980) proposes a gamma distribution, while Stevenson (1980) suggests a truncated-normal distribution for u_i. Once the distribution of u_i has been determined, the stochastic frontier production function given by Equation 4.3 is estimated by using either the MLE or COLS method.

As noted by Schmidt and Sickles (1984), the SFA model based on cross-sectional data has three weaknesses. First, although the composite error term (v_i - u_i) can be easily estimated, it is difficult to decompose this error term into statistical noise (v_i) and technical inefficiency (u_i) (Jondrow *et al.* 1982). The average of technical inefficiency can be estimated but a consistent estimation of technical efficiency (u_i) for each observation is difficult to obtain, since the variance of the conditional mean for each individual firm does not go to zero as the cross-section size increases (Kumbhakar and Lovell 2000). If the technical efficiency of each firm cannot be measured, it becomes difficult to compare levels of efficiency across observations. Second, specific assumptions are required to separate the statistical noise (v_i) and the technical inefficiency (u_i). However, it is not clear how robust the results are to these assumptions. Third, it may not be correct if the SFA assumes that technical inefficiency (u_i) is independent of the regressors (x_i). There may be an endogeneity problem, which means that if a firm knows its technical inefficiency level, it affects its choice of inputs.

However, the weaknesses of the cross-sectional SFA mentioned above can be addressed by using panel data (Schmidt and Sickles 1984, Kumbhakar and Lovell 2000, Coelli *et al.* 2005). First, increasing the number observations for each producer leads to a consistent estimate of the technical efficiency as $T \rightarrow \infty$. Second, panel data do not require a strong distributional assumption since evidence of inefficiency can be found in repeated observations over time. Third, not all panel data estimations require an assumption that the inefficiency component of the error term is uncorrelated with the regressors. A variety of estimators can be chosen depending on the assumption about the distribution of technical inefficiency and the potential correlation between technical inefficiency and the regressors. In addition, repeated observations can substitute for the assumption of independence.

Early applications of SFA to panel data are used by Pitt and Lee (1981), Schmidt and Sickles (1984), Kumbhakar (1987) and Battese and Coelli (1988). The general functional relationship applied these studies can be expressed as:

$$\boldsymbol{Y_{it} = f\,(X_i;\alpha_0,\beta\,)\mathbf{exp}(v_{it} - u_i)} \qquad \mathbf{4.4}$$

It can be seen that compared to the stochastic frontier model in Equation 4.1, the stochastic frontier model in Equation 4.4 has an additional subscript *t* to index time. This additional *t* shows that the data used are panel data, with a cross-sectional dimension of i $(i = 1, 2, \ldots, N)$ and time dimension t $(t = 1, 2, \ldots, T)$. In a log-linear format for firm i at time t, Equation 4.4 can be written as:

$$\begin{aligned} y_{it} &= \alpha_0 + x_{it}\,\beta + v_{it} - u_i \\ &= \alpha_i + x_{it}\,\beta + v_{it} \end{aligned} \qquad \mathbf{4.5}$$

where y_{it} is the scalar of the logarithm of output for firm i $(i = 1, 2, \ldots, N)$ at time t $(t = 1, 2, \ldots, T)$, x_{it} is a $(1\mathrm{x}k)$ vector of the logarithm of inputs used by firm i at time t, β is a $(k\mathrm{x}1)$ vector of unknown parameters to be estimated, $\alpha_i = \alpha_0 - u_i$ is the intercept for firm i which is invariant with respect to time t.

Equation 4.5 shows that the early panel data SFA models impose the assumption that u_i is dependent on i (firm) but independent of t (time). In other words, technical inefficiency (u_i) is constant for the firm over time or time-invariant. This assumption is very strong, particularly if firms are operating under a competitive environment. Schmidt (1985) and Coelli *et al.* (2005) argue that after a period of time, technical inefficiency levels decrease through learning and firms adjust their input choice accordingly. Thus, technical inefficiency levels may change systematically over time.

Recent developments in SFA models have shown that the assumption of time-invariant technical efficiency can be relaxed. Generally, in a log-linear format the panel data SFA model with time-varying technical efficiency (TE) is written as:

$$y_{it} = \alpha_{0t} + x_{it}\,\beta + v_{it} - u_{it} \qquad \mathbf{4.6}$$

where α_{0t} is the production frontier intercept common to all firms in time t, $\alpha_{it} = \alpha_{0t} - u_{it}$ is the intercept for firm i $(i = 1, 2, \ldots, N)$ at time t $(t = 1, 2, \ldots, T)$. Compared with Equation 4.5 the technical efficiency component, u, in Equation 4.6 has an additional subscript t which represents the time-varying TE. Equation 4.6 is a standard model of time-varying TE.

Different time-varying models have emerged as different choices for the form of u_{it}. There are several papers on SFA incorporating time-varying technical inefficiency effects. Cornwell *et al.* (1990) propose firm-specific patterns of temporal change in technical inefficiency. Lee and Schmidt (1993) offer flexibility in the pattern of technical efficiency over time. Kumbhakar (1990) suggests a model with systematic variation of the inefficiency effects. Battese and Coelli (1992) assume the inefficiency effects to be an exponential function of time. Cuesta (2000) proposes a model that each individual firm has its own temporal pattern of technical inefficiency. Each of these technical efficiencies patterns has its own merits and demerits.[13]

4.2.1 The Panel Data SFA with Inefficiency Effects Model

An important development of the panel data SFA model has focused on factors which may affect a firm's technical inefficiency. In this model, a firm's technical efficiency is defined to be an explicit function of some firm-specific characteristics. Such factors can be firm size, age of firm, ownership structure, degree of competition or economic policies taken by the government. These factors are incorporated into the SFA model by including them as exogenous variables which affect technical inefficiency.

In a general form, the panel data SFA with exogenous variables affecting technical efficiency can be written as follows:

$$y_{it} = \alpha_0 + x_{it}\beta + v_{it} - u_{it} \qquad \textbf{4.7}$$

$$u_{it} = z_{it}\vartheta + \omega_{it} \qquad \textbf{4.8}$$

where z is a *(1xm)* vector of explanatory variables which affect technical efficiency, ϑ is a *(mx1)* vector of parameters of the technical inefficiency function and ω is a random variable.

One of first attempts that analyses exogenous variables affecting firms' technical inefficiency is conducted by Pitt and Lee (1981). Using a two-stage approach, they examine the effect of firm-specific factors such as size, age and ownership on a firm's technical inefficiency. In the first stage, the SFA production frontier is estimated as in Equation 4.7 and the technical efficiency index for each individual firm is measured. In the second stage, the technical efficiency index obtained from the first stage is regressed against a set of firm-specific factors, as in Equation 4.8 using the standard ordinary least square (OLS) method to explain the variation in the technical efficiency index.

Following Pitt and Lee (1981), subsequent researchers adopt the two-stage approach in their empirical studies. Empirical studies applying this two-stage approach include Kalirajan (1981, 1982, 1989), Kalirajan and Shand (1986, 1990, 1999), Mahadevan

[13] Cuesta (2000) provides an excellent review of different time-varying SFA models.

(2002) and Salim (2003, 2008). All these studies evaluate the effect of firm-specific factors on technical efficiency.

The two-stage approach as used by researchers mentioned above has at least two serious drawbacks (Kumbhakar *et al.* 1991, Wang and Schmidt 2002). First, exogenous variables that affect technical efficiency might be correlated with the production inputs. It implies a correlation between the inefficiency term and the production inputs in the first-stage equation leading to inconsistent estimates of the regression parameters in the production frontier. Second, if technical efficiency is affected by exogenous variables in the second stage of the OLS method, the independent and identical distribution assumption of the one-sided error term is invalid in the first step (Coelli *et al.* 2005). These two drawbacks lead to a potential bias in the estimates derived from the two-stage approach.

The limitations of the two-stage approach provide justification for the one-stage approach to overcome these limitations. The use of the one-stage approach is proposed by Kumbhakar *et al.* (1991), Reifschneider and Stevenson (1991), Huang and Liu (1994), and Audibert (1997). While the first three papers apply the one-stage approach in cross-sectional data, the last paper extends the approach to panel data.

Under the one-stage approach, the parameters of both the production frontier function and technical efficiency effect are estimated using a single estimation method, given appropriate distributional assumptions for the composite error term (v_{it} and u_{it}). On the basis of the advantage of the one-stage approach and its compatibility with the application of panel data analysis, this thesis adopts Audibert (1997) model. The details of Battese and Coelli (1995) model are explained in the following subsection.

4.2.2 Estimation Procedures for the Battese and Coelli (1995) Model

The one-stage approach SFA panel data estimation proposed by Battese and Coelli (1995) accommodates a firm's specific inefficiency effect, technical change and time varying technical inefficiency changes. The stochastic frontier production function for panel data as formulated by Battese and Coelli can be written as follows:

$$Y_{it} = f\ (X_{it};\ \beta\ )\exp(v_{it} -\ u_{it}) \qquad \textbf{4.9}$$

where Y_{it} denotes the output for firm *i (i = 1, 2, …, N)* at time *t (t = 1, 2, …, T)* , X_{it} is a *(1*x*k)* vector of inputs used by firm i at time t, β is a *(k*x*1)* vector of unknown parameters to be estimated in the model. The v_{it} is a random error which is assumed to be $iid\ N(0,\sigma_v^2)$ and is distributed independently of the u_{it}. The u_{it} is a technical inefficiency effect which is assumed to be independent, but not identically distributed, such that u_{it} is obtained by truncation (at zero) of the normal distribution with mean, m_{it} and variance σ_u^2, that is $u_{it}\sim N^+(m_{it},\sigma_u^2)$. The mean of the distribution of the u_{it} can be written as:

$$m_{it} = g(z_{it},\delta) \qquad \textbf{4.10}$$

where z_{it} is a (*1*x*s*) vector of exogenous variables with a constant term associated with firm specific technical efficiency for firm i at time t, is a *(s*x*1)* vector of unknown parameters to be estimated with a chosen functional form g (.). In a linear format, the technical inefficiency effect u_{it} can be written as:

$$\boldsymbol{u_{it}} = \boldsymbol{z_{it}\delta} + \boldsymbol{w_{it}} \qquad \textbf{4.11}$$

where w_{it} is an unobservable random error and is defined by the truncation of a $N^+(0,\sigma_w^2)$ distribution with point of truncation at $-z_{it}\delta$. This assumption implies that $w_{it} \geq -z_{it}\delta$. Battese and Coelli (1995) show that this last assumption is consistent with the assumption that $u_{it}\sim N^+(m_{it},\sigma_u^2)$.

The parameters of the stochastic production frontier and the technical inefficiency effects in Equations 4.9 and 4.11 are simultaneously estimated using a maximum likelihood (ML) method. The likelihood function is parameterized in terms of the variance parameters, $\sigma_s^2 \equiv \sigma_v^2 + \sigma_u^2$ and $\gamma \equiv \frac{\sigma_u^2}{\sigma_u^2+\sigma_v^2}$ (Audibert 1997). The derivation of the maximum likelihood for v_{it} and u_{it} is explained in Battese and Coelli (1993), with the logarithm of the likelihood function expressed by:

$$L^*(\theta;y) = -\frac{1}{2}\left(\sum_{i=0}^{I}\sum_{t=0}^{T}\right)\{\ln 2\pi + \ln\sigma_s^2\} - \frac{1}{2}\left(\sum_{i=0}^{I}\sum_{t=0}^{T}\right)\left\{\frac{(y_{it} - x_{it} + z_{it}\delta)^2}{\sigma_s^2}\right\}$$
$$-\frac{1}{2}\left(\sum_{i=0}^{I}\sum_{t=0}^{T}\right)\{\ln\Phi(d_{it}) - \ln\Phi(d_{it}^*)\} \qquad \textbf{4.12}$$

where L^* is the logarithm of the likelihood function, θ represents the estimated parameters $(\widehat{\beta}, \widehat{\delta}, \widehat{\sigma_s^2}, \widehat{\gamma})$, y denotes the logarithm of the vector of sample observations, $\Phi(.)$ represents the distribution function for the standard normal random variable, T is total period of time, I is total number of firms, $d_{it} = \frac{z_{it}\,\delta}{(\gamma.\sigma_s^2)^{\ 1/2}}$, and $d_{it}^* = \frac{(1-\gamma)z_{it}\,\delta - \gamma(y_{it} - x_{it}\,\beta)}{[\gamma(1-\gamma)\sigma_s^2]^{\ 1/2}}$. The partial derivatives of the logarithm of the likelihood function with respect to the parameters, β, δ, σ_s^2 and γ can be expressed as follows:

$$\frac{\partial L^*}{\partial \beta} = \sum_{i=0}^{I}\sum_{t=0}^{T} \left\{\frac{y_{it} - x_{it}\,\beta + z_{it}\,\delta}{\sigma_s^2} + \frac{\phi(d_{it}^*)}{\Phi(d_{it}^*)}\frac{\gamma}{\sigma_*}\right\} x_{it}' \qquad \textbf{4.13}$$

$$\frac{\partial L^*}{\partial \delta} = -\sum_{i=0}^{I}\sum_{t=0}^{T} \left\{\begin{gathered}\frac{y_{it} - x_{it}\,\beta + z_{it}\,\delta}{\sigma_s^2} + \\ \left[\frac{\phi(d_{it}^*)}{\Phi(d_{it}^*)}.\frac{1}{(\gamma.\sigma_s^2)^{\frac{1}{2}}} - \frac{\phi(d_{it}^*)}{\Phi(d_{it}^*)}.\frac{1-\gamma}{\sigma_*}\right]\end{gathered}\right\} z_{it}' \qquad \textbf{4.14}$$

$$\frac{\partial L^*}{\partial \sigma_s^2} = -\frac{1}{2}\left(\frac{1}{\sigma_s^2}\right)\left\{\begin{gathered}\left(\sum_{i=1}^{I} T_i\right) - \sum_{i=0}^{I}\sum_{t=0}^{T}\left[\frac{\phi(d_{it})}{\Phi(d_{it})}d_{it} - \frac{\phi(d_{it}^*)}{\Phi(d_{it}^*)}d_{it}^*\right] \\ -\sum_{i=0}^{I}\sum_{t=0}^{T}\frac{y_{it} - x_{it}\,\beta + z_{it}\,\delta}{\sigma_s^2}\end{gathered}\right\} \qquad \textbf{4.15}$$

$$\frac{\partial L^*}{\partial \gamma} = \sum_{i=0}^{I}\sum_{t=0}^{T}\left\{\frac{\phi(d_{it})}{\Phi(d_{it})}\frac{d_{it}}{2\gamma} + \frac{\phi(d_{it})}{\Phi(d_{it}^*)}\left[\frac{y_{it} - x_{it}\,\beta + z_{it}\,\delta}{\sigma_*} + \frac{d_{it}^*(1-2\gamma)}{2\gamma(1-\gamma)\sigma_*^2}\right]\right\} \qquad \textbf{4.16}$$

where $\phi(.)$ represents the density function for the standard normal variable and all other variables are as previously defined.

The parameters of the stochastic frontier as mentioned above can be estimated using the computer programs which deal with stochastic frontier analysis. One of the computer programs, developed by Coelli (1996), is FRONTIER 4.1. This program can be used to estimate the stochastic production frontier of Equation 4.9 and the inefficiency function of Equation 4.11 under the maximum likelihood method. To obtain the final maximum likelihood estimates, this program follows a three-step estimation method. First, ordinary least squares (OLS) is used to estimate the stochastic production function. All parameters β are unbiased except for the intercept α. Second, a two-phase grid search of γ is conducted, with β parameters (except the intercept α) set to OLS values and the intercept α and the σ_s^2 parameters adjusted using the corrected ordinary least squares formula. All other parameters (μ, η, δ) are set to zero during this grid search. Third, the values selected from the grid search are used as starting values in the iterative procedure to obtain the final maximum likelihood estimates using the Davidon-Fletcher-Powell Quasi-Newton method. The FRONTIER 4.1c computer program is used to estimate the parameters of the stochastic frontier model in this thesis.

For the purpose of this thesis, there are two groups of variables included in the technical efficiency function. The first group consists of trade reform variables, namely, the effective rate of protection and a measure of openness. These variables serve as measures for the impact of trade reform on technical efficiency. The second group represents firm-specific characteristics, including capital intensity, ownership, age and the share of non-production workers to total workers. Thus, the exogenous variables affecting technical inefficiency consist of two groups, namely, trade reform variables and firm-specific characteristics. The inefficiency model in Equation 4.11 can then be rewritten as:

$$u_{it} = TRE_{it}\tau + f_{it}\delta + w_{it} \qquad \textbf{4.17}$$

where TRE is a *(1*x*j)* vector of trade reform variables of firm i at time t, τ is a *(j*x*1)* vector of coefficients, f is a *(1*x*p)* vector of firm-specific variables of firm i at time t and δ is a *(p*x*1)* vector of coefficients for firm-specific variables. A particular interest of this thesis is on the estimated coefficients of τ in Equation 4.17.

4.2.3 Measuring Firm-Specific and Industry Technical Efficiency

The technical efficiency of firms and industry can be measured from the technical efficiency (TE) scores obtained from the stochastic frontier model in Equations 4.9 and 4.11. Following Battese and Coelli (1993), the scores of technical efficiency are calculated from the technical efficiency index as follows:

$$TE_{it} = \frac{y_{it}}{y_{it}^*}$$

$$= \frac{f(X_{it};\alpha,\beta)\exp(v_{it} - u_{it})}{(X_{it};\alpha,\beta)\exp(v_{it})}$$

$$= \exp(-u_{it})$$

$$= \exp(-z_{it}\delta - w_{it}) \qquad \textbf{4.18}$$

Equation 4.18 shows that the TE index is measured as a ratio of the actual output, y_{it}, to the maximum output, y_{it}^*, of the i-th firm at time t from a given set of inputs and production technology. Since u_{it} is a non-negative random variable, the TE scores vary between 0 and 1. The most technically efficient firm has a TE score equal to 1 and technically inefficient firms have TE scores below 1.

The TE scores are estimated using the FRONTIER 4.1c computer program. This software estimates TE indices for each firm in each observed period. When using panel data, TE scores for each firm *i(i=1,2,3…N)* at each period of *t (t=1,2,3…T)* are obtained from the TE index in Equation 4.18. The individual estimates of TE index can be used to calculate the average TE scores for each industry in each period.

4.3 Measuring the Total Factor Productivity (TFP) Index

The impact of trade reform on productivity growth in this thesis is examined by applying a two-stage procedure. In the first stage, TFP growth is measured by employing a TFP measurement technique proposed by O'Donnell (2011). In the second step, the trade reform variables are regressed against the TFP growth obtained from the first stage.

For measuring productivity growth, O'Donnell's approach of a multiplicatively-complete TFP index is used in this thesis. The advantage of this approach compared to other productivity indices is that it can be estimated without any restrictive assumptions related to the structure of technology, competition in the input and output markets or the optimizing behaviour of firms. According to the best knowledge of the author, earlier studies about productivity in Indonesia have never used this method. Thus, this thesis contributes to the literature by applying a relatively new method for measuring productivity growth. In addition, this approach can be applied when price data on inputs and outputs are not available. This additional advantage is also relevant to this thesis because price data on inputs and outputs are not available in the dataset used in this study.

The main requirement for O'Donnell's approach is an estimate of the production possibilities frontier. There are two main techniques for estimating the production possibilities frontier, namely, parametric and non-parametric techniques. The commonly used parametric technique is the stochastic frontier approach (SFA) and the usual non-parametric technique is the data envelopment analysis (DEA). Both parametric and non-parametric techniques have their own merits and limitations. The debate over which one is the most appropriate technique still continues in the literature. This thesis adopts a non-parametric (DEA) technique to estimate the production possibilities frontier because it does not require any explicit assumptions concerning error term, there are no statistical issues associated with estimating multiple-output and multiple-input technologies and a computer package to estimate this technique is available.

This section is organized as follows. The following sub-section provides a brief discussion of O'Donnell's approach to definition and decomposition of TFP. It is followed by the decomposition of efficiency in the second sub-section. The third sub-section presents the decomposition of technical change. The last sub-section discusses the use of panel data analysis to test the impact of trade reform on productivity growth.

4.3.1 O'Donnell's Approach on TFP Definition and Decomposition of TFP

To measure the TFP index, it is important to define the TFP index and choose a TFP index formula which is consistent with the definition. Following O'Donnell (2010a), the TFP index of a multiple output, multiple input firm is defined as the ratio of an aggregate output index to an aggregate input index. With this definition, TFP of firm *i* in period *t* can be expressed as:

$$TFP_{it} = \frac{Y_{it}}{X_{it}} \qquad \textbf{4.19}$$

where $Y_{it} \equiv Y(y_{it})$ is an aggregate output index, $X_{it} \equiv X(x_{it})$ is an aggregate input index, and $Y(.)$ and $X(.)$ are non-negative, non-decreasing and linearly homogenous aggregator functions.

The TFP index numbers constructed as in Equation 4.19 are named multiplicatively-complete TFP index numbers. O'Donnell (2008) shows that all multiplicatively-complete TFP index numbers can be further decomposed into:

$$TFP_{it} = TFP_{it}^{*} \times TFPE_{it} \qquad \textbf{4.20}$$

where $TFP_{it}^{*} = Y_t^{*}/X_t^{*}$ denotes the maximum TFP possible using the technology available in period t and $TFPE_{it}$ denotes TFP efficiency of firm i at time t. This efficiency component can be further decomposed into various measures of efficiency such as pure technical efficiency, pure scale efficiency and mix efficiency.

There are several TFP indices which can be categorized as multiplicatively-complete indices including Laspeyres, Paasche, Fisher, Törnquist, Hicks-Moorsten, Färe-Primont, Lowe and Geometric Young. However, Hulten (1978) shows that only some indices which are categorized as multiplicatively-complete index satisfy a set of economically-relevant axioms and tests of index number theory[14]. Using a hypothetical data set, O'Donnell (2011) shows that any TFP index used that does not satisfy a set of axioms and tests of index number theory can lead to unreliable estimates of TFP. The Fisher, Törnquist and Hicks-Moorsten indexes are the examples of TFP indices that satisfy all the identity axioms but these three indices fail the transitivity test.

There are three indices numbers that satisfy all axioms and tests of index number theory (O'Donnell 2011). These three indices are the Lowe, Geometric Young and Färe-Primont indices. While the Lowe and Geometric Young indices can be used to measure the TFP index if price data are available, the Färe-Primont index is used when price data are not available. In this thesis, the Färe-Primont index is used because price data are not available for Indonesian manufacturing.

The Färe-Primont TFP index proposed by O'Donnell (2011) can be formulated as:

$$TFP_{ns,it} = \frac{D_O\,(x_0\,, y_{it}\,,\ t_0)}{D_O\,(x_0\,, y_{ns}\,,\ t_0)} \frac{D_I\,(x_{ns}\,, y_0\,,\ t_0)}{D_I\,(x_{it}\,, y_0\,,\ t_0)} \qquad \textbf{4.21}$$

The Färe-Primont aggregator function that is non-negative, non-decreasing, and linearly homogenous can be expressed as (O'Donnell 2011):

[14] Hulten (1978) provides an excellent explanation about the axioms and tests of index number theory.

$$Y(y) = D_O(x_0, y, t_0) \quad \textbf{4.22}$$

$$X(x) = D_I(x, y_0, t_0) \quad \textbf{4.23}$$

where y and x are vectors of output and input quantities and $D_O(.)$ and $D_I(.)$ are the output and input distance functions. The formulation in Equation 4.21 is proposed by O'Donnell (2011) but it is referred to a Färe-Primont TFP index because it is written as the ratio of output and input index defined by Färe and Primont (1995).

4.3.2 Decomposition of Efficiency

O'Donnell (2012) shows that all multiplicatively-complete indices can be decomposed into several meaningful measures of efficiency change. Following O'Donnell (2012), in this section, the ratio measures of technical, scale and mix efficiency for firm i that selects the combination of input and output (x_{it}, y_{it}) from the production possibilities frontier in period t are explained. Technical and scale efficiency measures are defined with reference to a restricted production possibilities frontier, which means that input and output vectors can be written as scalar multiples of x_{it} and y_{it}. Then, mix efficiency measures when all restrictions on the input and output mixes are relaxed.

The efficiency measures proposed by O'Donnell (2012) are represented in Figure 4.1. TFP efficiency measures the increase in TFP as the firm moves from point A to point E. The movement from point A to point E can be decomposed into technical, scale and mix efficiency.

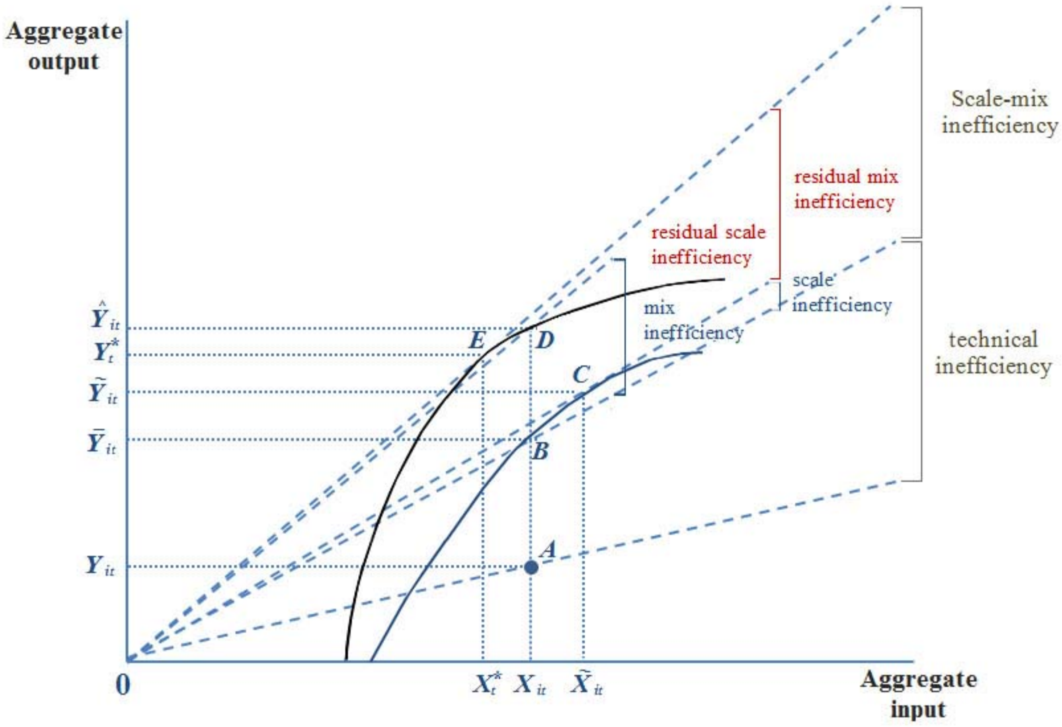
1) Output-oriented Technical Efficiency (OTE)

The concept of technical efficiency was first proposed by Farrell (1957). OTE measures the difference between observed aggregate output and the maximum aggregate output possible while holding the input vector and output mix fixed. OTE is illustrated in Figure 4.1. If the output vector and output mix are held fixed, the aggregate output and TFP are maximized by radially expanding output to point B. The curve passing through point B denotes the frontier of the restricted production possibilities set and point A stands for the input-output combination (x_{it}, y_{it}). This production possibilities set is restricted in the sense that it includes only input and output vectors which can be written as scalar multiples of x_{it} and y_{it}. In this figure, the vertical distance from point A to point B shows the measure of output-oriented technical efficiency. Thus, the output-oriented technical efficiency (OTE) can be written as:

$$OTE_{it} = \frac{Y_{it}/X_{it}}{\bar{Y}_{it}/X_{it}} = \frac{Y_{it}}{\bar{Y}_{it}} = D_O\,(x_{it}, y_{it}, t_0) \leq 1 \qquad \textbf{4.24}$$

where OTE_{it} is the output-oriented technical efficiency of firm i at time t, Y_{it} denotes the aggregate output, X_{it} denotes the aggregate input, and $\bar{Y}_{it}$ denotes the maximum aggregate output that is technically feasible when x_{it} is used to produce a scalar multiple of y_{it}.

Figure 4.1: Output-Oriented Measures of Efficiency for a Multiple-Input and Multiple-Output Firm



Source: Figure 1(O'Donnell 2011, p.6).

2) Output-oriented Scale Efficiency (OSE)

The output-oriented scale efficiency (OSE) is the measure as formulated by Balk (2001). It measures the difference between aggregate output at the technically efficient point and the maximum aggregate output that is possible while the input and output mixes are held fixed. In Figure 4.1, firm *i* can maximize its TFP by shifting to a point where a line through the origin is tangent to the restricted production possibilities frontier. This point is represented as point C and referred as the point of mix-invariant optimal scale (MIOS). The quantity difference between TFP at B, which is the technically efficient point, and TFP at C, which is the point of MIOS, is named as pure scale efficiency by O'Donnell (2008). The term *pure* is used since input and output mix are being held fixed, so the change in TFP is a pure scale effect. Mathematically, the pure output-oriented scale efficiency (OSE) is formulated as follows:

$$OSE_{it} = \frac{\bar{Y}_{it} / X_{it}}{\tilde{Y}_{it} / \tilde{X}_{it}} \leq 1 \qquad \textbf{4.25}$$

where OSE_{it} is the output-oriented scale efficiency of firm *i* at time t, $\bar{Y}_{it}$ denotes the maximum aggregate output that is technically feasible when x_{it} is used to produce a scalar multiple of y_{it}, X_{it} denotes the aggregate input, $\tilde{Y}_{it}$ and $\tilde{X}_{it}$ are the aggregate output and input obtained when TFP is maximized subject to the constraint that the output and input vectors are scalar multiples of y_{it} and x_{it}, respectively.

3) Output-oriented Mix Efficiency (OME)

The output-oriented mix efficiency (OME) measures the difference between TFP at the technically efficient point on the restricted frontier and the maximum TFP on the unrestricted frontier, holding neither the input vector nor output vector fixed. In other words, mix efficiency measures the change in TFP when the output and input mixes are relaxed from the restrictions. In Figure 4.1, the curve passing through point D denotes the unrestricted production frontier which is the production possibilities set when all mix restrictions on input and output are relaxed. The mix efficiency is named as pure mix efficiency by O'Donnell (2008) because neither the input vector nor the output vector is held fixed, so the change in TFP is a pure mix effect. The mix efficiency can be written as follows:

$$OME_{it} = \frac{\bar{Y}_{it} / X_{it}}{\hat{Y}_{it} / X_{it}} = \frac{\bar{Y}_{it}}{\hat{Y}_{it}} \leq 1 \qquad \textbf{4.26}$$

where OME_{it} is the output-oriented mix efficiency of firm *i* at time t, $\bar{Y}_{it}$ denotes the maximum aggregate output that is technically feasible when x_{it} is used to produce a scalar multiple of y_{it}, X_{it} denotes the aggregate input, and $\hat{Y}_{it}$ is the maximum aggregate output that is feasible when using x_{it} to produce any output vector.

4) Output-oriented Residual Scale Efficiency (ROSE)

The output-oriented residual scale efficiency (ROSE) measures the difference between TFP at the technically- and mix-efficient point and TFP at the point of maximum productivity. In Figure 4.1, point E refers to the point of maximum productivity, where a straight line through the origin is tangent to the unrestricted production possibilities set. Thus, the ROSE, measures the increase in TFP of firm *i* since it moves around the unrestricted frontier from point D to point E. O'Donnell (2008) uses the term *scale* since any movement around an unrestricted production possibilities set is a movement from one mix-efficient point to another mix-efficient point, thus any movement in TFP is basically a scale effect. The term *residual* is also used by O'Donnell (2008). The use of term *residual* is for two reasons. The first reason is that the movement from point A to point E may also include a change in scale effect, and the second reason is that in the context of movement from point A to point E, ROSE is the component which remains after accounting for the pure technical and pure mix efficiency effects. The output-oriented residual scale efficiency can be written as follows:

$$ROSE_{it} = \frac{\hat{Y}_{it} / X_{it}}{TFP_t^*} \leq 1 \qquad \textbf{4.27}$$

5) Output-oriented Residual Mix Efficiency (RME)

The output-oriented residual mix efficiency (RME) measures the difference between TFP at the maximum point of mix-invariant optimal scale and TFP at the maximum productivity point. The difference is represented in Figure 4.1 when firm *i* moves from point C on the mix-invariant restricted production possibilities set to point E on the unrestricted production possibilities set. O'Donnell (2008) uses the term *mix* because the movement from point C to point E is a movement from an optimal point on a restricted production possibilities set to an optimal point on the unrestricted production possibilities set, thus the difference is basically a mix effect. The term *residual* is also used by O'Donnell (2008) for two reasons. The first reason is that the movement from point C to point E may involve a change in scale effect. The second reason is that in the context of the movement from point A to E, RME is the component which remains after accounting for pure technical and pure scale efficiency effects. The output-oriented residual mix efficiency effect can be written as follows:

$$RME_{it} = \frac{\tilde{Y}_{it} / \tilde{X}_{it}}{TFP_t^*} \leq 1 \qquad \textbf{4.28}$$

where RME_{it} is the output-oriented residual mix efficiency of firm *i* at time *t*; $\tilde{Y}_{it}$ and $\tilde{X}_{it}$ are the aggregate output and input obtained when TFP is maximized subject to the constrain that the output and input vectors are scalar multiples of y_{it} and x_{it}, respectively and TFP_t^* denotes he maximum TFP possible using the period *t* technology.

4.3.3 Decomposition of TFP Change

The previous section has explained the case of firm *i* that selects the input-output combination (x_{it}, y_{it}) from the period *t* production possibilities set T^t. In Figure 4.1, firm i is shown at point A. In terms of aggregate quantities, the TFP of firm i is measured as the ratio of observed TFP to the maximum TFP possible using the available technology. The TFP efficiency of firm i in period t is:

$$TFPE_{it} = \frac{TFP_{it}}{TFP_t^*} = \frac{Y_{it}/X_{it}}{Y_t^*/X_t^*} \leq 1 \qquad \textbf{4.29}$$

where $TFPE_{it}$ is TFP efficiency of firm i at time t, TFP_{it} is the observed TFP, Y_{it} and X_{it} denote the aggregate output and input, TFP_t^* denotes the maximum TFP possible using the period t technology and Y_t^* and X_t^* denote the aggregate output and aggregate input, respectively, at the TFP-maximizing point (point E in Figure 4.1).

According to O'Donnell (2008), TFP efficiency in Equation 4.29 measures the proportionate increase in TFP of firm i since firm i moves from point A to point E. It can be seen from Figure 4.1, there are two pathways for firm i to move from point A to point E. Thus, there are two ways to decompose TFP efficiency: the first way is pathway A-C-D-E and the second way is pathway A-B-C-E. In relation to the measures of efficiency defined in Equations 4.24 to 4.28, these two output-oriented TFP efficiency decompositions are:

$$TFPE_{it} = \frac{TFP_{it}}{TFP_t^*} = \frac{Y_{it}/X_{it}}{Y_t^*/X_t^*} = OTE_{it} \times OME_{it} \times ROSE_{it} \qquad \textbf{4.30}$$

and

$$TFPE_{it} = \frac{TFP_{it}}{TFP_t^*} = \frac{Y_{it}/X_{it}}{Y_t^*/X_t^*} = OTE_{it} \times OSE_{it} \times RME_{it} \qquad \textbf{4.31}$$

Equations 4.30 and 4.31 can be used to decompose an output-orientated and multiplicatively-complete TFP index. Recalling Equation 4.20 and rephrasing Equations 4.30 and 4.31, the TFP index can be written as:

$$TFP_{it} = TFP_t^* \times TFPE_{it} = TFP_{it}^* \times (OTE_{it} \times OME_{it} \times ROSE_{it}) \qquad \textbf{4.32}$$

and

$$TFP_{it} = TFP_t^* \times TFPE_{it} = TFP_{it}^* \times (OTE_{it} \times OSE_{it} \times RME_{it}) \qquad \textbf{4.33}$$

where TFP_t^* denotes the maximum TFP possible using the period t technology and other measures of technical efficiency are as previously defined.

An analogous equation holds for firm n in period s. Thus, the TFP index which compares the TFP of firm i in period t with the TFP of firm n in period s is formulated as:

$$TFP_{ns,it} = \left(\frac{TFP_t^*}{TFP_s^*}\right) \times \left(\frac{OTE_{it}}{OTE_{ns}} \times \frac{OME_{it}}{OME_{ns}} \times \frac{ROSE_{it}}{ROSE_{ns}}\right) \qquad \textbf{4.34}$$

and

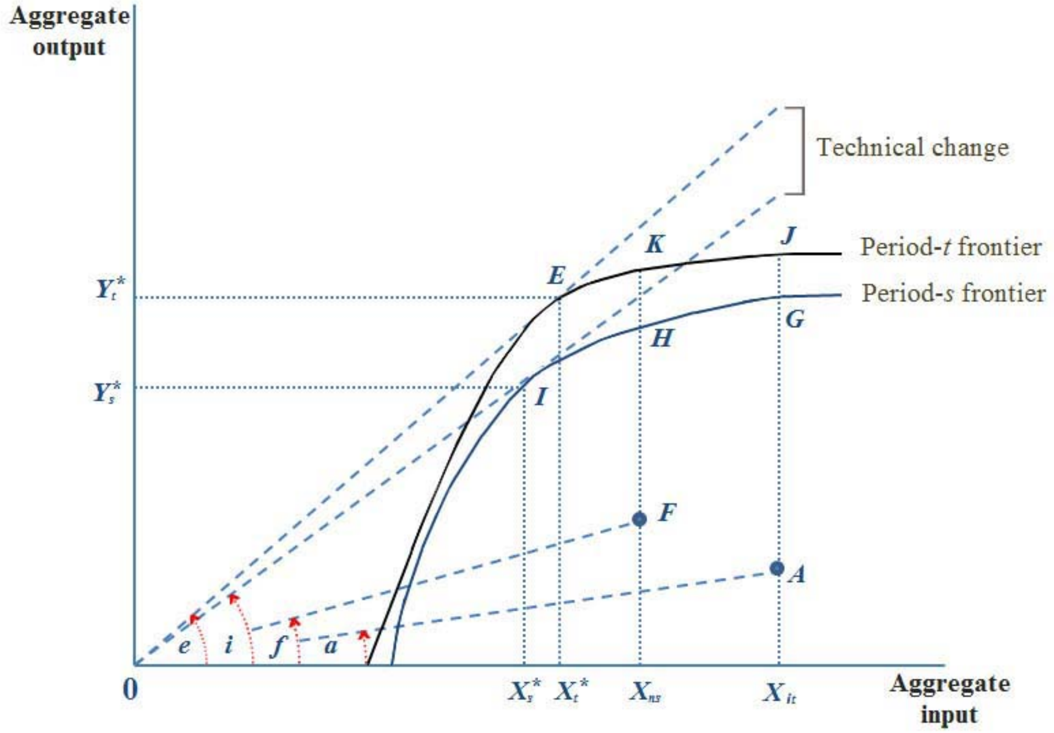
$$TFP_{ns,it} = \left(\frac{TFP_t^*}{TFP_s^*}\right) \times \left(\frac{OTE_{it}}{OTE_{ns}} \times \frac{OSE_{it}}{OSE_{ns}} \times \frac{RME_{it}}{RME_{ns}}\right) \qquad \textbf{4.35}$$

The first terms in the parentheses on the right-hand sides of Equations 4.34 and 4.35 are measures of technical change. They measure the difference between the maximum TFP possible using the technology in period t and the maximum TFP possible using the technology in period s. In Figure 4.2, TFP_t^*/TFP_s^* = tan *e*/tan *i*. This measures the change in the slope of the line which passes through point E. The firm/industry experiences technical progress or regress if TFP_t^*/TFP_s^* is greater than or less than one.

The second terms in the parentheses on the right-hand sides of Equation 4.34 is TFP_t^*/TFP_s^* = tan *e*/tan *i*. This measures the change in the slope of the line which passes through point E. The firm/industry experiences technical progress or regress if TFP_t^*/TFP_s^* is greater than or less than one.

The second terms in the parentheses on the right-hand sides of Equations 4.34 and 4.35 are measures of overall efficiency change as explained in Section 4.3.2. Thus, it is evident from Equations 4.34 and 4.35 that there are three components of technical efficiency. Equation 4.34 shows that efficiency change can be decomposed into pure technical efficiency, pure mix efficiency and residual scale efficiency. Alternatively, as shown in Equation 4.35, efficiency change can also be decomposed into pure technical efficiency, pure scale efficiency and residual mix efficiency.

Figure 4.2: Technical Change



Source: Figure 6 (O'Donnell 2010a, p.537).

The first and second terms of Equations 4.34 and 4.35 show that TFP change is driven by two different components, namely, technical change and technical efficiency. While technical change measures movements in the production frontier, technical efficiency measures movements towards or away from the frontier. Furthermore, technical efficiency can be decomposed into various components of technical efficiency. All these components contribute to TFP change.

4.3.4 Estimation Procedures for the Färe-Primont TFP Index Using Data Envelopment Analysis (DEA)

The estimation and decomposition of the Färe-Primont TFP index has become much easier with a computer program, DPIN 3.0, which specifically developed for decomposing productivity index numbers. This program uses the aggregate-quantity framework developed by O'Donnell (2008). It follows a two-step procedure to estimate and decompose productivity. In the first step, a data envelopment analysis (DEA) linear program (LP) is used to estimate the production technology and levels of productivity and efficiency. In the second step, the DPIN decomposes productivity and efficiency changes into pure technical change, technical efficiency change, scale efficiency change and mix efficiency change. The DPIN 3.0 computer program is used to estimate the production frontier and decompose productivity changes in this thesis.

The first step in estimating the Färe-Primont TFP index is to estimate a functional representation of technology. The DEA assumes that the frontier is locally linear. The term 'locally linear' is used by O'Donnell (2011) to refer to the fact that if firm i in period t is technically efficient (which means on the frontier), then in the neighbourhood (which means locally) of the point (y_{it}, x_{it}) the frontier takes the form $y'_{it}\alpha = \gamma + x'_{it}\beta$ (which is linear). In a linear format for firm i in period t, the (local) output distance function production frontier can be expressed as:

$$D_O = (x_{it}, y_{it}, t\,) = (y'_{it}\alpha)/\,(\gamma + x'_{it}\beta\,) \qquad \textbf{4.36}$$

where α and β are non-negative unknown parameters. γ denotes the assumptions about returns to scale. For example, a restriction of $\gamma = 0$ can be imposed to ensure that the technology exhibits local constant returns to scale (CRS), $\gamma \geq 0$ to exhibit local non-increasing returns to scale (NIRS), $\gamma > 0$ to exhibit local increasing returns to scale (IRS), $\gamma < 0$ to exhibit local decreasing returns to scale (DRS).

To minimize $OTE_{it}^{-1} = D_O\,(x_{it}, y_{it}, t\,)^{-1}$, the output-oriented DEA problem selects the values of the unknown parameters in Equation 4.36. The resulting DEA LP for the Färe-Primont index is (O'Donnell 2011):

$$\begin{aligned} D_O\,(x_{it}, y_{it}, t\,)^{-1} &= OTE_{it}^{-1} \\ &= \min_{\alpha,\gamma,\beta}\{\gamma + x'_{it}\beta : \gamma\iota + X'\beta \geq Y'\alpha;\ y'_{it}\alpha = 1;\ \alpha \geq 0; \beta \geq 0\,\} \qquad \textbf{4.37} \end{aligned}$$

where Y is a J x M_t matrix of observed outputs, X is K x M_t matrix of observed inputs, and ι is an M_t x 1 unit vector, and M_t denotes the number of observations used to estimate the frontier in period t. DPIN 3.0 uses LP Equation 4.37 to compute the output-oriented productivity index and various measures of output-oriented efficiency (change).

DPIN 3.0 estimates the Färe-Primont aggregates by solving the following LP (O'Donnell 2011):

$$D_O\,(x_0, y_0, t_0\,)^{-1} = \min_{\alpha,\gamma,\beta}\{\gamma + x_0'\beta : \gamma\iota + X'\beta \geq Y'\alpha;\ y_0'\alpha = 1;\ \alpha \geq 0; \beta \geq 0\,\} \quad \textbf{4.38}$$

The aggregated outputs and inputs of Färe-Primont are estimated as (O'Donnell 2011):

$$Y_{it} = (y_{it}'\alpha_0)/\,(\gamma_0 + x_0'\beta_0\,) \quad \textbf{4.39}$$

$$X_{it} = (x_{it}'\eta_0)/\,(y_0'\,\phi_0 - \delta_0\,) \quad \textbf{4.40}$$

where t_0 defines the observations that are used to estimate the representative frontier and α_0, β_0, γ_0, ϕ_0, δ_0, and η_0 solve Equations 4.39 and 4.40. The DPIN 3.0 uses sample mean vectors as representative output and input vectors in LP Equation 4.38. The representative technology in this LP is the technology obtained under the assumption and allows the technology to exhibit variable returns to scale (VRS).

After estimating the production frontier as discussed above, the second step is to decompose productivity and various efficiency changes. The DPIN 3.0 measures the pure technical change, technical efficiency change, scale efficiency change and mix efficiency change by solving the LPs for each of these efficiency components. Other efficiency and productivity measures, such as residual scale efficiency, residual mix efficiency and scale mix efficiency are computed residually by DPIN 3.0. The computational details to estimate the productivity index and efficiency measures using DPIN 3.0 is provided by O'Donnell (2011).

4.3.5 Testing the Impact of Trade Reform on TFP Growth

After measuring the TFP growth and its sources using the Färe-Primont index as explained in the previous sub-sections, the second stage is to test the hypothesis of the impact of trade reform on TFP growth. Trade reform variables are regressed against each component of TFP growth separately using a panel data regression. By doing so, the impacts of trade reform on each component of productivity can be examined empirically. The panel data regression model can be written as:

$$\Delta Y_{it} = \propto_i + TRE_{it}\beta + L_{it}\delta + \varphi_{it} \quad \textbf{4.41}$$

where $\Delta Y = (TFP^{*}, OTE, OME, ROSE, OSE, RME)$, i denotes firm, t denotes time period (t = 1, 2, …, T), TRE is a vector of trade reform variables, L is a vector of firm-specific variables, i denotes firm i , t denotes time, $\propto$, β and δ are parameters to be estimated, and φ denotes an error term.

There are three panel data models used in this thesis; they are common effect (or pooled), fixed-effect (or Least Squares Dummy Variable, LSDV), and random-effect (or Generalized Least Squares, GLS) models. To choose the most appropriate model to be used in the analysis, a *Chow* test (F-test) is employed for testing the common effect model against the fixed-effect model. Following Chow (1960) and Greene (2008), the F-test can be written as:

$$F_{[N-1,N(t-1)-K]} = \frac{(R_U^2 - R_R^2)/(N-1)}{(1- R_U^2)/(NT-N-K)} \qquad \textbf{4.42}$$

where R_U^2 is the R-squared value of the unrestricted model (fixed-effect), R_R^2 is the R-squared value of the restricted model (common effect), N is the number of firms, T is the number of periods, and K is the number of parameters in the unrestricted model. The null hypothesis for the F-test is no fixed specific effects. In contrast, the alternative hypothesis is that there are fixed specific effects. If the null hypothesis is rejected, it implies that the common effect estimators are biased and inconsistent (Baltagi 2008).

To compare the fixed-effect and the random effect models, the *Hausman* test is used. The test is a *chi-square* test based on a Wald criterion, which is expressed as (Hausman 1978, Greene 2008):

$$W = \chi^2[K-1] = [b_{FE} - b_{RE}]'[Var(b_{FE}) - Var(b_{RE})]^{-1}[b_{FE} - b_{RE}] \qquad \textbf{4.43}$$

where b_{FE} is a vector of estimated parameters from the fixed effect model, b_{RE} is a vector of estimated parameters from the random effect model, $Var(b_{FE})$ and $Var(b_{RE})$ are the corresponding variance-covariance matrices from the fixed-effect and random-effect, respectively. W is asymptotically distributed as chi-squared with K degrees of freedom. The null hypothesis is that both the fixed- and random-effect models provide a consistent estimator, as opposed to the alternative hypothesis that only the fixed-effect model provides a consistent estimator.

4.4 Conclusion

This chapter suggests two alternative methods for estimating the impact of trade reform on technical efficiency and TFP growth. The standard production function assumes that firms are operating at a full efficiency level, technology exhibits constant return to scale and firms are operating in perfect competition markets. These assumptions are too strong. The two alternative methods proposed in this chapter relax these assumptions. Further, the two alternative methods allow for decomposing TFP growth into technical change and various measures of technical efficiency.

The two alternative methodologies for measuring technical efficiency and factor productivity growth are the one-stage stochastic frontier analysis (SFA) proposed by Battese and Coelli (1995) and the Färe-Primont total factor productivity (TFP) index proposed by O'Donnell (2011). In the one-stage SFA, the stochastic frontier production function is used to estimate a production function and inefficiency function simultaneously. The parameters of both the production function and inefficiency function are estimated simultaneously by the maximum-likelihood method. The effect of trade reform on technical inefficiency is examined by incorporating trade reform variables as exogenous variables in regressions explaining technical inefficiency. The positive impact of trade reform on technical efficiency is shown by a reduction in a firm's technical inefficiency.

As an alternative approach to examine the impact of trade reform on TFP changes, this thesis employs a two-step procedure. In the first step, the Färe-Primont total factor productivity (TFP) index proposed by O'Donnell (2011) is used. This method decomposes productivity growth into four components (technological change, technical efficiency change, scale efficiency change, and mix efficiency change) and, therefore, offers a more comprehensive analysis in identifying the drivers of TFP changes. In the second step, the trade reform variables are regressed against TFP change and each component of efficiency for testing the impact of trade reform on TFP growth using a panel data regression.

Thus, the impact of trade liberalization on technical efficiency of selected Indonesian manufacturing industries is analysed in Chapter 5. The decomposition analysis of TFP growth is given in Chapter 6 and finally, second stage analysis of the impact of trade reform on the various components of TFP growth is discussed in Chapter 7.

Chapter 5
The Effects of Trade Liberalization on Firm-Level Technical Efficiency

5.1 Introduction

Trade liberalization is generally believed to generate improvements in technical efficiency and productivity. Although the theoretical literature leaves no doubt concerning the positive impacts of trade reform on technical inefficiency and productivity, the empirical evidence is inconclusive. As explained in Chapter 3, the different results of earlier empirical studies may be due to different methods used in these studies and the differences in the impact of trade reform across industries. A study of the impact of trade reform on technical efficiency and productivity by using a more rigorous method and considering industrial characteristics is needed to contribute to the debate in the literature.

This study makes an important contribution to the literature because trade liberalization may improve technical efficiency and productivity in many developing countries, including Indonesia. Havrylyshyn (1990), Edwards (1993) and López (2005) argue that the country-specific analysis based on firm-level data appears to have more specific empirical evidence concerning the link between trade reform and productivity. Drawing on these arguments, two alternative methods are developed in the previous chapter to examine the effects of trade reform on firm-level productivity. The first method, a one-stage production frontier, is applied to the analysis in this chapter. The second method, the Färe-Primont TFP index proposed by O'Donnell (2011), is employed in the following chapter.

As explained in Chapter 4, a one-stage stochastic production frontier is used in this chapter to estimate the effects of trade reform on technical efficiency in four industries (food, textile, chemical, and metal products). This chapter begins by specifying the empirical model and estimation method in Section 5.2. The data sources used and the construction of the dataset are presented in Section 5.3, followed by the definition and measurement of the variables in Section 5.4. The results and interpretations are discussed in Section 5.5. Conclusions are drawn at the end of the chapter in Section 5.6.

5.2 Empirical Model and Estimation Method

As specified in Section 4.2.2 of Chapter 4, the one-stage stochastic frontier model of Battese and Coelli (1995) is adopted in this chapter. Based on theoretical model, as explained in Equations 4.9 and 4.11, this study uses a flexible *translog* (Transcendental Logarithmic) production frontier. This functional form is chosen because it is more flexible and imposes relatively fewer restrictions on the structure of production. One important change to the economic conditions during the period of observation was the economic crisis that occurred in 1997. This study considers economic crisis by including the dummy for the economic crisis and the variables that interact with the dummy in Equations 5.1 and 5.2. The functional form of the *translog* production frontier is written as follows:

$$\begin{aligned}
\ln y_{it} = {} & \beta_0 + \beta_L \ln L_{it} + \beta_K \ln K_{it} + \beta_M \ln M_{it} + \beta_E \ln E_{it} + \beta_t t \\
& + 0.5\,\beta_{LL}[\ln L_{it}]^2 + 0.5\,\beta_{KK}[\ln K_{it}]^2 + 0.5\,\beta_{MM}[\ln M_{it}]^2 \\
& + 0.5\,\beta_{EE}[\ln E_{it}]^2 + 0.5\,\beta_{tt}[t]^2 + \beta_{LK}[\ln L_{it} * \ln K_{it}] \\
& + \beta_{LM}[\ln L_{it} * \ln M_{it}] + \beta_{LE}[\ln L_{it} * \ln E_{it}] + \beta_{KM}[\ln K_{it} * \ln M_{it}] \\
& + \beta_{KE}[\ln K_{it} * \ln E_{it}] + \beta_{ME}[\ln M_{it} * \ln E_{it}] + \beta_{Lt}[\ln L_{it} * t] \\
& + \beta_{Kt}[\ln K_{it} * t] + \beta_{Mt}[\ln M_{it} * t] + \beta_{Et}[\ln E_{it} * t] + \beta_D D \\
& + \beta_{LD}[\ln L_{it} * D] + \beta_{KD}[\ln K_{it} * D] + \beta_{MD}[\ln M_{it} * D] \\
& + \beta_{ED}[\ln E_{it} * D] + \beta_{tD}[t * D] + \{0.5\,\beta_{LLD}[\ln L_{it}]^2 * D\} \\
& + \{0.5\,\beta_{KKD}[\ln K_{it}]^2 * D\} + \{0.5\,\beta_{MMD}[\ln M_{it}]^2 * D\} \\
& + \{0.5\,\beta_{EED}[\ln E_{it}]^2 * D\} + \{0.5\,\beta_{ttD}[t]^2 * D\} \\
& + \beta_{LKD}[\ln L_{it} * \ln K_{it} * D] + \beta_{LMD}[\ln L_{it} * \ln M_{it} * D] \\
& + \beta_{LED}[\ln L_{it} * \ln E_{it} * D] + \beta_{KMD}[\ln K_{it} * \ln M_{it} * D] \\
& + \beta_{KED}[\ln K_{it} * \ln E_{it} * D] + \beta_{MED}[\ln M_{it} * \ln E_{it} * D] \\
& + \beta_{LtD}[\ln L_{it} * t * D] + \beta_{KtD}[\ln K_{it} * t * D] + \beta_{MtD}[\ln M_{it} * t * D] \\
& + \beta_{EtD}[\ln E_{it} * t * D] + v_{it} - u_{it} \qquad \textbf{5.1}
\end{aligned}$$

where y represents output, L represents labour, K is capital, M is material, E is energy, t is time, i is firm, D is a dummy crisis, βs are parameters to be estimated, ln denotes natural logarithm, v_{it} is the stochastic error term and u_{it} is the technical efficiency variable.

In this study, the technical inefficiency effect is a function of a set of trade reform variables, specifically effective rate of protection (*ERP*) and import ratio (*IMP*). Also included is a set of other variables that affect efficiency, namely, age of firm (*AGE*), capital intensity (*CI*), ratio of non-production workers (*NPW*), foreign ownership (*FOREIGN*), and a dummy crisis (*D*). Therefore, the inefficiency function can be written as:

$$u_{it} = \delta_0 + \delta_1 ERP_{it} + \delta_2 IMP_{it} + \delta_3 AGE_{it} + \delta_4 CI_{it} + \delta_5 NPW_{it} + \delta_6 FOREIGN_{it} + \delta_7(ERP_{it} * D) + \delta_8(IMP_{it} * D) + \delta_9(AGE_{it} * D) + \delta_{10}(CI_{it} * D) + \delta_{11}(NPW_{it} * D) + \delta_{12}(FOREIGN_{it} * D) + \delta_{13}D + w_{it} \quad \textbf{5.2}$$

where w is an error term.

The parameters of the stochastic production frontier and the technical inefficiency effects in Equations 5.1 and 5.2 are simultaneously estimated using a maximum likelihood (ML) method. The likelihood function is parameterized in terms of the variance parameters, $\sigma_s^2 \equiv \sigma_v^2 + \sigma_u^2$ and $\gamma \equiv \frac{\sigma_u^2}{\sigma_u^2+\sigma_v^2}$ (Battese and Coelli 1995). As noted in Chapter 4, γ is a parameter associated with variance in inefficiency effect, u_{it}, in Battese and Coelli's (1995) model. If γ is zero, the model reduces to a traditional mean response function in which the variables—*ERP*, *IMP*, *AGE*, *CI*, *NPW*, *FOREIGN*, *D* and all variables that interact with the dummy—can be directly included in the production frontier.

Various sub-models of the *translog* are considered and tested under many null hypotheses, given the specification of the *translog* model in Equation 5.1. The first null hypothesis confirms whether the no-effect of crisis is an appropriate model for the dataset by imposing restrictions (*i.e.*, $\beta_D = \beta_{LD} = \beta_{KD} = \beta_{MD} = \beta_{ED} = \beta_{tD} = \beta_{LLD} = \beta_{KKD} = \beta_{MMD} = \beta_{EED} = \beta_{ttD} = \beta_{LKD} = \beta_{LMD} = \beta_{LED} = \beta_{KMD} = \beta_{KED} = \beta_{MED} = \beta_{LtD} = \beta_{KtD} = \beta_{MtD} = \beta_{EtD} = 0$), on Equation 5.1. A null hypothesis of the second order parameters equal zero (*i.e.*, $\beta_{LL} = \beta_{KK} = \beta_{MM} = \beta_{EE} = \beta_{tt} = \beta_{LK} = \beta_{LM} = \beta_{LE} = \beta_{KM} = \beta_{KE} = \beta_{ME} = \beta_{LLD} = \beta_{KKD} = \beta_{MMD} = \beta_{EED} = \beta_{ttD} = \beta_{LKD} = \beta_{LMD} = \beta_{LED} = \beta_{KMD} = \beta_{KED} = \beta_{MED} = 0$) tests whether the Cobb-Douglas frontier is appropriate for the data set. A null hypothesis of the interacting parameters of input and time equal zero (*i.e.*, $\beta_{Lt} = \beta_{Kt} = \beta_{Mt} = \beta_{Et} = \beta_{LtD} = \beta_{KtD} = \beta_{MtD} = \beta_{EtD} = 0$) tests for Hicks-neutral technological progress. Similarly, a null hypothesis of the time parameters equal to zero (*i.e.*, $\beta_t = \beta_{tt} = \beta_{Lt} = \beta_{Kt} = \beta_{Mt} = \beta_{Et} = \beta_{tD} = \beta_{ttD} = \beta_{LtD} = \beta_{KtD} = \beta_{MtD} = \beta_{EtD} = 0$) is used for no technology progress on the frontier, and a null hypothesis of the parameters of inefficiency function equal zero (*i.e.*, $\delta_0 = \delta_1 = \ldots = \delta_{13} = 0$) is used for a no-inefficiency condition.

To test the relevant null hypotheses, a generalized likelihood ratio statistic is employed. This ratio statistic is written as follows:

$$\lambda = -2\,[l\,(H_0) - l\,(H_1)] \qquad \textbf{5.3}$$

where $l\,(H_0)$ is the log-likelihood value of the restricted frontier model, and $l\,(H_1)$ is the log-likelihood value of the model defined in Equation 5.3. If the null hypothesis is true, the test statistic has approximately a *chi-square* distribution with degrees of freedom equal to the number of parameters involved in the restrictions. The test statistic under the null hypothesis of no-inefficiency effects has approximately a mixed *chi-square* distribution, and the critical value for this test is taken from Table 1 of Kodde and Palm (1986).

The FRONTIER 4.1c computer program is used to jointly estimate the stochastic production frontier of Equation 5.1 and the inefficiency function of Equation 5.2 under the maximum likelihood method (Coelli 1996). To obtain the final maximum likelihood estimates, this program follows a three-step estimation method. First, ordinary least squares (OLS) is used to estimate the stochastic production function in Equation 5.1. All β parameters are unbiased except for the intercept β_0. Second, a two-phase grid search of γ is conducted, with β parameters (except the intercept β_0) set to OLS values and the intercept β_0 and the σ_s^2 parameters adjusted with the corrected ordinary least squares (COLS) formula. All other parameters are set to zero during this grid search. Third, the values selected from the grid search are used as starting values in the iterative procedure to obtain the final maximum likelihood estimates by using the *Davidon-Fletcher-Powell Quasi-Newton* method.

5.3 Data Sources and Construction of the Dataset

5.3.1 Description of Data Sources

The main data source in this study is the Annual Survey of Medium and Large Manufacturing Firms (*Survei Tahunan Statistik Industri Perusahaan Menengah dan Besar* or SI) conducted by the Indonesian Central Board of Statistics (BPS; *Badan Pusat Statistik*). The survey is conducted yearly and covers the basic information of each Indonesian manufacturing firm with at least 20 employees, such as industrial classification, firm-specific identification code and first year of production. This survey also covers ownership information (domestic, foreign and government), location (sub-district, province), production information (gross output, energy consumption, material, number of workers, and value of fixed capital and investment), and other information (such as income, non-production expenditures, share of production exported and value of imported material). The number of firms varies depending on the year, with a minimum number of 7,469 manufacturing firms in 1975 to a maximum number of 29,468 firms in 2006. The summary form of the survey, *Statistik Industri (SI)*, is released annually, while firm-level data are available in electronic form and can be obtained under license from BPS.

The annual manufacturing surveys have been conducted since 1975, and the most recent data available are for 2013; however, this study uses only the data from 1981 to 2000. This time period is chosen to capture the largest number of firms that appear consistently before and after trade liberalization period.

The BPS classifies firm-level data in SI in five-digit industrial codes based on the International Standard Industrial Classification (ISIC) with some modification that follow the conditions of Indonesian manufacturing. During the observation period, the BPS changed the classification twice to accommodate the growing number of manufacturing firms and to follow the changes in ISIC. The reclassification occured in 1990 and 1998, and adjustments are thus needed to obtain a consistent classification code. The adjustments are explained in Section 5.3.3

This study also uses data from several sources as supplementary data for the SI. Table 5.1 presents the types and sources of the supplementary data. Output and material are deflated by using the wholesale price index (WPI). Similarly, capital and electricity are deflated by using the price index of machinery and the price index of electricity, respectively. Fuel is deflated by using the fuel price index, which is calculated from crude oil price FOB (free on board) Spot Brent published by Thomson Reuters. The ERPs are taken from earlier empirical studies. A more detailed discussion on the use of these data to construct variables is provided in Section 5.4.

Table 5.1: Sources and Descriptions of Data

No.	Data	Source	Description
Primary Data			
1	Survey of Industries (SI)	The Indonesian Central Board of Statistics (BPS)	The SI is an industrial survey conducted yearly that covers medium and large firms with twenty or more employees, and the number of firms varies from 7,942 establishments in 1981 to 22,174 in 2000 and consists of more than 120 variables.
Supplementary Data			
2	Wholesale Price Index (WPI)	BPS	The WPI used in this study is a WPI with four-digit ISIC product codes.
3	WPI of Machinery	BPS	The price index of machinery includes the prices of all machinery (excluding electrical products), transport equipment and residential and non-residential building.
4	WPI of Electricity	BPS	The price index of electricity is calculated from the WPI index of electrical machinery, apparatuses, appliances and supplies with two-digit ISIC product codes.
5	Fuel Price Index	Data Stream 5.1 (Thomson Reuters)	The fuel price index is calculated from crude oil price FOB Spot Brent. The US$ values of oil price FOB Spot Brent are converted to Indonesian rupiah by using the annual average exchange rate published by the Central Bank of Indonesia.
6	Effective Rate of Protection (ERP)		The effective rates of protection used in this study are the ERP calculated from previous studies, the World Bank (1981), Pangestu and Boediono (1986), Fane and Phillips (1991), Fane and Condon (1996) and Widodo (2008

Source: Author's compilation.

5.3.2 Limitations of the SI Data and Procedure for Constructing a Consistent Balanced Panel Set

Some researchers consider that the SI dataset provides a good long-term dataset and that is among the best datasets containing industrial statistics (Amiti and Konings 2007, Narjoko and Hill 2007). However, the dataset has several weaknesses that require adjustments to obtain a consistent dataset. A consistent dataset is needed to obtain a reliable empirical analysis. A consistent balanced panel dataset is constructed by following several steps of adjustment as follows:

Step 1: Adjusting for the variable definitions

In some years, the BPS changes the name of the variables. The author has checked and compared questionnaires for each year to ensure that the collected variables are correct and consistent. If the definitions are inconsistent, the author recalculates the variables to obtain consistent definitions throughout the selected period.

Step 2: Cleaning for noise

The following steps are taken in this study to minimize noise:

a. The firms that have zero or negative value of output, labour, material or energy are removed.
b. Obvious typing mistakes (or typographical errors) in the raw data are adjusted for consistency. One example is the sharp changes in foreign share, where the foreign share in all years is 100% but 0 for certain years. Corrections are made by adjusting 0% to 100%.

Step 3: Back-casting the missing values for capital

Many establishments report zero or missing values of capital. To fill these gaps, the capital is regressed against the lagged value of real output to obtain predictions for capital at the firm-level. The replacement value of fixed capital is used as the proxy for capital. This thesis follows the methodology introduced by Vial (2006). Appendix 5.1 provides the details of this methodology.

Step 4: Matching firms to construct a balanced panel dataset

A balanced panel data set is obtained by matching firms based on the specific identification code (PSID) by using STATA13 software.

Step 5: Deflating output and input (capital, material and energy) by using various indices and expressed in 1993 Indonesian rupiah.

The output and material values are deflated using the wholesale price index. The value of capital is deflated by using the machinery price index. The nominal value of energy is the summation of electricity and fuel expenditures, which are deflated by using the electricity price index and fuel price index, respectively.

5.3.3 Sample Industries for Empirical Analysis

There are nine two-digit industries, namely, food and beverage (31), textile and leather (32), woods and wood products (33), paper and paper products (34), chemical (35), non-minerals (36), basic metal (37), metal products (38) and other manufacturing (39). As noted in Chapter 2, food and beverage (31), textile and leather (32), chemical (35) and metal products (38) are the four largest industry groups in terms of contribution to value added, export, and employment. In 2012, these industries together contributed to approximately 74, 68, and 75% to total value added, exports and employment, respectively. Given the importance of these industries and the availability of consistent data, this thesis has chosen these four industry groups for empirical analysis.

By following the steps of adjustment as explained in Section 5.3.2, the final dataset consists of 1,146 firms with 22,920 observations. The number of firms in the selected industries is presented in Table 5.2.

Table 5.2: The Number of Firms and Observations in Four Selected Indonesian Industries

Industry	Number of Firms	Number of Observations
1. Food and Beverage (31)	521	10,420
2. Textile and Leather (32)	291	5,820
3. Chemical (35)	241	4,820
4. Metal Products (38)	93	1,860

Source: Author's compilation

5.4 Definition and Measurement of Variables

An important element of empirical studies is the variable definition. Using the SI data and other relevant information from the literature, this study defines variables for the empirical model in Equations 5.1 and 5.2. The variables are divided into two groups: a stochastic production frontier as formulated in Equation 5.1 and an inefficiency function as formulated in Equation 5.2. For the inefficiency function, the variables are further divided into two categories of trade reform variables and other variables. Table 5.3 gives the definition of variables and their formulation.

Table 5.3: Definition of Variables

Variables	Definition
Production Function	
Y	Output (in million rupiah), which is deflated by using a WPI at 1993 constant prices
L	Labour (number of workers) is the total number of employees directly and indirectly engaged in productions
K	Capital (billion rupiah), which is deflated by using a WPI for machinery at 1993 constant prices
M	Material (million rupiah), which is deflated by using a WPI at 1993 constant prices
E	Energy (million rupiah) is the sum of electricity and fuel expenditures, which are deflated by using a WPI for electricity and fuel price indices at 1993 constant prices
Inefficiency Function	
ERP	ERP are calculated using the Corden formula
IMP	The import ratio is measured by the proportion of import material to total material used by firms
AGE	The age of firms is measured by the different between the survey year and the year of beginning production
CI	The capital intensity ratio is measured by the proportion of capital to the total number of workers employed by firms
NPW	The ratio of non-production workers is measured by the proportion of non-production workers to total workers employed by firms
FOREIGN	Foreign ownership is measured by a dummy variable: 1 if the share of foreign ownership is greater than 0% and 0 otherwise
D	Economic crisis is measured by a dummy variable: 1 if the year of observation is 1997 onward and 0 if the year of observation is before 1997

Source: Author's compilation

5.4.1 Output and Input Variables in the Stochastic Production Frontier

The following sub-subsections discuss the variables used in the production frontier equation. This study uses output as the dependent variable and labour, capital, material and energy as the independent variables of the production frontier.

5.4.1.1 Output (Y)

Two alternative measures of output can be obtained from the SI, namely, gross output and value added. Value added is defined as an additional value of output produced by a firm. Gross output is defined as the total value of output produced by a firm, which includes intermediate inputs.

Each measure has its own advantages and disadvantages. The key reasons for choosing value added over gross output are that it allows comparisons between firms that may have different characteristics in choosing material inputs and it accounts for the differences in and changes to the quality of inputs (Salim 1999, Salim and Kalirajan 1999, Hossain and Karunaratne 2004). Value added has disadvantage, however, because it requires a value added deflator that is not available in the data; it can also be difficult to separate the inputs that are used in the production process (Aswicahyono and Hill 2002).

Considering these arguments, gross output figures are used in this study to represent output.[15] Because the gross output figures are in monetary nominal value, the WPI index for the firm's four-digit ISIC product code in 1993 constant price is used to deflate the nominal gross output. These data are available in the SI.

5.4.1.2 Labour (L)

Ideally, labour input is measured with both quality and quantity of labour. The quality of labour includes education levels, type of work, age and sex, while quantity of labour comprises the number of workers and the number of hours worked. Unfortunately, the qualitative data of labour are not available in the SI data and this study therefore relies on quantitative data of labour.

The SI data classify labour input into production, non-production and family workers. These data include the employees who are directly and indirectly involved in the production process. This measure is commonly used in empirical studies on productivity analysis (Sjöholm 1999a, Aswicahyono and Hill 2002, Takii and Ramstetter 2005, Ikhsan 2007, Suyanto 2010).

5.4.1.3 Capital (K)

The data on capital are not continuously available in the SI. Usually, capital is estimated by using the perpetual inventory method, which requires information on interest rates, depreciation rates and gross investment series. This information is not available in the SI. Following recent empirical studies, such as Ikhsan (2007) and Suyanto (2010), this thesis uses the replacement value of an establishment's fixed assets as a proxy for capital stock. The replacement value of fixed assets is deflated by using the price index of machinery, which incorporates the price index of machinery (excluding electrical products), transport equipment and residential and non-residential building in 1993 constant prices. In some years, as previously

[15] SI provides multiple-output data but does not provide input data for each output. Input data are available in terms of total. Therefore, this thesis uses gross total output and total input. For future research, if multiple-output and multiple-input data are available, an SFA estimation that uses multiple-output and multiple-input can be used (Lothgren 2000).

mentioned in Section 5.3.2, data on the replacement value of fixed assets are not available. The missing values are estimated with a methodology similar to Vial (2006), Ikhsan (2007) and Suyanto (2010). The details of this methodology are presented in Appendix 5.1.

5.4.1.4 Material (M)

This thesis follows the definition of material in the SI such that material consists of domestic and imported material. Both are presented in monetary values. The real values are obtained by deflating monetary value with the WPI of the four-digit industries at 1993 constant prices. All data (domestic, imported material and WPI) are available in the SI.

5.4.1.5 Energy (E)

In the SI, there are two components of energy, namely, electricity and fuel, and both are measured in monetary values. Electricity inputs are the summation of electricity provided by a state-owned electricity company (PLN; *Perusahaan Listrik Negara*) and by private firms. Ideally, to obtain the real values of electricity inputs, the monetary values of electricity inputs are deflated by using the wholesale electricity price index provided by PLN. Unfortunately, the wholesale electricity price index data are not available before 1985. Therefore, in this study, the WPI index of electrical machinery, apparatuses, appliances and supplies of the two-digit ISIC product codes at 1993 constant price is used to deflate the monetary values of electricity inputs. Fuel inputs consist of nine types of fuel, namely, benzene, diesel, coal, gas, solar, kerosene, cokes, lubricant and other fuels. The real values of fuels are calculated by deflating the monetary values with the fuel price index, which is constructed from crude oil price FOB Spot Brent published by Data Stream 5.1 at 1993 constant prices. The real value of energy is the summation of the real values of electricity and fuel inputs.

5.4.2 Trade Reform Variables

The main variables in the inefficiency function are the trade reform variables. This study uses two trade reform variables: the ERP and import ratios. These variables are chosen because the data for these variables are the most consistently available throughout the selected period.[16] A discussion of the measurement of these two variables is given below.

5.4.2.1 Effective Rates of Protection (ERP)

The ERP calculated by World Bank (1981), Pangestu and Boediono (1986), Fane and Phillips (1991), Fane and Condon (1996) and Widodo (2008) are used in this study. The first two studies are chosen to represent ERP of the trade regime before trade liberalization (1981-1986), while the last three studies concern the ERP after trade liberalization (1987-2000).

It is hypothesized that ERP have a positive effect on firms' technical efficiency. If the sign of the ERP coefficient is positive and statistically significant, then this result is viewed as evidence of positive effect of trade reform on firms' technical efficiency. Conversely, if the sign is negative and statistically significant, then the result suggests that trade reform has a negative effect on efficiency.

5.4.2.2 Import Ratio (IMP)

The second variable to represent trade reform is the IMP. It is hypothesized that IMP has a negative effect on firms' technical inefficiency. If the sign of IMP is negative and statistically significant, then this result is understood as evidence of negative effect on technical inefficiency (or a positive impact of IMP on firms' technical efficiency). If the sign of this coefficient is positive and statistically significant, this result may suggest a positive effect of IMP on technical inefficiency (or negative effect on technical efficiency).

In this study, IMP is measured as the proportion of the imported material to total material used by firms. The data are available in the SI. Because the imported material and total material are in monetary value, it is necessary to deflate the values into real values or constant price. The WPI of the corresponding four-digit industry is used to deflate the imported material and total material at 1993 constant prices.

5.4.3 Other Variables Affecting Inefficiency

In addition to trade reform variables, other variables may influence firms' efficiency. Based on earlier empirical studies, this study chooses five additional variables to explain firm efficiency, namely, age, capital intensity, ratio of non-production

[16] Greenaway *et al.* (1998) provide more detailed discussion regarding alternative measures of liberalization.

workers, ownership and economic crisis. A discussion of the measurements of these five variables is provided below.

5.4.3.1 Age

In the literature, the impact of firm age on technical efficiency is still a matter of debate. On the one hand, older firms may have more time to learn and gain more experience in handling the technology they use in production process (Malerba 1992). When firms are in production longer, firms have more management experience managing the production process. Therefore, older firms may have greater efficiency than younger firms. The process of using technology and equipment is usually called learning-by-doing. On the other hand, there is a contrary argument that younger firms can adopt more updated technology and knowledge when they start their production (Pitt and Lee 1981). Therefore, younger firms may have higher efficiency than older firms.

The empirical findings from earlier studies are mixed. Chen and Tang (1987) and Suyanto *et al.* (2012) find a positive relationship between age and technical efficiency. Pitt and Lee (1981) and Salim (2007) show that age has a negative impact on technical efficiency, whereas Kathuria (2001) and Jacob (2006) find that age has no significant effect on technical efficiency.

An interesting association between age and technical efficiency is found by Margono and Sharma (2006), who show that the effect of age on technical efficiency in four chosen manufacturing sector is not uniform. Using food, textile, chemical and metal products manufacturing sector in Indonesia, Margono and Sharma (2006) find that age has no significant impact on efficiency in the Indonesian food and textile sector; however, age has a significant impact on technical efficiency in the chemical and the metal products sector but with different sign. Although age has a positive effect on technical efficiency in the chemical sector, the impact of age on technical efficiency in the metal products sector is negative. From these empirical results, it can be inferred that the direction of the age-efficiency relationship remains uncertain.

In this study, age of firm is measured as the difference between the survey year and the first year of production. This information is available in the SI data and has been used by other researchers (see for example, Margono and Sharma (2006) and Jacob and Szirmai (2007)).

5.4.3.2 Capital Intensity (CI)

Two opposing arguments are made in relation to the impact of capital intensity on efficiency. On the one hand, firms with higher capital intensity are more likely to have higher efficiency because they have greater incentive to use their capital to minimize the cost of production. Some empirical studies support this contention (Winston 1974, Lecraw 1978, Hossain and Karunaratne 2004). On the other hand, in a situation when capital is inexpensive because of low interest rate, firms may accumulate more capital than is needed for production process and to operate at a lower technical efficiency. Thus, there may be a negative relationship between these two variables. In addition, in developing countries, firms' efficiency is more likely to depend on the availability of efficient infrastructure and skilled labour that is lacking in these countries (Pack 1984). The empirical findings that support the negative relationship between capital intensity and efficiency include Islam (1978) and Mahadevan (2000). Sharma *et al.* (2000) also find a negative relationship between capital intensity and technical efficiency, although it is not statistically significant. Drawing on these earlier empirical studies, the relationship between these two variables remains an empirical issue.

In this study, the capital intensity ratio is measured by the proportion of capital to the total number of workers employed by firms. This information is available from the SI. If there are missing values of capital, these missing values are calculated following a methodology similar to Vial (2006), Ikhsan (2007), Suyanto *et al.* (2009), Suyanto and Salim (2011) and Suyanto *et al.* (2012), as explained in Section 5.3.2.

5.4.3.3 Ratio of Non-Production Workers

Non-production workers include technical personnel, managerial administration and marketing personnel, who are indirectly engaged in production. Economic theory is indeterminate in formulating the relationship between this variable and technical efficiency. Campbell (1984) argues that non-production workers may contribute to the effective acquisition and combination of the productive resources because these workers are more receptive to new approaches to production and management; thus, they help to reduce inefficiency. Others argue, however, that an increase in the ratio of non-production workers may increase rigidities in the process of production, which leads to slow-down in the adjustments to demand variations and therefore contributes to increased inefficiency (Hossain and Karunaratne 2004).

Empirical studies show mixed evidence. Hossain and Karunaratne (2004) show that a higher proportion of non-production workers to total employment leads to greater inefficiency. A study conducted by Salim (1999) shows similar results to Hossain and Karunaratne (2004) for 1981 and 1987 only, whereas in 1991, the coefficient of non-production workers variable is not statistically significant in its effect on technical efficiency. Based on these empirical results, it can be argued that the direction of the impact of the ratio of non-production worker on efficiency remains inconclusive.

In this study, the ratio of non-production workers is measured as the proportion of non-production workers to total workers employed by firms. The data on non-production workers and total workers are available in the SI.

5.4.3.4 Foreign Ownership

In the economic development literature, it is generally believed that firms owned by multinational companies are more efficient than domestic firms because multinational companies are more likely to have good management experience and a good organization structure (Pitt and Lee 1981). In addition, these firms are usually more involved in research and development (Salim 1999). In this thesis, the ownership variable is constructed as a dummy variable defined as:

Foreign = 1 if the share of foreign ownership is greater than 0%

= 0 otherwise.

Joint venture companies with a share of foreign ownership are also classified as foreign ownership (dummy=1). This definition is consistent with previous studies (Aswicahyono and Hill 1995, Narjoko and Hill 2007, Suyanto *et al.* 2012).

5.4.3.5 Crisis (D)

A general economic contraction may impact firm technical efficiency. Recent empirical studies show that the impact of economic crisis on manufacturing industries depends on the characteristics of industry, the nature of the crisis and the performance of the financial sector (Dwor-Frecaut *et al.* 2000, Narjoko and Hill 2007).

In this study, economic crisis is measured by a dummy variable. The years before 1997 are assigned as zero, while the years from 1997 onward are assigned as one. This dummy variable is intended to test the impact of the economic crisis on firm technical efficiency. Following previous studies, an economic crisis can have either negative or positive impact on firms' technical efficiency. In addition to the dummy crisis, this study also considers the dummy interaction variables that show the impact of the economic crisis on the way each independent variable affects firm technical efficiency.

Table 5.4 presents a summary of the expected signs between output and input variables of production frontier and between technical inefficiency and the independent variables discussed above. The descriptive statistics for the variables of production frontier and inefficiency function are given in Appendix 5.2.

Table 5.4: Expected Signs of Parameter Estimates of the Stochastic Production Frontier

Variables	Expected Sign
Production Frontier (*dependent variable: lnY*)	
L (ln)	+
K (ln)	+
M (ln)	+
E (ln)	+
Inefficiency Function (*dependent variable: u*)	
ERP	+
IMP	-
AGE	+/-
CI	+/-
NPW	+/-
FOREIGN	+/-
CRISIS	+/-

Note: + indicates positive effect, - indicates negative effect, +/- indicates no expectation of effect.

5.5 Results and Interpretation

5.5.1 Testing for Model Specification

Given the general *translog* frontier, as specified in Equation 5.1, this thesis tests many null hypotheses to find the appropriate functional form that represents the dataset. The results of the relevant hypothesis tests are presented in Table 5.5. The first null hypothesis confirms whether a no-effect of crisis is an appropriate model for the dataset by imposing restrictions (*i.e.,* $\beta_D = \beta_{LD} = \beta_{KD} = \beta_{MD} = \beta_{ED} = \beta_{tD} = \beta_{LLD} = \beta_{KKD} = \beta_{MMD} = \beta_{EED} = \beta_{ttD} = \beta_{LKD} = \beta_{LMD} = \beta_{LED} = \beta_{KMD} = \beta_{KED} = \beta_{MED} = \beta_{LtD} = \beta_{KtD} = \beta_{MtD} = \beta_{EtD} = 0$) on Equation 5.1. The result of the log-likelihood test shows a strong rejection of the null hypothesis at the 1% level of significance in all four industries. This result suggests that a model that does not include the effect of economic crisis is an inappropriate specification, given the *translog* with the dummy crisis interaction variables.

Table 5.5: Log-likelihood Tests for Model Specification of the Stochastic Production Frontier

Restrictions	Industry				Critical Values (α=0.10)	Critical Values (α=0.05)	Critical Values (α=0.01)
	Food (31)	Textile (32)	Chemical (35)	Metal Products (38)			
No-effect of crisis ($\beta_D = \beta_{LD} = \beta_{KD} = \beta_{MD} = \beta_{ED} = \beta_{tD} = \beta_{LLD} = \beta_{KKD} = \beta_{MMD} = \beta_{EED} = \beta_{ttD} = \beta_{LKD} = \beta_{LMD} = \beta_{LED} = \beta_{KMD} = \beta_{KED} = \beta_{MED} = \beta_{LtD} = \beta_{KtD} = \beta_{MtD} = \beta_{EtD} = 0$)	6652.55***	2688.33***	8090.77***	1553.44***	29.61	32.67	38.93
Cobb-Douglas ($\beta_{LL} = \beta_{KK} = \beta_{MM} = \beta_{EE} = \beta_{tt} = \beta_{LK} = \beta_{LM} = \beta_{LE} = \beta_{KM} = \beta_{KE} = \beta_{ME} = \beta_{LLD} = \beta_{KKD} = \beta_{MMD} = \beta_{EED} = \beta_{ttD} = \beta_{LKD} = \beta_{LMD} = \beta_{LED} = \beta_{KMD} = \beta_{KED} = \beta_{MED} = 0$)	5441.9***	1359.5***	1069.67***	395.42***	30.81	33.92	40.29
Hicks-Neutral ($\beta_{Lt} = \beta_{Kt} = \beta_{Mt} = \beta_{Et} = \beta_{LtD} = \beta_{KtD} = \beta_{MtD} = \beta_{EtD} = 0$)	24.71***	40.19***	26.38***	4.72	13.36	15.51	20.09
No TP ($\beta_t = \beta_{tt} = \beta_{Lt} = \beta_{Kt} = \beta_{Mt} = \beta_{Et} = \beta_{tD} = \beta_{ttD} = \beta_{LtD} = \beta_{KtD} = \beta_{MtD} = \beta_{EtD} = 0$)	112.88***	2769.52***	77.25***	24.21***	18.55	21.03	26.22
No Inefficiency Effect ($\delta_0 = \delta_1 = \ldots = \delta_{13} = 0$)	1273.67***	1319.17***	487.42***	192.89**	19.21	21.74	27.02

Source: Author's calculation. Note: The log-likelihood ratio statistics are calculated from Equation 5.1. ***, **, and * denote significance at 1%, 5%, and 10%, respectively. The critical values are based on Chi-squared distribution.

The second null hypothesis is a test to confirm whether the log-linear production frontier (also known as the generalized Cobb-Douglas production function) is appropriate specification for the data under a restriction: $\beta_{LL} = \beta_{KK} = \beta_{MM} = \beta_{EE} = \beta_{tt} = \beta_{LK} = \beta_{LM} = \beta_{LE} = \beta_{KM} = \beta_{KE} = \beta_{ME} = \beta_{LLD} = \beta_{KKD} = \beta_{MMD} = \beta_{EED} = \beta_{ttD} = \beta_{LKD} = \beta_{LMD} = \beta_{LED} = \beta_{KMD} = \beta_{KED} = \beta_{MED} = 0$. Here, the null hypothesis is also rejected at the 1% level of significance in all four industries, which suggests that the generalized Cobb-Douglas model is not an appropriate specification, given the *translog* model.

The next test, the test for Hicks-neutral technical progress (TP) under a restriction ($\beta_{Lt} = \beta_{Kt} = \beta_{Mt} = \beta_{Et} = \beta_{LtD} = \beta_{KtD} = \beta_{MtD} = \beta_{EtD} = 0$), rejects the null hypothesis at the 1% level of significance in food, textile and chemical industries but accepts the null hypothesis in metal industry. However, to maintain the same regression equation in metal industry and in the other three industries, the cross-product terms involving time are used in the equation because retaining these terms does not lead to bias in the other coefficients.

The fourth test is a test for the null hypothesis of no-technological progress by imposing the restriction of $\beta_t = \beta_{tt} = \beta_{Lt} = \beta_{Kt} = \beta_{Mt} = \beta_{Et} = \beta_{tD} = \beta_{ttD} = \beta_{LtD} = \beta_{KtD} = \beta_{MtD} = \beta_{EtD} = 0$. The statistical results suggest that the no-TP specification is inappropriate, given the *translog* specification. The final null hypothesis for the no-inefficiency effect, which imposes the restriction of $\delta_0 = \delta_1 = \ldots = \delta_{13} = 0$, also shows a rejection of null hypothesis at 1% level of significance in all four industries.

Table 5.5 shows that the hypothesis that each of the dummy variable coefficients equal to zero is rejected. The full set of parameter estimates is given in Appendix 5.3. Given these results, one can conclude the observations must be divided into pre-crisis (1981-1996) and post-crisis (1997-2000). By splitting the observations into pre-crisis and post-crisis, the dummy crisis and the variables that interact with the dummy crisis variable are not required to be included in the equation. Therefore, the estimation of the stochastic frontier in this chapter uses the *translog* production frontier as follows:

$$
\begin{aligned}
\ln y_{it} = \ & \beta_0 + \beta_L \ln L_{it} + \beta_K \ln K_{it} + \beta_M \ln M_{it} + \beta_E \ln E_{it} + \beta_t t \\
& + 0.5\ \beta_{LL}[\ln L_{it}]^2 + 0.5\ \beta_{KK}[\ln K_{it}]^2 + 0.5\ \beta_{MM}[\ln M_{it}]^2 \\
& + 0.5\ \beta_{EE}[\ln E_{it}]^2 + 0.5\ \beta_{tt}[t]^2 + \beta_{LK}[\ln L_{it} * \ln K_{it}] \\
& + \beta_{LM}[\ln L_{it} * \ln M_{it}] + \beta_{LE}[\ln L_{it} * \ln E_{it}] + \beta_{KM}[\ln K_{it} * \ln M_{it}] \\
& + \beta_{KE}[\ln K_{it} * \ln E_{it}] + \beta_{ME}[\ln M_{it} * \ln E_{it}] + \beta_{Lt}[\ln L_{it} * t] \\
& + \beta_{Kt}[\ln K_{it} * t] + \beta_{Mt}[\ln M_{it} * t] + \beta_{Et}[\ln E_{it} * t] + v_{it} - u_{it} \qquad \textbf{5.4}
\end{aligned}
$$

where the variables are as previously defined in Equation 5.1.

The inefficiency function can also be written as follows:

$$u_{it} = \delta_0 + \delta_1 ERP_{it} + \delta_2 IMP_{it} + \delta_3 AGE_{it} + \delta_4 CI_{it} + \delta_5 NPW_{it} + \delta_6 FOREIGN_{it} + w_{it} \qquad \textbf{5.5}$$

where the variables are as previously defined in Equation 5.2.

5.5.2 Results for the Four Two-Digit ISIC Industries

Using the *translog* stochastic production frontier (SPF) and the inefficiency function specified in Equations 5.4 and 5.5, this study estimates the SPF and inefficiency function in each of four manufacturing industries both before and after the crisis. In each industry, the estimation results for the SPF are discussed first, followed by a discussion of the inefficiency function results, especially for the trade reform variables. Two variables, as mentioned in Section 5.4.2, are used to test the trade reform effects on technical efficiency.

5.5.2.1 Results for the Food Industry (31)

Table 5.6 displays estimation results of the stochastic frontier production function for food industry in Indonesia. In the one-stage approach, the SPF estimates are used to set a technology frontier, but they have limited direct economic implications on output. The impact of each input on output depends on the interactions of the coefficients of all terms involving the input (first and second degrees). Therefore, output elasticity with respect to labour, capital, material, energy and returns to scale have been calculated.[17] The firm-specific results are not presented here because of space limitations but are available upon request.

[17] The output elasticity of each input is obtained by taking a partial derivative of the *translog* model and evaluating them at their mean values of the variables. Based on the *translog* model in Equation 5.4, the output elasticity of labour is defined as $\varepsilon_L = \beta_L + \beta_{LL}[lnL] +$

As shown in Table 5.7, it is apparent that the average output elasticity with respect to labour is positive for all observed years and ranges from 0.02 to 0.06. Similarly, the elasticity to capital and elasticity to material are also positive, with average values of 0.39 for the elasticity to capital and 0.59 for the elasticity to material. The same is also true for energy because the average values of output elasticity are positive. Furthermore, the four elasticity values sum to the RTS coefficient. The annual average value of RTS is 1.14 between 1981 and 2000, which suggests increasing returns to scale for the Indonesian food industry.

The largest impact on output is due to the elasticity of material and ranges from 0.54 to 0.71 during the observed years. This finding is consistent with Aswicahyono (1998) that Indonesian manufacturing products are characterized by simple assembly processes, which usually rely largely on material input.

$\beta_{LK}[lnK] + \beta_{LM}[lnM] + \beta_{LE}[lnE] + \beta_{Lt}[t]$. Similarly, the output elasticity of capital, material, and energy are obtained by the partial derivatives of output to capital, output to material and output to energy.

Table 5.6: Maximum Likelihood Estimates of the Stochastic Production Frontier in Food Industry (ISIC 31)

	Pre-Crisis (1981-1996)		**Post-Crisis (1997-2000)**	
	Coefficient	**t-ratio**	**Coefficient**	**t-ratio**
Production Frontier *(Dependent Variable: lnY)*				
Constant	1.801	16.072***	2.036	7.298***
lnL	0.265	7.937***	0.299	4.037***
lnK	0.055	1.298*	0.296	2.918***
lnM	0.450	18.167***	0.313	5.841***
lnE	0.320	17.266***	0.224	5.433***
T	0.003	0.553	-0.060	-1.106
$[\ln L]^2$	0.005	0.559	0.006	0.297
$[\ln K]^2$	0.414	36.007***	0.360	14.833***
$[\ln M]^2$	0.199	54.083***	0.218	28.279***
$[\ln E]^2$	0.063	21.999***	0.039	6.488***
T^2	-0.001	-2.289**	0.069	5.202***
lnL* lnK	0.049	5.569***	0.063	3.879***
lnL* lnM	-0.033	-6.301***	-0.048	-5.175***
lnL* lnE	-0.024	-6.181***	-0.022	-2.773***
lnK* lnM	-0.242	-48.489***	-0.245	-21.431***
lnK* lnE	-0.064	-14.404***	-0.040	-4.274***
lnM* lnE	-0.006	-6.669***	-0.004	-5.376***
lnL* T	-0.001	-1.067	0.001	0.057
lnK* T	0.002	1.463	-0.025	-1.843**
lnM* T	0.000	0.555	0.002	0.320
lnE* T	-0.002	-4.297	0.015	2.924***
Log-likelihood		-1,114.342		-494.655
No. of Cross-sections		16		4
No. of Firms		521		521
Observation		8,336		2,084

Source: Author's calculation using the model specified in Equations 5.4. *** denotes 1% significance level, ** denotes 5% significance level and * denotes 10% significance level.

Table 5.7: Output Elasticity of the Inputs, Return to Scale (RTS) and Technical Change (TC) for the Indonesian Food Industry

Year	Output Elasticities of Inputs				RTS	TC
	Labour	Capital	Material	Energy		
1981	0.0648	0.4066	0.6047	0.0891	1.1652	0.0019
1982	0.0523	0.3830	0.5963	0.1184	1.1500	-0.0002
1983	0.0432	0.3704	0.5907	0.1366	1.1409	-0.0018
1984	0.0410	0.3691	0.6001	0.1298	1.1400	-0.0027
1985	0.0357	0.3575	0.6049	0.1346	1.1326	-0.0040
1986	0.0362	0.4181	0.5388	0.1567	1.1497	-0.0057
1987	0.0428	0.4138	0.5697	0.1252	1.1514	-0.0058
1988	0.0401	0.4278	0.5522	0.1339	1.1539	-0.0071
1989	0.0336	0.3854	0.5912	0.1276	1.1378	-0.0080
1990	0.0431	0.4538	0.5527	0.1133	1.1629	-0.0086
1991	0.0363	0.4504	0.5394	0.1309	1.1570	-0.0103
1992	0.0315	0.4244	0.5696	0.1222	1.1477	-0.0110
1993	0.0249	0.4120	0.5750	0.1292	1.1411	-0.0123
1994	0.0244	0.4262	0.5677	0.1261	1.1444	-0.0133
1995	0.0221	0.4269	0.5707	0.1232	1.1430	-0.0144
1996	0.0217	0.4157	0.5863	0.1158	1.1395	-0.0151
1997	0.0215	0.3470	0.6631	0.1002	1.1317	-0.0483
1998	0.0325	0.3524	0.6546	0.1004	1.1399	0.0146
1999	0.0369	0.3493	0.6329	0.1207	1.1398	0.0847
2000	0.0279	0.2517	0.7060	0.1263	1.1119	0.1515
1981-1996	0.0371	0.4088	0.5756	0.1258	1.1473	-0.0074
1997-2000	0.0297	0.3251	0.6641	0.1119	1.1308	0.0506
Total	0.0356	0.3921	0.5933	0.1230	1.1440	0.0042

Source: Author's calculation using the model specified in Equation 5.4 and coefficient estimates from Table 5.6.

The model specified in Equation 5.4 and coefficient estimates from Table 5.6 can also be used to calculate a rate of technical change (TC).[18] Table 5.7 shows that the annual average rate of technical change is 0.42% and the rate of technical change in the Indonesian food industry ranges from -4.83% to 15.15%. Most of the rate of technical change is negative, which means that there is technological regress during the observed years. The rate of technical change is negative in 1982 and more negative until 1997. From 1998 to 2000, however, the rate of technical change becomes positive. The positive rate of technical change is due to a negative coefficient of time and a positive coefficient of time squared in the post-crisis estimated production function, which is fitted to only four years of data. Looking at different sub-periods, the average rate of technical change is -0.74% during the pre-crisis period and 5.06% during the post-crisis period.

Moving to the inefficiency function in Table 5.8, the estimated coefficient of ERP before the economic crisis is positive and statistically significant at the 1% level, which suggestis that a decrease in the ERP contributes to decreasing technical inefficiency (or increasing technical efficiency). This result is consistent with the premise that protection increases inefficiency. After the economic crisis, however, the estimated coefficient of the ERP has negative effects on technical inefficiency and is statistically significant at the 1% level. This result suggests that after the economic crisis, a decrease in ERP leads to increased technical inefficiency (or decreased technical efficiency), which is inconsistent with the argument that trade reform increases technical efficiency. Apparently, the crisis interferes with the positive relationship between trade reform and efficiency.

[18] The rate of technical change is the partial derivative of the production function with respect to time, which can be defined as $TC = \frac{\partial \ln(y_{it})}{\partial t} = \beta_t + \beta_{tt}t + \beta_{Lt}[\ln L_{it}] + \beta_{Kt}[\ln K_{it}] + \beta_{Mt}[\ln M_{it}] + \beta_{Et}[\ln E_{it}]$. A positive rate of technical change means technological progress. Conversely, a negative rate of technical change means technological regress.

Table 5.8: Estimates of Technical Inefficiency Parameters in Food Industry (ISIC 31)

	Pre-Crisis (1981-1996)		Post-Crisis (1997-2000)	
	Coefficient	**t-ratio**	**Coefficient**	**t-ratio**
Inefficiency Function *(Dependent Variable: u)*				
Constant	-5.293	-25.778***	10.386	23.565***
ERP	**0.009**	**12.959*** **	**-0.305**	**-16.379*** **
Import Ratio	**-0.021**	**-24.802*** **	**0.006**	**1.698** **
AGE	-0.015	-13.172***	-0.024	-3.832***
Capital Intensity	0.010	18.525***	0.010	12.215***
Non-Production Workers	-0.008	-8.473***	-0.009	-3.098***
Foreign Ownership	-0.775	-9.687***	-1.398	-3.361***
Sigma-squared	0.864	29.417***	1.201	10.136***
Gamma	0.939	338.814***	0.950	175.155***
No. of Cross-sections	16		4	
No. of Firms	521		521	
Observation	8,336		2,084	

Source: Author's calculation using the model specified in Equation 5.5. *** denotes 1% significance level, ** denotes 5% significance level and * denotes 10% significance level.

The second variable that represents trade reform in this model is the IMP. Before the economic crisis, the estimated coefficient of the IMP is negative and statistically significant at the 1% level. This result indicates that IMP has negative effects on technical inefficiency (or positive effect on technical efficiency) and is consistent with the argument that trade liberalization increases technical efficiency. After the economic crisis, however, the IMP has positive effects and is significant at the 5% level. This result suggests that an increase in IMP leads to increased technical inefficiency (or decreased technical efficiency) and is inconsistent with the premise that trade reform increases technical efficiency. Similar to the results of the ERP, this finding indicates that the crisis interferes with the positive relationship between trade reform and efficiency.

Regarding variables not associated with trade reform variables, the coefficient of AGE is negative and statistically significant at the 1% level, which indicates that older firms have lower inefficiency in the food industry. After the economic crisis, the effect of AGE on technical inefficiency is still negative and statistically significant at 1% level. The result that older firms have lower inefficiency is consistent with the endogenous growth theory, which states that firms may accumulate knowledge through experience and process of learning by doing. This result is consistent with the finding of Suyanto *et al.* (2012) in garment and electronics industries.

The coefficient of capital intensity before the economic crisis is positive and statistically significant at the 1% level, which suggests that a higher ratio of capital intensity leads to increasing technical inefficiency (or decreasing technical efficiency). Similarly, in the post-crisis period, the effect of capital intensity on technical inefficiency is positive and statistically significant at the 1% level.

The coefficients of the ratio of non-production workers are negative and statistically significant at the 1% level for both the pre-crisis and post-crisis period. These results suggest that a higher ratio of non-production workers reduces technical inefficiency.

The estimated coefficients of foreign ownership are negative and statistically significant at the 1% level in both the pre-crisis and post-crisis period. These results suggest that foreign-owned firms are, on average, less inefficient than domestic firms. This finding is consistent with the premise that foreign firms generally have more experience in serving markets and have more current knowledge, which enables them to be more efficient than domestic firms.

5.5.2.2 Results for Textile Industry (32)

After a review of the estimation results in the Indonesian food industry, this section continues with a discussion of the Indonesian textile industry. Table 5.9 displays the coefficients of the *translog* stochastic production frontier in Indonesian textile industry. To evaluate the economic implications, the output elasticity of input and RTS coefficients are calculated by using the same procedure as in the food industry. The results for the selected period in textile industry are presented in Table 5.10.

The calculated elasticity values show that the average output elasticity with respect to labour range from -0.05 to 0.07. Most of the average output elasticity values with respect to labour are positive, except during the economic crisis (from 1998 to 2000) when the average values for labour are negative. The elasticities for capital and material are positive for all observed years, with average values of 0.33 for capital and 0.62 for material. The same is also true for energy, because the average values of output elasticity is positive, namely, 0.10. Furthermore, the four output elasticity values sum to the RTS estimate, which has an annual average value of 1.09 from

1981 to 2000, which suggests increasing return to scale for the Indonesian textile industry.

Table 5.9: Maximum Likelihood Estimates of the Stochastic Production Frontier on the Trade Reform Effects in Textile Industry (ISIC 32)

	Pre-Crisis (1981-1996)		**Post-Crisis (1997-2000)**	
	Coefficient	**t-ratio**	**Coefficient**	**t-ratio**
Production Frontier *(Dependent Variable: lnY)*				
Constant	3.574	14.937***	3.964	6.778***
lnL	0.377	5.635***	0.424	2.415***
lnK	0.166	1.444*	0.341	1.945**
lnM	0.295	5.863***	0.319	2.853***
lnE	0.048	1.583*	-0.139	-1.897**
T	0.064	7.818***	-0.299	-3.639***
$[\ln L]^2$	0.041	2.262**	0.087	1.831**
$[\ln K]^2$	0.168	14.802***	0.155	4.956***
$[\ln M]^2$	0.157	21.996***	0.216	17.710***
$[\ln E]^2$	0.020	5.632***	0.010	1.136
T^2	-0.002	-3.621***	0.079	4.435***
lnL* lnK	0.072	6.295***	0.116	3.150***
lnL* lnM	-0.063	-7.575***	-0.097	-4.599***
lnL* lnE	-0.035	-5.725***	-0.059	-3.875***
lnK* lnM	-0.145	-18.468***	-0.202	-13.766***
lnK* lnE	0.002	0.317	0.041	2.856***
lnM* lnE	-0.001	-0.333	-0.003	-2.985***
lnL* T	0.001	0.707	-0.022	-1.451*
lnK* T	0.000	0.090	0.044	2.341***
lnM* T	-0.002	-1.002	-0.015	-1.270
lnE* T	-0.001	-1.853**	-0.002	-0.332
Log-likelihood		-453.784		-203.574
No. of Cross-sections		16		4
No. of Firms		291		291
Observation		4,656		1,164

Source: Author's calculation using the model specified in Equation 5.4. *** denotes 1% significance level, ** denotes 5% significance level and * denotes 10% significance level.

Table 5.10: Output Elasticity of Inputs and Return to Scale (RTS) and Technical Change (TC) for the Indonesian Textile Industry

Year	Output Elasticities of Inputs				RTS	TC
	Labour	Capital	Material	Energy		
1981	0.0694	0.2530	0.6583	0.0947	1.0754	0.0277
1982	0.0610	0.2740	0.6372	0.1035	1.0757	0.0253
1983	0.0627	0.2807	0.6299	0.1048	1.0782	0.0232
1984	0.0396	0.2601	0.6550	0.1085	1.0632	0.0204
1985	0.0550	0.2979	0.6207	0.1082	1.0818	0.0184
1986	0.0454	0.2971	0.6238	0.1120	1.0783	0.0160
1987	0.0551	0.2933	0.6312	0.1039	1.0834	0.0139
1988	0.0457	0.2842	0.6454	0.1058	1.0811	0.0113
1989	0.0494	0.2845	0.6499	0.1013	1.0850	0.0091
1990	0.0657	0.3148	0.6246	0.0972	1.1024	0.0070
1991	0.0591	0.3188	0.6220	0.0985	1.0984	0.0047
1992	0.0581	0.3326	0.6096	0.1006	1.1009	0.0025
1993	0.0586	0.3511	0.5911	0.1047	1.1055	0.0004
1994	0.0502	0.3415	0.6010	0.1057	1.0983	-0.0019
1995	0.0546	0.3615	0.5872	0.1079	1.1112	-0.0043
1996	0.0570	0.3513	0.5959	0.1033	1.1075	-0.0063
1997	0.0160	0.3628	0.6092	0.0937	1.0817	-0.0807
1998	-0.0107	0.4002	0.5992	0.0946	1.0833	-0.0005
1999	-0.0311	0.4461	0.5820	0.0913	1.0883	0.0782
2000	-0.0494	0.4948	0.5626	0.0865	1.0945	0.1562
1981-1996	0.0554	0.3060	0.6239	0.1038	1.0891	0.0105
1997-2000	-0.0188	0.4260	0.5882	0.0915	1.0869	0.0383
Total	0.0406	0.3300	0.6168	0.1013	1.0887	0.0160

Source: Author's calculation using the model specified in Equation 5.4 and the coefficient estimates from Table 5.9.

Similar to the Indonesian food industry, the largest output elasticity in the Indonesian textile industry is for material. During the observed years, from 1981 to 2000, the elasticity values for material range from 0.56 to 0.66.

Using the same procedure as in the Indonesian food industry, Equation 5.4 and coefficient estimates from Table 5.9 are used to calculate the rate of technical change. The annual average rate of technical change is 1.60% and the rate of technical change ranges from -8.07% to 15.62%. Unlike the rate of technical change in the food industry, which is mostly negative during the observed years, in the Indonesian textile industry, the rate of technical change is mostly positive. This finding is consistent with the finding of Margono and Sharma (2006). The positive rate of technical change means that there is technical progress in the Indonesian textile industry. This positive rate of technical change, however, decreases continuously from 1981 to 1993 and becomes negative from 1994 to 1998. It turns positive again in 1999 and 2000. Comparing the average of technical change during the pre-crisis and the post-crisis period, the average rate of technical change is 1.05% and 3.8%, respectively.

A particular interest of this study is the estimated coefficients of the inefficiency function that are shown in Table 5.11. From the estimates, it is clearly seen that in the pre-crisis period, similar to the coefficient of ERP in the food industry, the coefficient of ERP in the Indonesian textile industry has a positive sign. However, this coefficient is not statistically significant. After the economic crisis, unlike the coefficient of ERP in the food industry which has a negative sign, the coefficient of ERP in the textile industry has a positive sign and is statistically significant at the 1% level. This result suggests that in the post-crisis period, a decrease in ERP leads to decreases technical inefficiency (or enhances technical efficiency), which is consistent with the premise that trade reform increases technical efficiency.

Table 5.11: Estimates of Technical Efficiency Parameters in theTextile Industry (ISIC 32)

	Pre-Crisis (1981-1996)		**Post-Crisis (1997-2000)**	
	Coefficient	**t-ratio**	**Coefficient**	**t-ratio**
Inefficiency Function *(Dependent Variable: u)*				
Constant	-5.478	-14.493***	-12.146	-6.845***
ERP	**0.001**	**0.873**	**0.025**	**3.733*** **
Import Ratio	**-0.016**	**-15.517*** **	**0.013**	**5.491*** **
AGE	0.005	2.085**	0.121	6.725***
Capital Intensity	0.009	15.392***	0.032	14.483***
Non-Production Workers	-0.002	-1.505*	0.009	2.523***
Foreign Ownership	-0.074	-1.802**	-0.938	-1.669**
Sigma-squared	0.742	27.644***	1.123	6.914***
Gamma	0.934	258.208***	0.955	93.652***
No. of Cross-sections		16		4
No. of Firms		291		291
Observation		4,656		1,164

Source: Author's calculation using the model specified in Equation 5.5. *** denotes 1% significance level, ** denotes 5% significance level, and * denotes 10% significance level.

The coefficients of IMP show the same pattern as in the food industry. The coefficient of IMP in the pre-crisis period is negative and statistically significant at the 1% level, which indicates that IMP has negative effects on technical inefficiency (or positive effect on technical efficiency). This result supports the argument that trade reform increases technical efficiency. In the post-crisis period, however, the coefficient of IMP has a positive sign and is statistically significant at the 1% level, which indicates that an increase in IMP leads to increase technical inefficiency. This result is inconsistent with the premise that trade liberalization decreases technical inefficiency (or increases technical efficiency). Again, it appears that the crisis interferes with the positive relationship between trade reform and efficiency.

Unlike the coefficients of AGE in the Indonesian food industry, which have negative sign in both the pre-crisis and post-crisis period, the coefficient of AGE in the Indonesian textile industry is positive and statistically significant at the 1% level in both the pre-crisis and post-crisis period. The finding that AGE has a positive effect on technical inefficiency supports the premise that older firms have higher inefficiency than younger firms. It could be that younger firms are likely to have modern technology than older firms, which enables them to produce goods more efficiently. As explained in Section 5.4.3.1, the AGE can affect inefficiency positively or negatively.

The coefficients of capital intensity before and after the economic crisis in the Indonesian textile industry are positive and statistically significant at the 1% level, suggesting that a higher ratio of capital intensity leads to increasing technical inefficiency (or decreasing technical efficiency). These results are similar to the results in the Indonesian food industry.

Similar to the coefficient of the ratio of non-production workers in the Indonesian food industry in the pre-crisis period, which is negative and statistically significant at the 1% level, the coefficient of the ratio of non-production workers in the Indonesian textile industry is also negative, but this coefficient is only statistically significant at the 10% level. This result suggests that a higher ratio of non-production workers decreases technical inefficiency. In the post-crisis period, however, the coefficient of the ratio of non-production workers in the textile industry is positive and statistically significant at the 1% level, suggesting that a higher ratio of non-production workers increases technical inefficiency.

The estimated coefficients of foreign ownership in the Indonesian textile industry both the pre-crisis and post-crisis period are positive and statistically significant at the 5% level, suggesting that, on average, foreign firms are more efficient than domestic firms as it is found to be the case in the Indonesian food industry.

5.5.2.3 Results for Chemical Industry (35)

This section explains the results from estimating the SPF and technical efficiency in the Indonesian chemical industry Table 5.12 displays the coefficients of the *translog* stochastic production frontier. Using the same calculation procedure as used in the Indonesian food and textile industries, these coefficients are used to calculate the output elasticity of labour, capital and material in the Indonesian chemical industry.

The annual average chemical elasticities for the Indonesian chemical industry are presented in Table 5.13. The calculated elasticity values demonstrate that the average output elasticity with respect to labour is negative for several years, particularly from 1983 to 1996. In contrast, the elasticity for capital and material are positive for all observed years, with average values of 0.71 for capital and 0.52 for material. The same is also true for energy because the average output elasticity is positive, namely, 0.08.

Unlike in the Indonesian food and textile industries, where output elasticity of material is largest, in the Indonesian chemical industry the largest is for capital (ranging from 0.48 to 0.79 during the years observed). As argued by Wacker *et al.* (2006), high elasticity capital is typically observed only in manufacturing industries that rely heavily on advanced technologies.

Summing the four elasticity values, the annual average value of RTS in the Indonesian chemical industry is 1.26 between 1981 and 2000. This result suggests an increasing return to scale for the Indonesian chemical industry. Comparing the annual average values of RTS before and during the crisis period, as shown in Table 5.13, the average value before the economic crisis (1981–1996) is 1.27, whereas the value is 1.23 during the crisis period (1997-2000).

Table 5.12: Maximum Likelihood Estimates of the Stochastic Production Frontier in the Chemical Industry (ISIC 35)

	Pre-Crisis (1981-1996)		Post-Crisis (1997-2000)	
	Coefficient	**t-ratio**	**Coefficient**	**t-ratio**
Production Frontier *(Dependent Variable: lnY)*				
Constant	2.228	3.013***	5.932	5.225***
lnL	0.237	2.058**	0.425	1.796**
lnK	-0.270	-1.420*	-2.023	-6.171***
lnM	0.505	7.259***	1.531	8.712***
lnE	0.418	6.074***	0.114	0.838
T	-0.054	-3.110***	0.017	0.110
$[\ln L]^2$	0.125	6.294***	0.103	2.810***
$[\ln K]^2$	0.315	11.519***	0.665	10.899***
$[\ln M]^2$	0.130	20.835***	0.199	10.397***
$[\ln E]^2$	0.047	6.949***	0.003	0.244
T^2	-0.005	-6.533***	0.077	3.015***
lnL* lnK	0.019	0.919	-0.022	-0.531
lnL* lnM	-0.065	-6.657***	-0.022	-1.102
lnL* lnE	-0.013	-1.521*	-0.030	-1.889**
lnK* lnM	-0.137	-12.790***	-0.335	-10.250***
lnK* lnE	-0.070	-5.911***	0.012	0.589
lnM* lnE	0.000	0.180	-0.004	-3.236***
lnL* T	-0.002	-1.266	0.009	0.556
lnK* T	0.014	4.648***	-0.057	-1.979**
lnM* T	-0.004	-2.773***	0.037	2.517***
lnE* T	-0.002	-2.657***	-0.009	-0.857
Log-likelihood		-1,547.875		-410.517
No. of Cross-sections		16		4
No. of Firms		241		241
Observation		3,856		964

Source: Author's calculation using the model specified in Equation 5.4. *** denotes 1% significance level, ** denotes 5% significance level and * denotes 10% significance level.

Table 5.13: Output Elasticity of Inputs, RTS and TC for the Indonesian Chemical Industry (ISIC 35)

Year	Output Elasticities of Inputs				RTS	TC
	Labour	Capital	Material	Energy		
1981	0.0011	0.6427	0.5331	0.0704	1.2473	0.0096
1982	0.0009	0.6467	0.4942	0.1035	1.2453	0.0047
1983	-0.0161	0.5937	0.5280	0.1151	1.2207	-0.0026
1984	-0.0176	0.6546	0.5231	0.0867	1.2468	-0.0057
1985	-0.0202	0.6483	0.5045	0.1099	1.2424	-0.0110
1986	-0.0214	0.6842	0.4997	0.0950	1.2575	-0.0152
1987	-0.0357	0.6842	0.5263	0.0808	1.2556	-0.0205
1988	-0.0447	0.6755	0.5351	0.0845	1.2504	-0.0261
1989	-0.0365	0.7311	0.5084	0.0728	1.2758	-0.0295
1990	-0.0333	0.7543	0.5014	0.0655	1.2879	-0.0342
1991	-0.0391	0.7701	0.4986	0.0632	1.2928	-0.0389
1992	-0.0446	0.7451	0.4766	0.1014	1.2784	-0.0449
1993	-0.0405	0.7661	0.4845	0.0815	1.2916	-0.0500
1994	-0.0550	0.7481	0.4905	0.0958	1.2794	-0.0557
1995	-0.0652	0.7851	0.5027	0.0709	1.2934	-0.0595
1996	-0.0774	0.7529	0.5110	0.0893	1.2757	-0.0661
1997	0.0007	0.6683	0.5285	0.0599	1.2574	-0.0668
1998	0.0150	0.6149	0.5661	0.0513	1.2473	0.0139
1999	0.0008	0.6284	0.5617	0.0444	1.2353	0.0746
2000	0.0416	0.4754	0.6474	0.0296	1.1939	0.1694
1981-1996	-0.0341	0.7052	0.5074	0.0866	1.2651	-0.0279
1997-2000	0.0145	0.5967	0.5759	0.0463	1.2335	0.0478
Total	-0.0244	0.6835	0.5211	0.0786	1.2588	-0.0127

Source: Author's calculation using the model specified in Equation 5.4 and the coefficient estimates from Table 5.12.

The annual average rate of technical change in the Indonesian chemical industry is -1.27% and the rate of technical change in the Indonesian chemical industry ranges from -6.68% to 16.94%. Similar to the rate of technical change in the Indonesian food industry, the rate of technical change is mostly negative during the observed years. The rate of technical change is negative in 1983 and more negative until 1997. From 1998 to 2000, however, the rate of technical change becomes positive. Looking at different sub-periods, the average rate of technical change is -2.79% during the pre-crisis period and 4.78% during the post-crisis period.

The analysis now moves to the estimation results of the inefficiency function in the Indonesian chemical industry as shown in Table 5.14. The estimated coefficients of ERP are positive and statistically significant at the 1% level in both the pre-crisis and post-crisis period, suggesting that the decrease in ERP contributes to decreasing technical inefficiency (or increasing technical efficiency). These results are consistent with the premise that trade reform increases technical efficiency.

Table 5.14: Estimates of Technical Inefficiency Parameters in the Chemical Industry (ISIC 35)

	Pre-Crisis (1981-1996)		**Post-Crisis (1997-2000)**	
	Coefficient	**t-ratio**	**Coefficient**	**t-ratio**
Inefficiency Function *(Dependent Variable: u)*				
Constant	-0.052	-2.529***	-5.078	-9.216***
ERP	**0.003**	**13.744*** **	**0.073**	**5.110*** **
Import Ratio	**-0.001**	**-4.659*** **	**-0.021**	**-15.455*** **
AGE	0.000	0.467	0.013	3.486***
Capital Intensity	0.002	14.527***	0.009	10.930***
Non-Production Workers	-0.005	-22.451***	-0.008	-3.732***
Foreign Ownership	-0.140	-22.906***	-2.032	-10.781***
Sigma-squared	0.131	34.119***	0.938	8.263***
Gamma	0.00008	17.696***	0.908	75.904***
No. of Cross-sections		16		4
No. of Firms		241		241
Observation		3,856		964

Source: Author's calculation using the model specified in Equation 5.5. The t-statistics are in parenthesis. *** denotes 1% significance level, ** denotes 5% significance level and * denotes 10% significance level.

The second variable representing trade reform in this model is the IMP. The results show that the estimated coefficients of IMP are negative and statistically significant at the 1% level both before and after the economic crisis, which indicates that IMP has negative effects on technical inefficiency (or positive effect on technical efficiency). These results support the premise that trade reform leads to decreased technical inefficiency (or increased technical efficiency).

Regarding the variables not associated with trade reform variables, the coefficient of AGE in the pre-crisis period is zero and not statistically significant. In the post-crisis period, AGE has positive effects on technical inefficiency and is statistically significant at the 1% level. This result indicates that in the chemical industry older firms have higher technical inefficiency than young firms, as found to be the case in the Indonesian textile industry.

The coefficients of capital intensity before and after the economic crisis are positive and statistically significant at the 1% level, suggesting that a higher ratio of capital intensity leads to increasing technical inefficiency (or decreasing technical efficiency). These similar results are also found in the Indonesian food and textile industries.

The coefficients of the ratio of non-production workers are negative and statistically significant at the 1% level both before and after the economic crisis, thus suggesting that a higher ratio of non-production workers reduces technical inefficiency. Similar results are also found in the Indonesian food industry.

The estimated coefficients of foreign ownership are negative and statistically significant at the 1% level in both the pre-crisis and post-crisis period, suggesting that foreign-owned firms are, on average, less inefficient than domestic firms. This finding is consistent with the premise that foreign firms generally have more experience in serving markets and have more current knowledge, which enables them to be more efficient than domestically owned firms. Similar results are also found in the Indonesian food and textile industries.

5.5.2.4 Results for the Metal Product Industry (38)

This section discusses the results from estimating the SPF and technical efficiency in the Indonesian metal industry. Table 5.15 shows the coefficients of the *translog* stochastic production frontier.[19] These coefficients are used to calculate the output elasticity of labour, capital and material in the Indonesian metal industry. The formula used to calculate the output elasticity is the same as formula used in the food, textile and chemical industry.[20]

[19] The post-crisis regression in the Indonesian metal industry using Frontier 4.1 fails to iterate and does not produce maximum likelihood regression results. Therefore, the coefficient estimates from the regression result with dummy crisis as written in Equations 5.1 and 5.2 are used to calculate elasticities and the effect of trade reform on technical inefficiency in the Indonesian metal products industry.

[20] For the post-crisis period, following Equation 5.1, the output elasticity of each input is obtained by taking a partial derivative of the *translog* model and evaluating them at their mean values of the variables. Based on the *translog* model in Equation 5.1, the output elasticity of labour is defined as $\varepsilon_L = \beta_L + \beta_{LL}[lnL] + \beta_{LK}[lnK] + \beta_{LM}[lnM] + \beta_{LE}[lnE] + \beta_{Lt}[t] + \beta_{LD}[D] + \beta_{LLD}[lnL * D] + \beta_{LKD}[\ln K_{it} * D] + \beta_{LMD}[\ln M_{it} * D] + \beta_{LED}[\ln E_{it} * D] + \beta_{LtD}[t * D]$. Similarly, the output elasticity of capital, material, and energy are obtained by the partial derivatives of output to capital, output to material, and output to energy.

The results of the annual average metal industry elasticities are presented in Table 5.16. From the calculated values, it is apparent that the average output elasticity with respect to labour is positive, ranging from 0.04 to 0.11, for all observed years. Similarly, the elasticities to capital and material are also positive, with average values of 0.28 for capital and 0.70 for material. The same is also true for energy, as the average value of output elasticity is positive, ranging from 0.05 to 0.08.

The annual average value of RTS in the Indonesian metal products industry is 1.11 from 1981 to 2000. Comparing the annual average values of RTS before and during the crisis period, as shown in Table 5.16, the average value before the economic crisis (1981–1996) is 1.10, whereas the value is 1.12 during the crisis period (1997-2000). Similar to the Indonesian food and textile industries, the largest output elasticity is for material. The average values of output elasticity with respect to material range from 0.62 to 0.77 between 1981 and 2000.

Table 5.15: Maximum Likelihood Estimates of the Stochastic Production Frontier in the Metal Products Industry (ISIC 38)

	Pre-Crisis (1981-1996)		Full Period with Dummy (1981-2000)	
	Coefficient	**t-ratio**	**Coefficient**	**t-ratio**
Production Frontier *(Dependent Variable: lnY)*				
Constant	1.932	4.129	2.033	4.63***
lnL	0.255	2.451	0.271	2.49***
lnK	0.559	3.526	0.535	3.14***
lnM	0.179	2.131	0.174	2.00**
lnE	0.193	2.801	0.195	2.82***
T	-0.030	-1.975	-0.029	-1.90**
$[\ln L]^2$	-0.035	-1.296	-0.030	-1.04
$[\ln K]^2$	0.267	7.201	0.269	6.85***
$[\ln M]^2$	0.244	15.808	0.244	15.84***
$[\ln E]^2$	0.021	1.637	0.018	1.41*
T^2	0.001	1.301	0.001	1.18
lnL* lnK	0.114	4.142	0.110	3.93***
lnL* lnM	-0.099	-5.699	-0.100	-5.96***
lnL* lnE	0.016	1.012	0.018	1.11
lnK* lnM	-0.233	-11.298	-0.232	-11.22***
lnK* lnE	-0.036	-2.908	-0.035	-2.88***
lnM* lnE	-0.001	-0.409	-0.001	-0.32
lnL* T	-0.001	-0.521	-0.001	-0.61
lnK* T	0.004	0.950	0.004	1.03
lnM* T	0.000	0.089	0.000	0.00
lnE* T	-0.002	-1.232	-0.002	-1.15
D			27.066	19.04***
lnL* D			-0.016	-0.05
lnK* D			-0.725	-1.76**
lnM* D			0.513	2.39***
lnE* D			-0.276	-1.83**
T* D			-2.668	-12.90***
$[\ln L]^2$*D			0.104	1.59*
$[\ln K]^2$*D			-0.022	-0.30
$[\ln M]^2$*D			-0.079	-3.03***
$[\ln E]^2$*D			0.002	0.10
T^2*D			0.140	9.62***
lnL* lnK*D			-0.075	-1.24
lnL* lnM*D			0.070	1.89**
lnL* lnE*D			-0.066	-1.94**
lnK* lnM*D			0.036	1.12
lnK* lnE*D			0.060	2.60***
lnM* lnE*D			-0.007	-0.70
lnL* T*D			0.002	0.50
lnK* T*D			-0.004	-0.34
lnM* T*D			0.006	0.95
lnE* T*D			-0.001	-0.33
Log-likelihood		-285.584		-364.065
No. of Cross-sections		16		20
No. of Firms		93		93
Observation		1,488		1860

Source: Author's calculation using the model specified in Equations 5.1 and 5.2. *** denotes 1% significance level, ** denotes 5% significance level, and * denotes 10% significance level.

Table 5.16: Output Elasticity of Inputs, RTS and TC for the Indonesian Metal Products Industry (ISIC 38)

Year	Output Elasticities of Inputs				RTS	TC
	Labour	Capital	Material	Energy		
1981	0.0371	0.2832	0.6820	0.0761	1.0784	-0.0064
1982	0.0555	0.3155	0.6462	0.0774	1.0947	-0.0056
1983	0.0667	0.3341	0.6266	0.0776	1.1050	-0.0047
1984	0.0632	0.3052	0.6510	0.0801	1.0995	-0.0041
1985	0.0738	0.3311	0.6277	0.0782	1.1108	-0.0030
1986	0.0824	0.3317	0.6227	0.0798	1.1166	-0.0023
1987	0.0528	0.3014	0.6702	0.0735	1.0979	-0.0009
1988	0.0470	0.2729	0.6999	0.0723	1.0921	0.0002
1989	0.0518	0.3029	0.6807	0.0666	1.1019	0.0017
1990	0.0352	0.3032	0.6957	0.0614	1.0955	0.0032
1991	0.0412	0.3296	0.6707	0.0626	1.1041	0.0041
1992	0.0491	0.3435	0.6567	0.0627	1.1119	0.0050
1993	0.0506	0.3588	0.6417	0.0649	1.1160	0.0056
1994	0.0422	0.3325	0.6633	0.0698	1.1078	0.0061
1995	0.0432	0.3514	0.6560	0.0633	1.1139	0.0076
1996	0.0494	0.3718	0.6445	0.0570	1.1227	0.0091
1997	0.0418	0.2320	0.7456	0.0244	1.0439	-0.2231
1998	0.0750	0.2967	0.6900	0.0196	1.0812	-0.0829
1999	0.0701	0.2570	0.7269	0.0108	1.0648	0.0574
2000	0.0629	0.2007	0.7789	0.0058	1.0483	0.1997
1981-1996	0.0526	0.3230	0.6585	0.0702	1.1043	0.0010
1997-2000	0.0625	0.2466	0.7354	0.0152	1.0596	-0.0122
Total	0.0546	0.3078	0.6738	0.0592	1.0953	-0.0017

Source: Author's calculation using the model specified in Equation 5.1 and coefficient estimates from Table 5.15.

The annual average rate of technical change in the Indonesian metal industry is -0.20% and the rate of technical change ranges from -22% to 20%.[21] The rate of technical change is negative from 1981 to 1987. Unlike the rate of technical change in the Indonesian food and chemical industries which is more negative until 1997, in the Indonesian metal products industry, there is an improvement of the rate of technical change, *i.e.*, it decreases by 0.60% in 1981 but only decreases by 0.10% in 1987. It becomes positive in 1988 and is more positive until 1996. In 1997 and 1998, however, the rate of technical change turns negative. It becomes positive again in

[21] Following Equation 5.1, the rate of technical change is obtained as the partial derivative of production function with respect to time, as follows: $TC = \frac{\partial \ln(y_{it})}{\partial t} = \beta_t + \beta_{tt}[t] + \beta_{Lt}[\ln L_{it}] + \beta_{Kt}[\ln K_{it}] + \beta_{Mt}[\ln M_{it}] + \beta_{Et}[\ln E_{it}] + \beta_{tD}[D] + \beta_{ttD}[t * D] + \beta_{LtD}[lnL * D] + \beta_{KtD}[lnK * D] + \beta_{MtD}[lnM * D] + \beta_{EtD}[lnE * D]$.

1999 and 2000. Comparing the average of technical change pre-crisis and post-crisis period, the average rate of technical change is 0.10% and -1.22%, respectively.

Now, the analysis is moving to the estimation results of the inefficiency function of the effect of trade reform on technical inefficiency in the Indonesian metal products industry, as shown in Table 5.17. The coefficient of ERP in the Indonesian textile industry in the pre-crisis period has a negative sign and is significant at the 1% level. This result suggests that a decrease in ERP contributes to increasing technical inefficiency (or decreasing technical efficiency). However, the economic crisis reverses the effect of ERP on technical inefficiency by 0.163. This additional effect is large relative to the effect before the economic crisis and is statistically significant at the 1% level. Thus, the total effect of ERP on technical inefficiency after the economic crisis is 0.161 and is consistent with the argument that trade reform enhances efficiency.[22]

[22] The total effect of each independent variable on the technical inefficiency after crisis is the sum of the pre-crisis coefficient estimate and the amount by which the effect increases or decreases after crisis. The increases or decreases in the effect after crisis is obtained from the coefficient estimate for the interaction with dummy variable. Based on the inefficiency model in Equation 5.2, the total effect of ERP on technical inefficiency is defined as $T_{ERP} = \delta_1 + \delta_7 = -0.002 + 0.163 = 0.161$. Similarly, the total effect of IMP, age, capital intensity, non-production workers, and foreign ownership on technical inefficiency after crisis is the sum of the pre-crisis coefficient estimate and the amount by which the effect increases or decreases after crisis for IMP, age, capital intensity, non-production workers and foreign ownership, respectively.

Table 5.17: Estimates of Technical Inefficiency Parameters in the Metal Products Industry (ISIC 38)

	Pre-Crisis (1981-1996)		Full Period with Dummy (1981-2000)	
	Coefficient	**t-ratio**	**Coefficient**	**t-ratio**
Inefficiency Function *(Dependent Variable: u)*				
Constant	-2.512	-7.308***	-2.240	-8.198***
ERP	**-0.002**	**-2.528*** **	-0.001	-2.670***
Import Ratio	**-0.015**	**-15.071*** **	-0.015	-7.013***
AGE	-0.072	-21.723***	-0.053	-9.442***
Capital Intensity	0.003	1.420*	0.003	8.250***
Non-Production Workers	0.008	1.087	0.010	3.469***
Foreign Ownership	-2.143	-13.104***	-2.084	-9.952***
ERP*D			**0.163**	**19.578*** **
Import Ratio*D			**-0.008**	**-4.460*** **
AGE*D			0.003	0.434
Capital Intensity*D			-0.003	-3.316***
Non-Production Workers*D			-0.009	-2.049**
Foreign Ownership*D			2.272	7.673***
D			-3.708	-9.524***
Sigma-squared	0.876	20.486	0.751	11.013***
Gamma	0.932	201.804	0.924	91.967***
No. of Cross-sections		16		20
No. of Firms		93		93
Observation		1,488		1,860

Source: Author's calculation using the model specified in Equations 5.2 and 5.5. *** denotes 1% significance level, ** denotes 5% significance level and * denotes 10% significance level.

Similar to the results in the Indonesian food, textile and chemical industries, the coefficient of IMP has a negative sign and is statistically significant at the 1% level, suggesting that IMP has negative effects on technical inefficiency (or positive effects on technical efficiency) in the pre-crisis period. With the economic crisis, the effect of IMP on technical inefficiency becomes more negative by 0.008, which is statistically significant at the 1% level. Summing the effect of IMP on technical inefficiency before the economic crisis and the coefficient of IMP after the economic crisis, the total effect of IMP on technical inefficiency after the crisis is -0.023. This result is consistent with the argument that trade liberalization decreases technical inefficiency (or increases technical efficiency).

The coefficient of AGE before the economic crisis is negative and statistically significant at 1% level, which indicates that older firms have lower inefficiency in the metal industry. The economic crisis reverses the effect of AGE on technical inefficiency by 0.003, but this effect is not statistically significant. The total effect of AGE on technical inefficiency after the economic crisis is -0.069.

Similar to the coefficient of capital intensity in the food, textile and chemical industries, the coefficient of capital intensity before the economic crisis is positive and statistically significant at the 10% level, suggesting that a higher ratio of capital intensity leads to increasing technical inefficiency (or decreasing technical efficiency). The effect of this variable on technical inefficiency decreases by 0.003 after the economic crisis and is statistically significant at the 1% level. The total effect of capital intensity on technical inefficiency after crisis is 0.001.

The coefficient of the ratio of non-production workers in the Indonesian metal industry before the economic crisis is positive but not statistically significant. The effect of this variable on technical inefficiency decreases by 0.009 after the economic crisis, and this effect is statistically significant at the 5% level. The total effect of the ratio of non-production workers on technical inefficiency after the economic crisis is -0.001, which indicates that a higher ratio non-production workers slightly decreases technical inefficiency.

The estimated coefficient of foreign ownership is negative and statistically significant at the 1% level, suggesting that foreign-owned firms are, on average, less inefficient than domestic firms. This finding is similar to the coefficient of foreign ownership in the Indonesian food, textile and chemical industries. The results show, however, that the economic crisis increases the technical inefficiency by 2.272 compared with domestic firms. This effect is statistically significant at the 1% level. Thus, the total effect of ownership status on technical inefficiency is 0.188, suggesting that, on average, after the economic crisis foreign firms are more inefficient than domestic firms. This result may suggest that foreign firms see the economic crisis as an abrupt change in the institutional environment that may increase legal uncertainty and less secure property right (Narjoko and Hill 2007). These conditions may diminish the efficiency of foreign firms.

5.6 Conclusion

This chapter explains the data sources used for empirical estimation of the impact of trade liberalization on firms in four Indonesian manufacturing industries (food, textile, chemical and metal products). The SI dataset is chosen as the main data because it is the most comprehensive data available on Indonesian manufacturing firms. To construct a consistent panel dataset and to overcome weaknesses in the SI data, several adjustments are made. The measurement and definitions of variables used for the empirical analysis are also presented in this chapter. By following concepts and formulas from the existing literature, variables for a production function and an inefficiency function are selected and appropriate measures identified.

Using the one-stage stochastic production frontier model developed by Battese and Coelli (1995), the effects of trade liberalization on technical inefficiency are estimated for firms in four selected Indonesian manufacturing industries. Five null hypotheses are tested to find the appropriate functional form that represents the datasets. The results suggest that the *translog* production frontier by splitting observations into the pre-crisis (1981-1996) and the post-crisis (1997-2000) appears to be the appropriate specification for the firms in all chosen industries except in the metal products industry. In the metal products industry, the regression for the post-crisis period does not iterate and thus, Frontier 4.1c does not generate parameter estimates. To address this, the parameter estimates from full set (1981-2000) *translog* model with a dummy variable are used to analyse the post-crisis period.

The parameter estimates from the *translog* production frontier are used to calculate output elasticity with respect to labour, capital, material and energy, along with RTS. The results suggest that all average output elasticity values are positive across industries, except average value of elasticity with respect to labour in the Indonesian chemical industry, which is negative. The annual average values show that there are increasing RTS in four selected industries. While in the food, textile and metal product industries, the largest impact on output is due to material, in the chemical industry, the largest output elasticity is for capital.

The parameter estimates from the *translog* production frontier are also used to calculate the rate of technical change. The results suggest that the rate of technical change is mostly negative, except in the textile and metal product industries. This finding is consistent with the findings of Margono and Sharma (2006). The results also show that the rate of technical change is unstable after the economic crisis, reflecting a negative coefficient of time and a positive coefficient of time square in the post-crisis estimated production function, which is fitted to only four years of data.

Regarding the inefficiency function, the effects of trade reform on technical inefficiency are estimated by splitting the observations into the pre-crisis and post-crisis period. Two variables represent trade reform in this empirical study: ERP and IMP. The empirical findings suggest that in the pre-crisis period, ERP has different effects on technical inefficiency across four selected industries, in terms of direction and magnitude. In the results from estimates in food, textile and chemical industries, ERP has positive effects on technical inefficiency, meaning that an increase in ERP increases inefficiency (or decreases technical efficiency). These effects are significant at the 1% level in the food and chemical industries only, whereas in the textile industry, ERP is not statistically significant. In contrast to the other industries, the effect of ERP on technical inefficiency in the metal products industry is negative and statistically significant at the 1% level, suggesting that an increase in ERP decreases technical inefficiency (or increases technical efficiency).

In the post-crisis period, ERP also has different effects across the four industries. While ERP has positive effects on technical inefficiency in the textile, chemical and metal products industries, ERP has negative effects on technical inefficiency in the food industry. The change for the food in direction of effect of ERP on inefficiency from the pre-crisis to post-crisis period suggests that the crisis alters the impact of trade reform on efficiency.

The second variable represents trade reform in the efficiency function is IMP. Unlike ERP in the pre-crisis period, which has different effects on technical inefficiency, in terms of direction and magnitude, IMP has negative effects on technical inefficiency and is statistically significant at the 1% level across the four chosen industries. These results suggest that in the pre-crisis period, an increase in IMP decreases technical inefficiency (or increases technical efficiency).

In the post-crisis period, IMP has different effects on technical inefficiency across industries, in terms of direction and magnitude. Results from estimates in the Indonesian food and textile industries show that IMP has positive effects on technical inefficiency, which means that an increase in IMP increases technical inefficiency (or reduces technical efficiency). In the food industry, IMP is significant at the 5%

level and in the textile industry IMP is significant at the 1% level. In the Indonesian chemical and metal products industries, however, IMP has negative effects on technical inefficiency that are statistically significant at 1% level. As with the impact of ERP, the findings suggest that the crisis interferes with the impact of trade reform on efficiency.

On the basis of the findings, this chapter concludes that trade reform generally enhances efficiency in the sample of Indonesian manufacturing industries, at least in the pre-crisis period. However, policy makers may need to consider that ERP is associated with decreased inefficiency in the food industry in the post-crisis period and that the direction of impact of both trade reform variables changes in both periods. The varying direction of the impact of trade reform variables across manufacturing industries is common in findings of Parameswaran (2002), Driffield and Kambhampati (2003), Kalirajan and Bhide (2004) and Ali *et al.* (2009).

For variables not related to trade reform, the coefficients of AGE are not uniform across four selected industries. These findings are consistent with the findings of Margono and Sharma (2006). In the pre-crisis period, the effect of AGE on technical inefficiency is negative and statistically significant at 1% level in the food and metal product industries, suggesting that older firms have lower inefficiency. Negative impacts of AGE on technical inefficiency are also found by Chen and Tang (1987) and Suyanto *et al.* (2012). In the textile and chemical industries, however, the effect of AGE on technical inefficiency is positive, indicating that older firms have higher inefficiency. While in the textile industry the coefficient of age is statistically significant at 5% level, in the chemical industry it is not statistically significant. The positive effect of AGE on technical inefficiency is consistent with the findings of Pitt and Lee (1981) , Salim (2007) and Suyanto (2010), whereas the insignificant effect of AGE on technical inefficiency is consistent with the findings of Margono and Sharma (2006).

In the post-crisis period, the coefficients of AGE have also varying effects on technical inefficiency. In the food industry, AGE has a negative effect on technical inefficiency and is statistically significant at the 1% level. In the textile and chemical industries, however, AGE has a positive effect on technical inefficiency and is statistically significant at the 1% level. There is no change in terms of direction of

AGE on technical inefficiency in the food, textile and chemical industries from the pre-crisis to post-crisis period.

The second variable affecting inefficiency is capital intensity. The coefficients of capital intensity are uniform across the four chosen industries. The estimates of capital intensity have positive effects on technical inefficiency across all four chosen industries, suggesting that a higher ratio of capital intensity leads to increasing technical inefficiency. They are statistically significant at the 1% level in all four selected industries both the pre-crisis and post crisis period, except in the metal products industry, which is significant at the 10% level in the pre-crisis period. The positive impact of capital intensity on technical inefficiency is also found by Islam (1978).

The third variable affecting inefficiency is ratio of non-production workers. The coefficients of the ratio of non-production workers are different across the four chosen industries. The coefficients of the ratio of non-production workers are negative and statistically significant in the food, textile and chemical industries, indicating that an increase in the ratio of non-production workers ratio leads to decreasing technical inefficiency. While the effects of the ratio of the non-production workers are statistically significant at the 1% level in the food and chemical industries, in the textile industry, the effect is significant at the 10% level. The negative effect of the ratio of non-production workers is consistent with the argument of Campbell (1984). In the metal products industry, however, it is found that the effect of the ratio of non-production workers on technical inefficiency is not statistically significant. An insignificant impact of the ratio of non-production workers on technical inefficiency is also found by Salim (1999).

The estimated coefficients of the ratio of non-production workers also have different effects across the four chosen industries in the post-crisis period. In the food and chemical industries, the estimates of the ratio of non-production workers are negative and statistically significant at the 1% level. In the chemical industry, however, the ratio of non-production workers on technical inefficiency is positive and statistically significant at the 1% level, which means that an increase of the ratio of non-production workers leads to increasing technical inefficiency. The positive impact of the ratio of non-production workers on efficiency is also found by Salim (1999) and Hossain and Karunaratne (2004). While there is no change in the direction of the ratio of non-production workers on inefficiency in the food and chemical industries from the pre-crisis to post-crisis period, the direction of the ratio of non-production workers changes in the textile industry.

The last variable affecting inefficiency in this thesis is ownership status. The estimated coefficients of ownership status have negative signs and are statistically significant in all four industries in the pre-crisis period. The negative signs of ownership status suggest that the foreign-owned firms are, on average, less inefficient than domestic firms. The estimates of ownership status are statistically significant at the 1% level in all selected industries, except in the textile industry, which is significant at the 5% level.

In the post-crisis period, the estimated coefficients of ownership status are also negative and statistically significant at the 1% level in the food, textile and chemical industries. These negative effects of ownership status on technical inefficiency confirm findings of Pitt and Lee (1981), Suyanto (2010) and Suyanto *et al.* (2012).

Although the estimation results clearly show that ERP and IMP have different effects on technical inefficiency across four selected industries and across sub-periods, in terms of direction and magnitude, these results do not directly represent the effects of trade reform on total factor productivity (TFP) growth. Conceptually, TFP growth can be decomposed into at least three components, *i.e.*, technical change, scale and efficiency change (Kumbhakar and Lovell 2000, Coelli *et al.* 2005, O'Donnell 2012). The next chapter discusses and analyses the decomposition of TFP growth in the four selected Indonesian manufacturing industries. This discussion presents the various components that contribute to TFP growth in these industries.

Chapter 6
The Decomposition of Total Factor Productivity (TFP) Growth

6.1 Introduction

Chapter 5 discusses the effects of trade reform on firm-level technical efficiency, which is estimated using the stochastic production frontier (SPF). Technical efficiency is defined as a movement in the process of production towards the best-practice frontier without requiring extra inputs. This movement occurs due to various factors, such as the accumulation knowledge in the learning-by-doing process, diffusion of new technology and improved managerial skills. Technical efficiency, as discussed in Chapter 5, is one of the components of TFP growth. However, there are at least two additional sources of productivity growth, namely technological change and scale efficiency change (Coelli *et al.* 2005).

To continue the discussion from the previous chapter, this chapter analyses the decomposition of TFP growth in four selected Indonesian manufacturing industries during the period from 1981 to 2000. This period is crucial because the Indonesian government implemented various trade reform policies, leading the country from strongly inward orientation to outward-oriented economy. The decomposition of productivity growth offers further insights into the sources of productivity growth and whether productivity gains emerge from the efficient use of inputs or through an upward shift in the production technology frontier (technological progress). From this perspective, the decomposition analysis of productivity growth is expected to provide a proper analysis of the four selected Indonesian manufacturing industries, which can help the Indonesian government develop effective trade reform policies. Thus, identifying the sources of productivity growth allows the government to formulate correct policies to be implemented.

The decomposition of productivity growth in this thesis is calculated using the Färe-Primont productivity index proposed by O'Donnell (2012). This index decomposes TFP growth into broader measures compared with other indices, such as Malmquist productivity index. Six components of productivity growth can be derived from this index, unlike conventional index such as the Divisia index and Malmquist productivity index that decompose total factor productivity growth into three main components: technical progress, scale efficiency change and technical efficiency change.[23] Furthermore, this index satisfies all economically relevant axioms and tests from index number theory, including transitivity and identity tests and is a reliable measure for comparing multi-temporal (many periods) and/or multilateral (many firms) indices of TFP and efficiency (O'Donnell 2012).

This chapter consists of six sections. Section 6.2 briefly discusses the measures of productivity and efficiency, followed by the methodology for the decomposition of TFP growth in Section 6.3. Section 6.4 discusses the data used for estimation. Section 6.5 provides the results and analysis of TFP growth and its decomposition in the four selected Indonesian manufacturing industries, and finally, a conclusion is presented in Section 6.6.

6.2 The Measures of Productivity and Efficiency

This chapter analyses the decomposition of productivity change within the aggregate quantity framework of O'Donnell (2010b). This section briefly explains this framework. Let $y_{it} \equiv (y_{1it}, \dots, y_{Kit})$ and $x_{it} \equiv (x_{1it}, \dots, x_{Kit})$ denote vectors of output and input quantities for firm i at time t. Recalling Equation 4.19, the TFP of a firm in the aggregate quantity framework of O'Donnell (2010b), is defined as

$$TFP_{it} = \frac{Y_{it}}{X_{it}} \qquad \textbf{6.1}$$

where $Y_{it} \equiv Y(y_{it})$ is an aggregate output index, $X_{it} \equiv X(x_{it})$ is an aggregate input index, and $Y(.)$ and $X(.)$ are non-negative, non-decreasing and linearly homogenous aggregator functions.

Based on Equation 6.1, the overall productive efficiency of a firm is the ratio of observed TFP to the maximum TFP possible using the available technology. Recalling Equation 4.29, the so-called TFP efficiency of firm i at time t is:

$$TFPE_{it} = \frac{TFP_{it}}{TFP_t^*} = \frac{Y_{it}/X_{it}}{Y_t^*/X_t^*} \qquad \text{(TFP efficiency)} \qquad \textbf{6.2}$$

[23] The Färe-Primont productivity index as proposed by O'Donnell (2012) decomposes the productivity growth into six components, where one of the components is the result of multiplication of the other components. For the decomposition of productivity growth using output-oriented approach, for example, the TFP growth can be decomposed into ΔTFP* (technological progress/technical progress), ΔTFPE (TFP efficiency change), ΔOTE (pure technical progress), ΔOSE (scale efficiency change), ΔOME (mix efficiency change) and ΔOSME (scale mix efficiency change). The letter O in each component means "output-oriented".

where $TFPE_{it}$ is TFP efficiency of firm i at time t, TFP_{it} is the observed TFP, Y_{it} and X_{it} denote the aggregate output and input, TFP_t^* denotes the maximum TFP possible using the period t technology, and Y_t^* and X_t^* denote the aggregate output and aggregate input at the TFP-maximizing point.

Recalling Equations 4.24 to 4.28, other measures of efficiency that feature in an output-oriented decomposition of TFP change are:

$$OTE_{it} = \frac{Y_{it}/X_{it}}{\bar{Y}_{it}/X_{it}} = \frac{Y_{it}}{\bar{Y}_{it}} \quad \text{(output-oriented technical efficiency)} \quad \textbf{6.3}$$

$$OSE_{it} = \frac{\bar{Y}_{it}/X_{it}}{\tilde{Y}_{it}/\tilde{X}_{it}} \quad \text{(output-oriented scale efficiency)} \quad \textbf{6.4}$$

$$OME_{it} = \frac{\bar{Y}_{it}/X_{it}}{\hat{Y}_{it}/X_{it}} = \frac{\bar{Y}_{it}}{\hat{Y}_{it}} \quad \text{(output-oriented mix efficiency)} \quad \textbf{6.5}$$

$$ROSE_{it} = \frac{\hat{Y}_{it}/X_{it}}{TFP_t^*} \quad \text{(residual output-oriented scale efficiency)} \quad \textbf{6.6}$$

$$RME_{it} = \frac{\tilde{Y}_{it}/\tilde{X}_{it}}{TFP_t^*} \quad \text{(residual mix efficiency)} \quad \textbf{6.7}$$

where $\bar{Y}_{it}$ is the maximum aggregate output that is technically feasible when x_{it} is used to produce a scalar multiple of y_{it}. $\hat{Y}_{it}$ is the maximum aggregate output that is feasible when using x_{it} to produce any output vector; $\tilde{Y}_{it}$ and $\tilde{X}_{it}$ are the aggregate output and input obtained when TFP is maximized subject to the constraint that the output and input vectors are scalar multiples of y_{it} and x_{it}, respectively.

The technical efficiency measures given by OTE in Equation 6.3 is usually attributed to Farrell (1957). The scale efficiency measure given by OSE in Equation 6.4 is the conventional measure defined by Balk (2001). The remaining measures of efficiency are first defined by O'Donnell (2008). Other important measure of efficiency is output-oriented scale mix efficiency (O'Donnell 2010b):

$$OSME_{it} = OME_{it} \times ROSE_{it} = OSE_{it} \times RME_{it} \quad \textbf{6.8}$$

where OSME, OME, and ROSE are previously defined.

6.3 The Decomposition of TFP Growth

The measures of efficiency defined in Section 6.2 provide a basis for output-oriented decomposition of a multiplicative index. Recalling Equation 4.20, in the aggregate quantity framework of O'Donnell (2012), TFP is written as follows:

$$TFP_{it} = TFP_{it}^{*} \times TFPE_{it} \quad \textbf{6.9}$$

where TFP_{it} is total factor productivity of firm i at time t, $TFP_{it}^{*} = Y_t^{*}/X_t^{*}$ denotes the maximum TFP possible using the technology available in period t and $TFPE_{it}$ denotes TFP efficiency of firm i at time t. $TFP_{it}^{*} = Y_t^{*}/X_t^{*}$ is a measure of technical progress or technological progress (TP).

The efficiency component can be further decomposed into various measures of efficiency, such as pure technical efficiency, pure scale efficiency and mix efficiency, as in Equation 4.31:

$$TFPE_{it} = \frac{TFP_{it}}{TFP_t^{*}} = \frac{Y_{it}/X_{it}}{Y_t^{*}/X_t^{*}} = OTE_{it} \times OSE_{it} \times RME_{it} = OTE_{it} \times OSME_{it} \quad \textbf{6.10}$$

where OTE, OSE, RME, and OSME are previously defined in Equations 6.3, 6.4, 6.7 and 6.8, respectively.

The decomposition implied by Equations 6.9 and 6.10 is written as follows:

$$TFP_{it} = TFP_t^{*} \times TFPE_{it} = TFP_{it}^{*} \times (OTE_{it} \times OSME_{it}) \quad \textbf{6.11}$$

In Equation 6.11, TFP growth can be decomposed into three different components: technical progress, a technical efficiency change and a scale mix efficiency change. Technical progress is a measure of movements in the production frontier, usually associated with the stock of scientific knowledge and/or other characteristics of the production environment. A technical efficiency change is a component that measures movement towards or away from the frontier, associated with the more effective use of technology and/or changes in the number of error made during the production process. The last component is a scale mix efficiency change, which measures movements around the frontier surface to capture the economies of scale and scope, usually associated with the changes in relative price and/or other production incentives. Other components of TFP decomposition are discussed in O'Donnell

(2012). The diagram of the decomposition of TFP growth in this section is provided in Section 4.3.2. This chapter focuses on the decomposition given by Equation 6.11.

6.4 Data

This chapter computes and decomposes Färe-Primont TFP index for four selected Indonesian industries over the period 1981-2000. The output variable is output of industry (Y) and input variables are capital (K), labour (L), raw materials (M) and energy (E). The definitions and measurements of these variables are explained in Chapter 5. To provide a deeper and broader analysis of the effects of trade reform, the analysis in this chapter is performed at the three-digit ISIC level. All the data used in this analysis are obtained from the Annual Survey of Medium and Large Manufacturing Firms (*Survei Tahunan Statistik Industri Perusahaan Menengah dan Besar* or SI) conducted by the Indonesian Central Board of Statistics (*Badan Pusat Statistik* or BPS).

The data are classified into three separate three-digit industries within both the food industry (ISIC 31) and the chemical industry (ISIC 35). For the textile industry (ISIC 32), the dataset is classified into five-digit industries. For the metal products industry (ISIC 38), the panel data are not divided into sub-sectors because most of firms in this industry belong to ISIC 381 (fabricated metal products, except machinery). The final dataset for this analysis is presented Table 6.1.

Table 6.1: Number of Firms and Observations in the Four Selected Indonesian Manufacturing Industries

Industry	Number of Firms	Number of Observations
ISIC 31 (Food and Beverage)		
1. ISIC 311 (Food Products)	224	4,480
2. ISIC 312 (Food Products n.e.c/not elsewhere classified)	166	3,200
3. ISIC 313+314 (Beverage and Tobacco)	131	2,620
ISIC 32 (Textile)		
1. ISIC 32112 (Sewing Thread)	170	3,400
2. ISIC 32111+32113+32114 (Spinning and Weaving)	63	1,260
3. ISIC 32115 to 32290 (Textile n.e.c/ not elsewhere classified)	58	1,160
ISIC 35 (Chemical)		
1. ISIC 352 (Other Chemical Products)	123	2,460
2. ISIC 355 (Rubber Products)	62	1,240
3. ISIC 351+356 (Industrial Chemical and Plastic Products)	56	1,120
ISIC 38 (Metal Products)	93	1,860

Source: Author's compilation

6.5 Results and Analysis

The TFP decomposition method as described in Sections 6.2 and 6.3 is performed using DPIN 3.0 program developed by O'Donnell (2011). This program uses data envelopment analysis (DEA) program to estimate the Färe-Primont TFP index given by Equations 6.9 to 6.11. The calculation includes the technical, scale and mix efficiency levels as presented in Equations 6.3 to 6.7.

The DEA linear program (LP) is non-parametric, because it does not involve any error terms, which means that it does not have any assumptions regarding the functional form of the production function. Rather, DEA assumes that the frontier is locally linear. The term 'locally linear' is used by O'Donnell (2011) to refer to the fact that if firm i in period t is technically efficient (which means on the frontier), then in the neighbourhood (which means locally) of the point (y_{it}, x_{it}) the frontier takes the form $y'_{it}\alpha = \gamma + x'_{it}\beta$ (which is linear).[24] In this analysis, DPIN is set to

[24]As in Equation 4.36, in a linear format for firm i in period t, the (local) output distance function production frontier can be expressed as: $D_O = (x_{it}, y_{it}, t) = (y'_{it}\alpha)/(\gamma + x'_{it}\beta)$.

allow for technical progress in some years and technical regress in other years. It is also set to allow for variable returns to scale.[25]

The analysis of TFP decomposition in each sub-section is divided into four periods of trade reform development in the Indonesian economy from 1981 to 2000. These four periods are as follows:

- 1981-1985: strongly inward oriented
- 1985-1992: early reform
- 1992-1996: further reform
- 1996-2000: the economic crisis period

6.5.1 Decomposition of TFP Growth in the Indonesian Food Industry (ISIC 31)

Table 6.2 shows the average annual rates of growth in TFP and its components in the Indonesian food industry. The results of the average annual growth of TFP in this table are calculated based on the levels/scores for TFP and its components from DPIN 3.0. The levels of TFP and its component for selected years and the calculation of total change over each sub-period are presented in Appendix 6.1. The firm-specific, time-varying results are not presented here due to space limitations but can be obtained from the author upon request.

From the estimates, in the Indonesian food industry (ISIC 31), TFP grew by an annual average of 1.09% over the full period. The growth was mostly driven by technical progress, with an annual average growth rate of 2.43%. Technical efficiency and scale mix efficiency contributed negatively to TFP growth (annual averages -0.95% and -0.40% per year, respectively). These results confirm the findings of Ikhsan (2007), although he decomposes TFP growth based on stochastic frontier analysis (SFA) as proposed by Kumbhakar and Lovell (2000). The results regarding efficiency also similar to the finding of Suyanto (2010), who also finds negative annual growth rates of technical efficiency, although he uses Malmquist productivity index to decompose TFP growth. However, a different result from this thesis is found by Suyanto (2010) , who finds positive growth rates. The results of this thesis also differ from the findings of Margono and Sharma (2006), who use

[25] Technical regress may occur when different output-input mixes are used during the same period by different firms within an industry and it may take several years for a new technology completely displace the previous one (Nin *et al*. 2003).

SFA as proposed by Kumbhakar and Lovell (2000) and find that TFP growth rates are positive, with negative annual growth rates of technical and positive annual growth rates of scale efficiency.[26]

Dividing the observed years into four sub-periods, in the food industry (ISIC 31), Table 6.2 shows that the average annual growth of TFP was higher in the inwardly oriented period (1981-1995) than in the two other sub-periods (early reform and further reform). Generally, technological progress was the key contributor to TFP growth, except in the inwardly oriented period, where technical efficiency was the main driver of TFP growth. The results showing that during the further reform period, the main contributor to TFP growth was technological progress are consistent with the findings of Ikhsan (2007) and Suyanto (2010).[27]

[26] While Ikhsan (2007) and Suyanto (2010) decomposes TFP growth and its components from 1988 to 2000, Margono and Sharma (2006) decomposes TFP and its components from 1994 to 2000.

[27] There is a slight difference of periodization between this thesis and Ikhsan (2007) and Suyanto (2010) empirical studies. Ikhsan (2007) and Suyanto (2010) classify 1988-1992, 1993-1996, and 1997-2000 as the early liberalization, the second part of liberalization, and the crisis period.

Table 6.2: Average Annual Rates of Growth in TFP and Components (%) in the Indonesian Food Industry (ISIC 31)

Sub-sector/Industry	1981 – 1985 (inward oriented)	1985 – 1992 (early reform)	1992 – 1996 (further reform)	1996 – 2000 (economic crisis)	1981 - 2000
ISIC 311: Food Products					
TFP	3.11	0.69	-0.54	0.06	0.81
TP	0.39	2.85	10.10	7.19	4.77
OTE	-2.44	-1.18	-7.64	-2.07	-2.99
OSME	5.16	-0.99	-2.97	-5.06	-0.97
ISIC 312: Food Products n.e.c					
TFP	3.92	-0.93	1.56	0.06	0.82
TP	-5.84	5.14	-12.55	6.74	-0.56
OTE	6.36	-6.00	14.23	-7.30	0.59
OSME	3.38	-0.06	-0.12	0.62	0.79
ISIC 313 + 314: Beverage+Tobacco					
TFP	6.62	0.55	1.21	-1.08	1.62
TP	9.89	-2.66	8.91	0.53	3.09
OTE	0.75	-4.48	1.70	3.33	-0.43
OSME	-3.99	7.67	-9.40	-4.91	-1.03
ISIC 31: Food Industry					
TFP	4.55	0.10	0.74	-0.32	1.09
TP	1.48	1.78	2.15	4.82	2.43
OTE	1.56	-3.89	2.76	-2.01	-0.95
OSME	1.52	2.20	-4.17	-3.12	-0.40

Source: Author's calculation from the output of DPIN 3.0
Note : n.e.c : not elsewhere classified

In contrast to the three sub-periods of liberalization, TFP decreased by an average of -0.32% per year during the crisis period (1996-2000). This negative productivity growth was driven by technical efficiency and scale mix efficiency. Although technological progress was positive during this crisis period, relatively large decreases in technical efficiency and scale mix efficiency, by an average -2.01% and -3.12% per year, respectively, drove down TFP growth. This negative annual growth rate of TFP growth in the Indonesian food industry supports the findings of Margono and Sharma (2006), Ikhsan (2007), and Suyanto (2010).[28]

Looking at TFP growth in the three-digit food industry, Table 6.3 shows that during the whole period, the overall growth in the Indonesian food industry was led by beverage and tobacco industries (1.62% per year), followed by food products n.e.c (not elsewhere classified) and food products industries, which show growth by 0.82% and 0.81% per year, respectively. Generally, the main driver of TFP growth was technological progress, except in the Indonesian food products n.e.c, where scale mix efficiency was the main contributor to TFP growth.

Comparing the productivity growth of the three sub-sectors across sub-periods of trade liberalization in the Indonesian food industry, it is apparent that the annual rates of TFP growth in the inwardly oriented period (1981-1985) were higher than those in the other three sub-periods. It is also clear that the economic crisis had different effects on these three sub-sectors. While a negative annual TFP growth rate is found for Indonesian beverage and tobacco, in the food products and food products n.e.c, the average annual growth rates of TFP growth are found to be positive, although they are lower than those in the inwardly oriented policy period.

Three important points can be observed from Table 6.2. The first is that there is a high variability in the TFP growth rate components in the sub-periods. The main reason for this high variability is the large variation in the estimated measures of technical progress. As indicated by O'Donnell (2010a), the reasons for this high variability in the estimates are threefold. First, recall that technical progress is a broad measure of the change in production possibilities that is caused by any changes in the environment, in which production process occurs. Thus, the measure will

[28] Margono and Sharma (2006) decompose TFP growth using SFA and calculate TFP growth over the period 1994 to 2000. They divide the sample into two sub-periods: before and after the economic crisis.

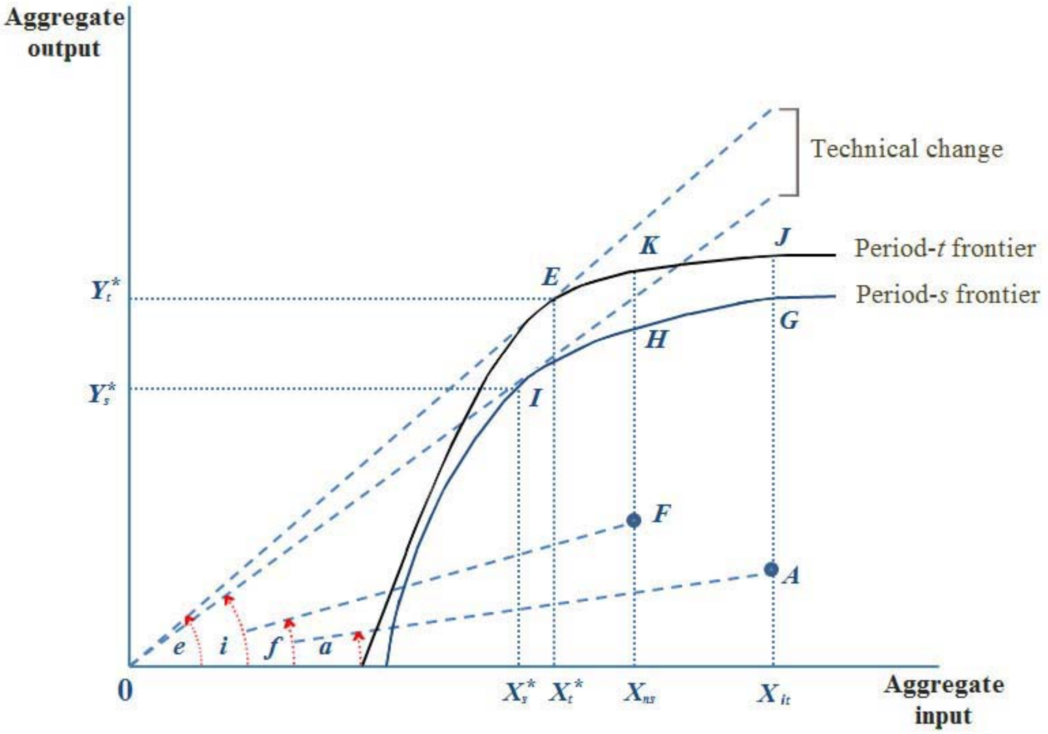
capture variations in technical know-how and variations in any factors that are not accounted for by the input and output variables that have been included in the analysis, such as new stocks of scientific discovery and technical knowledge. A related aspect of technical progress is environmental factor, which include anything from labour quality to government policies. If such environmental factors are favourable for the Indonesian food industry, then the maximum output possible using any given level of inputs is higher than the maximum output possible when environmental conditions are poor. In this context, favourable environmental conditions are a form of technical progress (O'Donnell 2012).

The second reason of the high variability in technical progress is that DEA is used to estimate the production frontier, and DEA makes no allowance for statistical noise beyond the firm’s control, such as errors in measurement, strikes, luck, unusual weather conditions and omitted variables. These factors may have effects on the value of TFP.

The last reason for high variability in technical progress is related to the definition of technical progress from one period to another. As presented in Section 4.3 and presented in Figure 6.1, technical progress is measured as the difference in TFP at points I and E. When TFP at these points is estimated using DEA, the measure will be sensitive to the measured TFP of one firm that is identified as TFP-maximizing in each period. Table 6.3 reports TFP maximizing firms for selected years in the three sub-sectors of the Indonesian food industry. For example, from 1992 to 1996 in the food products sub-sector, technical progress increased by 50% (i.e., TP = 0.13/0.09 = 1.50).[29] This table reveals that TFP was maximized by firm 207 and firm 173, in 1992 and 1996, respectively. The average rate of technical progress from 1992 to 1996 was 10.10% per annum.

[29] The increase in TP from 1992 to 1996 is 50 %, which is calculated from (1.50-1)*100.

Figure 6.1: Technical Progress (TP)



Source: Figure 6 (O'Donnell 2010a, p.537).

Table 6.3: Technical Progress (TP): Maximizing Firms in the Indonesian Food Industry (ISIC 31), selected years

Year/Sub-sector		ISIC 311: Food Products	ISIC 312: Food Products n.e.c	ISIC 313+314: Beverage and Tobacco	ISIC 31: Food Industry
1981	Firm ID	85	59	166	
	TP	0.07	0.19	0.21	0.14
1985	Firm ID	88	6	302	
	TP	0.07	0.15	0.32	0.15
1992	Firm ID	207	159	166	
	TP	0.09	0.22	0.26	0.17
1996	Firm ID	173	159	166	
	TP	0.13	0.13	0.37	0.19
2000	Firm ID	209	24	166	
	TP	0.17	0.17	0.38	0.23

Source: Author's calculation from DPIN 3.0

The second important point that can be observed from Table 6.2 is that there is less variation across components for the full period than for the sub-periods. This is due to lessening the impact of annual variation in TFP value and its components for individual.

The last important point from Table 6.2 is that there is less variation across components of TFP growth for the aggregated industry (two-digit industry) than for the sub-sectors (three-digit industry). Regarding the comparison of TFP variations for sub-periods to TFP variations for the full period, the TFP values and their components for the sub-sectors in the industry are less than in the aggregated food industry.

To evaluate whether the policy reforms taken by the government in each sub-period have different impact from other sub-periods, this thesis uses means of TFP and its components to compare sub-periods. Unlike the analysis of TFP and its components in Table 6.2, which focuses of the findings in terms of growth, the analysis of the impact of policy reforms on TFP and its components in each sub-period is conducted by focussing on levels. Thus, the analysis uses the means of the levels of TFP and its components.

To test statistically whether the means of TFP and its component are different between sub-periods, two tests are used in this study: the F-test and the t-test. The tests are as follows:

1. F-test

This test is used to determine whether the means of TFP and its components in different sub-periods are equal. The hypothesis tested is as follows:

$H_0 : \mu_1 = \mu_2 = \mu_3 = \mu_4$ **6.12**

H_a : the means are not equal **6.13**

where:

μ_1 = the mean of TFP/TP/OTE/OSME for period 1981-1985 (inwardly oriented policy)

μ_2= the mean of TFP/TP/OTE/OSME for period 1986-1992 (early reform)

μ_3= the mean of TFP/TP/OTE/OSME for period 1993-1996 (further reform)

μ_4= the mean of TFP/TP/OTE/OSME for period 1997-2000 (economic crisis period)

The alternative hypothesis in Equation 6.13 captures any difference in the means and includes, for example, the situation where all four of the means are unequal, where one is different from the other three or where two are different. Thus, the alternative hypothesis captures all the possible situations other than equality of all the means specified in the null hypothesis.

2. t-test. Two t-tests are used in this thesis:

2.a. The first t-test is used to test whether the mean for one sub-period and the means of all other sub-periods are equal. This test can be used to identify which sub-periods are distinctly different from other periods.

The hypotheses are as follows:

$H_0 : \mu_1 = \mu$, $H_a : \mu_1 \# \mu$ **6.14**

$H_0 : \mu_2 = \mu$, $H_a : \mu_2 \# \mu$ **6.15**

$H_0 : \mu_3 = \mu$, $H_a : \mu_3 \# \mu$ **6.16**

$H_0 : \mu_4 = \mu$, $H_a : \mu_4 \# \mu$ **6.17**

where $\mu_{1,}$ $\mu_{2,}$ $\mu_{3,}$ and μ_4 are previously defined, and μ is the mean of all other sub-periods.

2.b. The second t-test is used to test whether the mean for one sub-period and another sub-period is equal. The hypotheses are as follows:

$H_0 : \mu_1 = \mu_{2,}$ $H_a : \mu_1 \# \mu_2$ **6.18**

$H_0 : \mu_2 = \mu_{3,}$ $H_a : \mu_2 \# \mu_3$ **6.19**

$H_0 : \mu_3 = \mu_{4,}$ $H_a : \mu_3 \# \mu_4$ **6.20**

where: $\mu_{1,}$ $\mu_{2,}$ $\mu_{3,}$ and μ_4 are previously defined

The results of the F-test for the Indonesian food industry are presented in the Appendix 6.2. All the tests are conducted at the 5% significance level. The results vary across sub-sectors. At the two-digit level (food industry), the results show that H_0 is rejected for TFP, TP, and OSME, suggesting that the means of TFP, TP, and OSME are not equal. At the sub-sector level, H_0 is rejected for TFP and OTE in the food products n.e.c industry. In the beverage and tobacco industries, H_0 is rejected for TFP, TP, and OSME. In the food products sub-sector (ISIC 311), H_0 is accepted for TFP and all the components, meaning that all the means are equal.

The next test is the t-test. The first t-test examines whether the mean of TFP and its components for one sub-period is equal to the mean for all the other sub-periods. All tests are conducted at the 5% significance level. The results of this test are presented in Appendix 6.3. The results vary across TFP and its components and across sub-sectors. When comparing the mean of TFP and its components for one sub-period and all the other sub-periods, the results also vary. The results, for sub-periods where H_0 is rejected, show that the mean of TFP and its components can be below or above the mean TFP and its components for all the other sub-periods.

At the aggregated industry level (food industry/ISIC 31), H_0 is rejected for TFP in the inwardly oriented and further reform periods, suggesting that in these two periods, at the 5% of significance level, the means of TFP are significantly different from other years. While in the inwardly oriented period, the mean of TFP is below the overall mean, in the further reform period, the mean of TFP is above the overall mean. Table 6.4 shows these results. The t-test for hypothesis in Equation 6.14 is employed by using the levels of data of TFP from the output of DPIN 3.0.

Table 6.4: Example of the first t-test, which compares the mean of TFP for one sub-period with the means of all other sub-periods in the Indonesian Food Industry (ISIC 31), at the 5% significance level

Year	Hypothesis $H_0 : \mu_1 = \mu$, $H_a : \mu_1 \# \mu$		Hypothesis $H_0 : \mu_4 = \mu$, $H_a : \mu_4 \# \mu$	
	Inward Oriented	Other	Further Reform	Other
1981	0.0222			0.0222
1982	0.0241			0.0241
1983	0.0256			0.0256
1984	0.0232			0.0232
1985	0.0267			0.0267
1986		0.0263		0.0263
1987		0.0255		0.0255
1988		0.0247		0.0247
1989		0.0259		0.0259
1990		0.0276		0.0276
1991		0.0277		0.0277
1992		0.0268		0.0268
1993		0.0276	0.0276	
1994		0.0280	0.0280	
1995		0.0265	0.0265	
1996		0.0277	0.0277	
1997		0.0284		0.0284
1998		0.0262		0.0262
1999		0.0255		0.0255
2000		0.0273		0.0273
Mean	0.0243	0.0267	0.0274	0.0258
t stat		-2.8165		2.9755
t critical value two tail		2.5706		2.1604
Conclusion		Reject the null hypothesis		Reject the null hypothesis

Source: Author's calculation from the output of DPIN 3.0

H_0 is also rejected for TP and OTE in both the inwardly oriented and the economic crisis period, meaning that at the 5% significance level, the means of TP and OTE are significantly different from the overall mean. For TP, the means are below and above the overall mean in the inwardly oriented and the economic crisis periods, respectively. For OTE, the means are above and below the overall mean in the inwardly and economic crisis periods, respectively. For OSME, H_0 is rejected for the further reform and economic crisis periods, suggesting that at the 5% significance level, the means of OSME in these two sub-periods are significantly different from the overall mean. While in the further reform period, the mean of OSME is higher than the overall mean, in the economic crisis period, the mean of OSME is below the overall mean. The summary of these results is presented in Appendix 6.3.

At the disaggregated industry level, the results of the t-test examining whether the mean of TFP/OTE/OSE/OSME is significantly different from the overall mean show that in the food products industry (ISIC 311), H_0 is rejected for TFP in the inwardly oriented and further reform periods. While in the inwardly oriented period, the mean of TFP is below the overall mean, in the further reform period, it is above the overall mean. H_0 is rejected for TP and OTE in the inwardly oriented period; the means for TP and OTE are below and above the overall mean, respectively. H_0 is rejected for OSME in the inwardly oriented and economic crisis periods; the means of OSME are above and below the overall mean in the inwardly oriented and economic crisis periods, respectively.

In the Indonesian food products n.e.c industry (ISIC 312), H_0 is rejected for TP and OTE. The mean of TP is below the overall mean in the further reform period. For OTE, the means are above and below the overall mean in the further reform and economic crisis periods, respectively.

In the beverage and tobacco industries (ISIC 313 and 314), H_0 is rejected for TFP and OTE in the inwardly oriented and further reform periods. The means of TFP are below and above the overall mean in the inwardly oriented and further reform periods, respectively, while the means of OTE are below and above the overall mean in the inwardly oriented and further reform periods, respectively. H_0 is rejected for OSME in the early reform and economic crisis periods. While in the early reform, the mean of OSME is above the overall mean, in the economic crisis, it is below the overall mean. H_0 is rejected for TP in the economic crisis period only and is above the overall mean.

The second t-test is used to examine whether there is a difference in the mean of TFP and its components between two sub-periods, as provided in Equations 6.18 and 6.20. The results of this test are presented in Appendix 6.4. In the food industry (ISIC 31), hypothesis in Equation 6.20 is rejected for TP and OSME, meaning that the means of TP and OSME in the further reform period are significantly different from the means of TFP and OSME in the economic crisis period. While for TP, the mean in the further reform is below the mean of TP in the economic crisis period, for OSME, the mean in the further reform period is above its mean in the economic crisis period. Table 6.5 shows these results.

Table 6.5: Example of the second t-test, which compares the means of TP and OSME for one sub-period with another sub-period in the Indonesian Food Industry (ISIC 31), at the 5% significance level.

TP Hypothesis $H_0 : \mu_3 = \mu_4,\ H_a : \mu_3 \# \mu_4$				OSME Hypothesis $H_0 : \mu_3 = \mu_4,\ H_a : \mu_3 \# \mu_4$			
Year	Further Reform	Year	Crisis	Year	Further Reform	Year	Crisis
1993	0.1650	1997	0.2530	1993	0.3421	1997	0.2508
1994	0.1893	1998	0.2299	1994	0.3334	1998	0.2428
1995	0.1928	1999	0.2458	1995	0.3240	1999	0.2653
1996	0.1862	2000	0.2258	1996	0.3274	2000	0.2890
Mean	0.1833		0.2386		0.3317		0.2620
t stat			-6.1587				6.3987
t critical value two tail			2.4469				2.7764
Conclusion			Reject the null hypothesis				Reject the null hypothesis

Source: Author's calculation from the output of DPIN 3.0

The results in Table 6.5 are different from Table 6.2. While the calculation of the t-test in Table 6.5 is based on the means of levels of TP and OSME, the calculation in Table 6.2 is based on the average of growth rates of the levels of TP and OSME.[30] Thus, the same output of levels of TFP and OSME from DPIN 3.0 are used for different analyses. Unlike the method of the average annual growth rates that the calculation is based on two points of data (the first and the end of sub-period) and does not accommodate the fluctuation between the two points of data, the evaluation of policy reform is based on the means of the levels of TFP and its components, which accommodates the fluctuation of the levels of TFP and its components each year. This evaluation can provide important additional insights into the drivers of productivity and efficiency change.

For example, in terms of levels (Table 6.5), the means of TP in the further reform period and economic crisis periods are 0.1833 and 0.2386, respectively, which means that the mean of TP in the further reform is below the mean in the economic crisis and the means of TP in both sub-periods are significantly different.[31] In terms of

[30] It is mentioned previously that the calculation in Table 6.5 is to examine whether the mean for one sub-period is statistically different from another sub-period and the calculation in Table 6.2 is to analyse the average of growth rates for each sub-periods and the whole period.

[31] The mean of TP in the further reform period (1993-1996) is 0.1833 = (0.1650+0.1893+0.1982+0.1862)/4 and the mean of TP in the economic crisis period (1997-2000) is 0.2386 = (0.2530+0.2299+0.2458+0.2258)/4.

growth rates (Table 6.2), TP increased by an average of 2.15% and 4.82% per annum in the further reform period and economic crisis, respectively.[32]

Another example is for OSME. In terms of levels (Table 6.5), the means of OSME in the further reform period and economic crisis are 0.3317 and 0.2620, respectively, which means that the mean of OSME in the further reform is above the mean in the economic crisis the means of TP in both sub-periods are significantly different. In terms of growth rates (Table 6.2), OSME decreased by an average of -4.17% and -3.12% per annum in the further reform period and economic crisis, respectively, which means that the average annual growth rate of OSME in the further reform period was lower than the average annual growth rate of OSME in the economic crisis period. The negative of the annual average growth rates of OSME were because of the decreased in the levels of OSME from 0.3868 in 1992, 0.3274 in 1996 and 0.2896 in 2000.

Hypotheses in Equations 6.18 to 6.20 are accepted for the Indonesian food products (ISIC 311) across TFP and its component, suggesting that in this sub-sector there is no difference in the mean of TFP and its components between sub-periods. In the food products n.e.c (ISIC 312), the results show that hypothesis in Equation 6.20 is rejected for OTE only, suggesting that the mean of OTE in the further reform is significantly different form the mean of OTE in the economic crisis period. In this case, the mean of TP in the further reform period is higher than it is in the economic crisis period. The summary of results of this test is presented in Appendix 6.4.

In the Indonesian beverage and tobacco industries, hypotheses in Equations 6.18 to 6.20 are rejected for TFP and TP, respectively. While for TFP, the mean of TFP in the inwardly oriented period is below the mean in the early reform period, for TP, the mean in the early reform period is above the mean in the further reform period. For OTE, hypothesis 6.20 is rejected, meaning that the mean of OTE in the further reform is below the mean of OTE in the economic crisis period. For OSME, hypotheses in Equations 6.18 to 6.20 are rejected. The findings reveal that the mean of TFP in the inwardly oriented period is below the mean in the early reform period,

[32] The average annual rate of TP in the further reform period (1992-1996) is $\Delta TP = \frac{\ln(TP_{1996}/TP_{1992})}{(1996-1992)} = \frac{\ln(0.1862/0.1708)}{4} = 0.0215$ or 2.15% per annum. The average annual rate of TP in the economic crisis period (1996-2000) is $\Delta TP = \frac{\ln(TP_{2000}/TP_{1996})}{(2000-1996)} = \frac{\ln(0.2258/0.1862)}{4} = 0.0482$ or 4.82% per annum.

and the mean of OSME in the further reform period is above the mean in the economic crisis period. The summary of results of this test is presented in Appendix 6.4.

6.5.2 Decomposition of TFP Growth in the Indonesian Textile Industry (ISIC 32)

Having discussed the decomposition of TFP growth in the Indonesian food industry, this section now discusses the decomposition of TFP growth in the Indonesian textile industry. Table 6.6 shows the average annual rates of growth for TFP and its components in the Indonesian textile industry. The results of the average annual growth rates in this table are calculated based on the levels/scores for TFP and its components from DPIN 3.0. The levels of TFP growth and its component for selected years and the calculation of total change over each sub-period are presented in Appendix 6.5. The firm-specific, time-varying results are not presented here due to space limitations but can be obtained from the author upon request.

From the estimates, in the Indonesian textile industry (ISIC 32), TFP grew by annual average of 2.86% over the full period. The growth was mostly driven by technical progress, with an annual average of 3.49%. Technical efficiency and scale mix efficiency contributed negatively to TFP growth (annual average -0.42% and -0.21% per year, respectively).

The positive annual growth rate of TFP supports the findings of Ikhsan (2007) and Suyanto (2010), who decompose TFP growth rate in the Indonesian textile industry from 1988 to 2000. Both of these studies find that technological progress was the main driver for TFP growth. Further, similar to this thesis, Ikhsan (2007) also finds that technical efficiency and scale efficiency showed negative growth. There is a slight difference between the results of this thesis and those of Suyanto (2010), who finds that the annual technical efficiency growth was negative but the annual growth rate of scale efficiency was positive. The results of this thesis differ from the findings of Margono and Sharma (2006), who decompose TFP growth of the Indonesian textile industry over from 1994 to 2000 and find that the annual growth rate of TFP was negative during that period, with a positive contribution of growth in technical efficiency and negative growth in scale efficiency.

Table 6.6: Average Annual Growth Rates of Growth in TFP and Components (%) in the Indonesian Textile Industry (ISIC 32)

Sub-sector/Industry	1981 – 1985 (inward oriented)	1985 – 1992 (early reform)	1992 – 1996 (further reform)	1996 – 2000 (economic crisis)	1981 - 2000
ISIC 32112: Sewing Thread					
TFP	2.07	1.33	-0.31	2.45	1.38
TP	-6.41	6.33	13.63	-16.30	0.42
OTE	0.53	-1.79	-9.39	6.89	-1.07
OSME	7.94	-3.20	-4.57	11.86	2.03
ISIC 32111+32113+32114: Spinning and Weaving					
TFP	-2.38	4.54	0.81	6.72	2.76
TP	6.91	-5.01	8.43	8.50	3.17
OTE	-5.49	4.48	-7.84	3.83	-0.35
OSME	-3.80	5.07	0.22	-5.62	-0.07
ISIC 32115 to 32290: Textile n.e.c					
TFP	4.57	4.97	5.53	2.28	4.44
TP	12.78	1.03	13.68	4.35	6.87
OTE	-2.15	2.51	-6.25	4.70	0.15
OSME	-6.05	1.42	-1.89	-6.78	-2.58
ISIC 32: Textile Industry					
TFP	1.42	3.61	2.01	3.81	2.86
TP	4.43	0.78	11.92	-1.15	3.49
OTE	-2.37	1.73	-7.82	5.14	-0.42
OSME	-0.64	1.10	-2.08	-0.18	-0.21

Source: Author's calculation from the output of DPIN 3.0

Comparing the productivity growth across sub-periods at the two-digit level of textile industry, the estimates for TFP growth show that the highest annual TFP growth rate was during the economic crisis period (1996-2000). During this period, the main contributor to TFP growth was technical efficiency, while the annual growth rates technical and scale mix efficiency were negative. The positive annual rate of TFP growth during the economic crisis contradicts the findings of Margono and Sharma (2006), Ikhsan (2007) and Suyanto (2010), who find that TFP annual growth rates were negative during the economic crisis.

It is also apparent from Table 6.6 that the annual rates of TFP growth in the Indonesian textile industry (ISIC 32) were higher in the early reform period than in the inwardly oriented period. TFP growth in the further reform period (1992-1996) is found to have to be lower compared with the early period of reform (1985-1992). The main driver of TFP growth varies across sub-periods. The findings that the annual TFP growth rates were positive during the early and further reform periods are in line the findings of Ikhsan (2007) and Suyanto (2010).

Looking at TFP growth in the sub-sectors of textile industry, Table 6.6 shows that during the whole period, the overall growth in the Indonesian textile industry was led by the textile n.e.c industry (4.44% per year), followed by the spinning and weaving industry and the sewing thread industry, which showed 2.76% and 1.38% per year, respectively. Generally, the main driver of TFP growth was technological progress, except in the Indonesian sewing thread industry, where scale mix efficiency was the main driver of TFP growth.

Comparing the productivity growth across sub-periods and across sub-sectors, Table 6.6 shows that all three sub-sectors of the Indonesian textile industry had positive annual growth rates during the economic crisis. In the sewing thread and the spinning and weaving industries, the highest annual growth rates occurred during the economic crisis. In the textile n.e.c (not elsewhere classified) industry, the TFP annual growth rate was still positive, although slower compared with the TFP growth rates in the other three sub-periods in this sub-sector.

Similar to the case for the Indonesian food industry, there are also three important points to be noted from Table 6.6. First, there is high variability in the growth components of TFP in the different sub-periods. One of the reasons for these results is the influence of changing the individual firm that operates as the TFP-maximizing firms over the study period. Table 6.7 reports the TFP maximizing firms for selected years in the three sub-sectors of the Indonesian textile industry. For example, from 1992 to 1996 in the textile n.e.c sub-sector, technical progress increased by 73% (i.e., TP = 0.28/0.16 = 1.73).[33] This table shows that maximum TFP is achieved by firm 16 in 1992 and by firm 25 in 1996. The average rate of technical progress from 1992 to 1996 is 13.68% per year. Another reason for high variability in technical progress, as discussed in Section 6.5.1, is that all environmental conditions are included in this measure. Further, DEA does not include measurement errors or other sources of statistical noise, which may be responsible for the identity of the TFP-maximizing firm changing from year to year.

The other two important points can be observed from Table 6.6, as discussed in the Indonesian food industry, are that there is less variation across components over the full period than for the sub-periods and that there less variation across components for the aggregated industry than for the sub-sectors.

Table 6.7: Technical Progress (TP): Maximizing Firms in the Indonesian Textile Industry (ISIC 32), selected years

Year/Sub-sector		ISIC 32112: Sewing Thread	ISIC 32111+32113+32114: Spinning and Weaving	ISIC 32115 to 32290: Textile n.e.c.	ISIC 32: Textile Industry
1981	Firm ID	10	183	151	
	TP	0.12	0.14	0.09	0.11
1985	Firm ID	149	46	142	
	TP	0.09	0.18	0.15	0.14
1992	Firm ID	88	217	16	
	TP	0.14	0.13	0.16	0.14
1996	Firm ID	8	36	25	
	TP	0.25	0.18	0.28	0.23
2000	Firm ID	47	179	16	
	TP	0.13	0.25	0.33	0.22

Source: Author's calculation from DPIN 3.0

To evaluate whether the policy reforms in each sub-period have different impact from other sub-periods, similar to what have been done in the Indonesian food industry, the F-test and the t-test are used. These tests are conducted in terms of levels. The results of the F-test for the Indonesian food industry are presented in Appendix 6.6. The results vary for TFP and its components across sub-sectors. The

[33] The increase in TP from 1992 to 1996 is 73%, which is calculated from (1.73-1)*100.

hypothesis in Equation 6.12 is rejected for TFP, TP, and OSME at the aggregated industry level (textile industry/ISIC 32) and for the textile n.e.c. In the sewing thread and the spinning and weaving industries, H_0 in Equation 6.12 is rejected for TFP. The rejection of H_0 for TFP and its components in these sub-sectors suggest that the means of TFP/TP/OSME are not equal across sub-periods.

To test which sub-periods are different statistically from the overall mean, Equations 6.14 to 6.17 are used. The results are presented in Appendix 6.6. The results of these hypotheses also vary for TFP and its components across sub-sectors. At the aggregated level for textile (ISIC 32), hypotheses in Equations 6.14, 6.16, and 6.17 are rejected for TFP, suggesting that the means of TFP in the inwardly oriented, further reform and economic crisis periods are significantly different from the overall means of TFP for the full period. While the mean of TFP in the inwardly oriented period is below the overall mean, in the further reform and the economic crisis periods, the means of TFP are above the overall mean. Table 6.8 shows these results.

Table 6.8: Example of the first t-test, which compares the mean of TFP for one sub-period with the means of all other sub-periods in the Indonesian Textile Industry (ISIC 32), at the 5% significance level

Year	Hypothesis $H_0 : \mu_1 = \mu$, $H_a : \mu_1 \# \mu$		Hypothesis $H_0 : \mu_3 = \mu$, $H_a : \mu_3 \# \mu$		Hypothesis $H_0 : \mu_4 = \mu$, $H_a : \mu_4 \# \mu$	
	Inward Oriented	Other	Further Reform	Other	Economic Crisis	Other
1981	0.0341			0.0341		0.0341
1982	0.0313			0.0313		0.0313
1983	0.0342			0.0342		0.0342
1984	0.0368			0.0368		0.0368
1985	0.0361			0.0361		0.0361
1986		0.0389		0.0389		0.0389
1987		0.0395		0.0395		0.0395
1988		0.0401		0.0401		0.0401
1989		0.0457		0.0457		0.0457
1990		0.0468		0.0468		0.0468
1991		0.0463		0.0463		0.0463
1992		0.0464		0.0464		0.0464
1993		0.0460	0.0460			0.0460
1994		0.0482	0.0482			0.0482
1995		0.0498	0.0498			0.0498
1996		0.0503	0.0503			0.0503
1997		0.0548		0.0548	0.0548	
1998		0.0523		0.0523	0.0523	
1999		0.0536		0.0536	0.0536	
2000		0.0586		0.0586	0.0586	
Mean	0.0345	0.0478	0.0486	0.0435	0.0548	0.0419
t stat		-7.6422		2.2344		6.2557
t critical value two tail		2.1098		2.1009		2.1788
Conclusion		Reject the null hypothesis		Reject the null hypothesis		Reject the null hypothesis

Source: Author's calculation from the output of DPIN 3.0

Hypotheses 6.14 and 6.17 are rejected for TP. While in the inwardly oriented period, the mean of TP is below the overall mean, in the economic crisis period, the mean of TP is above the overall mean. Hypothesis 6.16 is rejected for OSME, where the mean of OSME in the further reform period is above the overall mean. The summary of these results is in Appendix 6.7.

At the sub-sector level, the results show that hypotheses 6.14 and 6.17 are rejected for TFP in the sewing thread industry. The means of TFP in the inwardly oriented and economic crisis are lower and higher than the overall mean, respectively. Hypothesis 6.14 is also rejected for OSME in the sewing thread industry, where the mean is below the overall mean of OSME. Similar results are also found for the spinning and weaving industry, where hypotheses 6.14 and 6.17 are rejected for TFP and hypothesis 6.14 is rejected for OSME.

In the textile n.e.c industry, at least two of the hypotheses in Equations 6.14 to 6.17 are rejected for TFP and its components, except for OTE, where all the hypotheses in Equations 6.14 to 6.17 are accepted. H_0 in Equations 6.14, 6.16 and 6.17 is rejected for TFP. While the mean of TFP is below the overall mean in the inwardly oriented period, in the further reform and economic crisis period, the means of TFP are above the overall mean. For TP, the means are below and above the overall mean in the inwardly oriented and economic crisis periods, respectively. For OSME, the means of OSME are above and below the overall mean of OSME in the further reform and economic crisis, respectively.

Moving to the results of the t-tests comparing the means between one sub-period and other sub-periods, the results vary for TFP and its components across sub-sectors. The results are presented in Appendix 6.8. At the aggregated level (textile industry/ISIC 32), the hypothesis in Equation 6.18 is rejected for TFP, where the mean of TFP in the inwardly period is below the mean of TFP in the early reform period. Table 6.9 shows these results.

There are different results between Table 6.9 and Table 6.6. These two tables analyse TFP from different method but the same output levels from DPIN 3.0. While Table 6.9 uses the mean of the levels of TFP to test whether the mean of TFP for one sub-period is statistically from another sub-period, Table 6.6 uses the average annual growth to analyse the growth in each sub-period. The evaluation of policy reform based this method can add more information concerning TFP and its components.

For example, in terms of levels (Table 6.9), the means of TFP in the inwardly oriented and early reform are 0.0345 and 0.043, respectively, and the t-test result show that there are significant differences between the means of TFP in these sub-periods.[34] In terms of growth rates (Table 6.6), the average annual growth rates of TFP in the inwardly oriented and early reform periods are 1.42% and 3.61%, respectively.[35]

The hypotheses in Equations 6.18 and 6.20 are rejected for TFP, where the means of TFP in the early reform and further reform periods are below the mean of TFP in the further reform and economic crisis periods, respectively. Table 6.9 shows these results.

[34] The mean of TFP in the inwardly oriented period (1981-1985) is 0.0345 = (0.0341+0.313+0.342+0.0368+0.0361)/5 and the mean of TFP in the early reform is 0.0434 = (0.0389+0.0395+0.0401+0.0457+0.0468+0.0463+0.0464)/7.

[35] The average annual rate of TFP in the inwardly oriented period (1981-1985) is $\Delta TFP = \frac{(TFP_{1985}/TFP_{1981})}{1985-1981} == \frac{ln(0.0361/0.0341)}{4}$ 0.0142 or 1.42% per annum. The average annual rate of TFP in the early reform period (1985-1992) is $\Delta TFP = \frac{(TFP_{1992}/TFP_{1985})}{1992-1985} = \frac{ln(0.0464/0.0361)}{7} = 0.0361$ or 3.61% per annum.

Table 6.9: Example of the second t-test, which compares the means of TFP for one sub-period with another sub-period in the Indonesian Textile Industry (ISIC 32), at the 5% significant level

Hypothesis $H_0 : \mu_1 = \mu_2,\ H_a : \mu_1 \# \mu_2$				Hypothesis $H_0 : \mu_2 = \mu_3,\ H_a : \mu_2 \# \mu_3$				Hypothesis $H_0 : \mu_3 = \mu_4,\ H_a : \mu_3 \# \mu_4$			
Year	Inward Oriented	Year	Early Reform	Year	Early Reform	Year	Further Reform	Year	Further Reform	Year	Economic Crisis
1981	0.0341	1986	0.0389	1986	0.0389	1993	0.0460	1993	0.0460	1997	0.0548
1982	0.0313	1987	0.0395	1987	0.0395	1994	0.0482	1994	0.0482	1998	0.0523
1983	0.0342	1988	0.0401	1988	0.0401	1995	0.0498	1995	0.0498	1999	0.0536
1984	0.0368	1989	0.0457	1989	0.0457	1996	0.0503	1996	0.0503	2000	0.0586
1985	0.0361	1990	0.0468	1990	0.0468						
		1991	0.0463	1991	0.0463						
		1992	0.0464	1992	0.0464						
Mean	0.0345		0.0434		0.0434		0.0486		0.0486		0.0548
t stat	-5.3178			-3.0893				-3.7360			
t critical value two tail	2.2281			2.2622				2.5706			
Conclusion	Reject the null hypothesis			Reject the null hypothesis				Reject the null hypothesis			

Source: Author's calculation from the output of DPIN 3.0

Hypotheses 6.18 and 6.20 are also rejected for TP and OSME, respectively. While for TP, the mean in the inwardly oriented period is below the mean in the early reform period, for OSME, the mean in the further reform period is above the mean in the economic crisis period. The summary of these results is in Appendix 6.8.

At the sub-sector level, in the sewing thread industry, hypotheses 6.18 to 6.20 are generally accepted, except hypothesis 6.18, which is rejected for TFP. The results show that the mean of TFP in the inwardly oriented is below the mean in the early reform period. In the spinning and weaving industry, hypotheses 6.18 to 6.20 are also generally accepted, except for TFP, where hypotheses 6.18 and 6.20 are rejected. In these industries, the means of TFP in the inwardly oriented and further reform periods are below the means in the early reform and economic crisis periods, respectively. The summary of these results is in Appendix 6.8.

In the textile n.e.c industry, hypotheses 6.18 to 6.20 are generally rejected, except for OTE, where hypotheses 6.18 to 6.20 are accepted. Hypotheses 6.18 to 6.20 are rejected for TFP. The means of TFP in the inwardly oriented, early reform, and further reform periods are below the means in the early reform, further reform, and economic crisis periods, respectively. For TP, hypotheses 6.18 and 6.20 are rejected. The means of TP in the inwardly oriented and further reform periods are below the mean in the early reform and economic crisis periods, respectively. For OSME, only hypothesis 6.20 is rejected, where the mean of OSME in the further reform period is above the mean in the economic crisis period. The summary of these results is in Appendix 6.8.

6.5.3 Decomposition of TFP Growth in the Indonesian Chemical Industry (ISIC 35)

This section discusses TFP growth and its components in the Indonesian chemical industry. Table 6.10 shows the average annual rates of growth in TFP and its components in the three sub-sectors and industry level for the Indonesian chemical industry. The results of the average annual TFP growth rates in this table are calculated based on the levels/scores of TFP and its components from DPIN 3.0. The levels of TFP growth and its component for selected years and the calculation of total change over each sub-period are presented in Appendix 6.9. The firm-specific, time-varying results are not presented here due to space limitations but can be obtained from the author upon request.

From the estimates, in the Indonesian chemical industry (ISIC 35), TFP grew by annual average of 2.44% over the full period. Unlike in the Indonesian food and textile industries discussed earlier, where the main contributor to TFP growth was technical progress, in the Indonesian chemical industry, the main driver of TFP growth was technical efficiency, with an annual average of 3.33%. While technical progress contributed positively to TFP growth, with an annual average of 1.39% per annum, scale mix efficiency contributes negatively to TFP growth, with an annual average of -2.29% per annum. The positive annual growth rates of TFP in the Indonesian chemical industry are consistent with the previous findings of Margono and Sharma (2006), Ikhsan (2007), and Suyanto (2010).[36]

Dividing the observed years into four sub-periods, in the Indonesian chemical industry, the average annual growth rate was higher in the inwardly oriented period than in the other three sub-periods. As shown in Table 6.10, the main driver of TFP growth varied across sub-periods at the aggregated industry level. While in the inwardly oriented and early reform periods, technical efficiency growth was the main driver of TFP growth, in the further reform and the economic crisis periods, technical progress was the main driver of TFP growth.

In contrast to the three sub-periods of liberalization, TFP decreased by -1.43% per annum during the crisis period. This negative TFP growth was driven by the changes in scale mix efficiency and technical efficiency. Although technical progress was positive, 4.3% per year during the economic crisis period, a relatively large decrease in scale mix efficiency and technical progress, by an average -5.10% and -0.46% per year, respectively, drove down TFP growth. The negative annual growth rate of TFP during the economic crisis confirms the findings of Margono and Sharma (2006), Ikhsan (2007) and Suyanto (2010).

[36] See footnote 26. While Margono and Sharma (2006) and Ikhsan (2007) decompose TFP growth based on SFA as proposed by Kumbhakar and Lovell (2000), Suyanto (2010) decomposes TFP growth based on Malmquist productivity index.

Table 6.10: Average Annual Rates of Growth in TFP and Components (%) in the Indonesian Chemical Industry (ISIC 35)

Sub-sector/Industry	1981 – 1985 (inward oriented)	1985 – 1992 (early reform)	1992 – 1996 (further reform)	1996 – 2000 (economic crisis)	1981 - 2000
ISIC 352: Other Chemical					
TFP	6.28	0.08	5.37	0.49	2.59
TP	-1.19	-6.79	21.16	5.38	2.83
OTE	27.18	-2.57	5.07	-1.59	5.51
OSME	-19.67	9.41	-20.85	-3.27	-5.75
ISIC 355: Rubber Products					
TFP	8.13	3.20	0.28	-2.68	2.39
TP	-7.58	3.33	-0.18	-1.34	-0.69
OTE	6.85	0.16	1.05	-0.37	1.65
OSME	8.86	-0.29	-0.59	-0.98	1.43
ISIC 351 + 356: Chemical and Plastic Products					
TFP	10.70	1.15	0.47	-2.10	2.33
TP	5.63	-1.79	-1.19	8.35	2.03
OTE	0.35	7.98	-1.42	0.61	2.84
OSME	4.70	-5.03	3.08	-11.05	-2.54
ISIC 35: Chemical					
Industry	8.37	1.48	2.04	-1.43	2.44
TFP	-1.05	-1.75	6.60	4.13	1.39
TP	11.46	1.86	1.57	-0.45	3.33
OTE	-2.04	1.36	-6.12	-5.10	-2.29
OSME					

Source: Author's calculation from the output of DPIN 3.0

As for the TFP growth at the three-digit chemical industry, Table 6.10 shows that during the whole period, the overall growth in the Indonesian chemical industry was led by the other chemical industry (2.59% per year), followed by rubber products and chemical and plastic products industries, which showed growth by 2.39 and 2.33% per year, respectively. In these three sub-sectors, the main driver of TFP growth was technical efficiency.

Comparing the productivity growth of three sub-sectors across sub-periods in the Indonesian chemical industry, Table 6.10 reveals that the annual growth rates of TFP growth in the inwardly oriented period (1981-1985) were higher than those in the other three sub-periods. Further, the annual TFP growth rates were negative during the economic crisis, except in the other chemical industry, where the annual growth rates of TFP were positive but slowing compared with the further reform and inwardly oriented periods.

To compare the means across sub-periods for TFP and its components, similar to the industries discussed above, the F-test and t-test are used. Both of these tests use the output of DPIN 3.0 in terms of levels. Hypothesis 6.12 is used to examine whether there is any difference in the means of TFP and its components across sub-periods. The results of the F-test for the Indonesian chemical industry are presented in Appendix 6.10. The results vary across sub-sectors and TFP components. At the aggregated industry (ISIC 35), H_0 is rejected for TFP and OTE, suggesting that the mean of TFP and OTE are not equal across sub-periods. At the disaggregated level (three-digit level), H_0 is rejected for TFP only in the other chemical industry (ISIC 352). In the rubber products industry, H_0 is rejected for TFP and OSME, and in the chemical and plastic products industries (ISIC 351 and 356), H_0 is rejected for TFP and OTE.

To test which sub-periods have distinctly different means from the overall mean, t-test of the hypotheses as described in Equation 6.14 to 6.17 are used. Similar to what have been done in the previous industries, both of these test use the means of the levels of TFP and its components. The results of these tests are presented in Appendix 6.11. The results vary across sub-sectors, across sub-periods, and across TFP and its components. At the two-digit level (ISIC 35), H_0 is generally accepted, except in several sub-periods for TFP and its components. H_0 is rejected for TFP in the inwardly oriented period, where the mean of TFP is below the overall mean. Table 6.11 shows this result.

Table 6.11: Example of the first t-test, which compares the means of TFP in all other sub-periods in the Indonesian Chemical Industry (ISIC 35), at the 5% significance level.

Year	Hypothesis $H_0 : \mu_1 = \mu$, $H_a : \mu_1 \# \mu$	
	Inward Oriented	Other
1981	0.0242	
1982	0.0236	
1983	0.0286	
1984	0.0302	
1985	0.0338	
1986		0.0336
1987		0.0320
1988		0.0344
1989		0.0366
1990		0.0387
1991		0.0393
1992		0.0374
1993		0.0412
1994		0.0465
1995		0.0342
1996		0.0406
1997		0.0416
1998		0.0341
1999		0.0344
2000		0.0384
Mean	0.0281	0.0375
t stat	-4.2963	
t critical value two tail	2.3646	
Conclusion	Reject the null hypothesis	

Source: Author's calculation from the output of DPIN 3.0

H_0 is also rejected for TP and OSME in the early reform period. While in TP, the mean in the early reform period is below the overall mean, in OSME, the mean in the early reform period is above the overall mean. For OTE, H_0 is rejected for the inwardly oriented and early reform periods. The means of OTE in the inwardly oriented and early reform periods are below and above the overall mean, respectively. The summary of these results is in Appendix 6.11.

At the sub-sector level, H_0 is generally accepted in the other chemical industry (ISIC 352), except hypothesis 6.14 for TFP and hypothesis 6.15 for TP. For both TFP and TP, the means are below the overall mean. In the rubber products industry (ISIC 355), H_0 is also generally accepted, except for TFP for hypothesis 6.14, OTE for hypothesis 6.17, and OSME for hypothesis 6.15. For TFP, the mean in the inwardly oriented period is below the overall mean, while for OTE and OSME, the means are both above the overall mean. The summary of these results is in Appendix 6.11.

In the chemical and plastic products industries (ISIC 351 and 356), hypotheses 6.14 and 6.16 are rejected for TFP. While in the inwardly oriented period, the mean of TFP is below the overall mean, in the further reform period, the mean of TFP is above the overall mean. Hypotheses 6.17 and 6.16 are rejected for TP and OSME, respectively. Both are above the overall mean. For OTE, hypotheses 6.14 and 6.15 are rejected. While the mean of OTE is below the overall mean in the inwardly oriented period, in the early reform period, the mean of OTE is above the overall mean. The summary of these results is in Appendix 6.11.

Moving to the t-test comparing the mean in different sub-period, the results show that hypothesis 6.18 to 6.20 are generally accepted, except hypothesis 6.17 for TFP and several of its components. The results are presented in Appendix 6.12. At the industry level (chemical industry/ISIC 35), hypothesis 6.17 is rejected for TFP and OTE, and the means of TFP and OTE in the inwardly oriented period are below the means in the early reform period. Table 6.12 shows these results.

The results in Table 6.12 are different from Table 6.10. While the calculation of the t-test in Table 6.12 is based on the means of levels of TFP and OTE, the calculation in Table 6.10 is based on the average of growth rates of the levels of TFP and OTE. Unlike the method of the average annual growth rates that calculates the annual growth rates based on two points of data and does not accommodate the fluctuation of each year between the two points of data, the evaluation of policy reform is based on the means of the levels of TFP and its components, which accommodates the fluctuation of the levels of TFP and its components each year. The evaluation of policy reform using this method can add more perspective of the drivers of productivity and efficiency.

For example, in terms of levels (Table 6.12), the means of TFP in the inwardly oriented and early reform periods are 0.0281 and 0.0360, respectively, which means that the mean of TFP in the inwardly oriented was below the mean of TFP in the early reform period, and the t-test result shows that the means of both sub-periods are significantly different.[37] In terms of growth rates (Table 6.10), TFP increased by an average of 8.37% and 1.48% per annum in the inwardly oriented and early reform periods, respectively, which means that the average of annual growth rate of TFP in the early period was higher than the average of annual growth rate of TFP in the early reform period.[38] In this example the lower mean of TFP in the inwardly oriented period than in the early reform period does not mean that the average annual growth of TFP in the inwardly oriented period was lower than the average annual growth of TFP in the early reform period. A similar example can also be seen for OTE, as shown in Table 6.12.

Table 6.12: Example of the second t-test, which compares the means of TFP and OTE for one sub-period with another sub-period in the Indonesian Chemical Industry (ISIC 35), at the 5% significance level

TFP Hypothesis $H_0 : \mu_1 = \mu_2, H_a : \mu_1 \# \mu_2$				OTE Hypothesis $H_0 : \mu_1 = \mu_2, H_a : \mu_1 \# \mu_2$			
Year	Inward Oriented	Year	Early Reform	Year	Inward Oriented	Year	Early Reform
1981	0.0242	1986	0.0336	1981	0.3220	1986	0.5796
1982	0.0236	1987	0.0320	1982	0.4847	1987	0.6075
1983	0.0286	1988	0.0344	1983	0.5194	1988	0.6386
1984	0.0302	1989	0.0366	1984	0.4130	1989	0.6083
1985	0.0338	1990	0.0387	1985	0.5094	1990	0.5462
		1991	0.0393			1991	0.5106
		1992	0.0374			1992	0.5801
Mean	0.0281		0.0360		0.4497		0.5816
t stat	-3.6729			-3.2701			
t critical value two tail	2.4469			2.4469			
Conclusion	Reject the null hypothesis			Reject the null hypothesis			

Source: Author's calculation from the output of DPIN 3.0

In the other chemical industry (ISIC 32), hypothesis 6.17 is rejected for TFP only, where the mean of TFP in the inwardly oriented period is below the mean in the early reform period. In the rubber products industry (ISIC 355), hypothesis 6.17 is rejected for TFP and OSME. While for TFP, the mean in the inwardly oriented period is lower than the mean of TFP in the early reform period, for OSME, the mean in the in the inwardly oriented period is higher than the mean in the early reform period. In the chemical and plastic products industries (ISIC 351 and 356),

[37] The mean of TFP in the inwardly oriented period (1981-1985) is 0.0281 = (0.0242+0.0236+0.0286+0.0302+0.0338)/5 and the mean of TFP in the early reform period is 0.0360 = (0.0336+0.0320+0.0344+0.0366+0.0387+0.0393+0.0374)/7.

[38] The average annual growth rate of TFP in the inwardly oriented period (1981-1985) is $\Delta TFP = \frac{\ln(TFP_{1985}/TFP_{1981})}{1985-1981} = \frac{\ln(0.0338/0.0242)}{4} = 0.0837$ or 8.37% per annum. The average annual growth rate of TFP in the early reform period (1985-1992) period is $\Delta TFP = \frac{\ln(TFP_{1992}/TFP_{1985})}{1992-1985} = \frac{\ln(0.0374/0.0338)}{7} = 0.0148$ or 1.48% per annum.

6.17 is rejected for TFP and OTE. The means of both TFP and OTE in the inwardly oriented period are below the means in the early reform period. The summary of these results is in Appendix 6.12.

6.5.4 Decomposition of TFP Growth in the Indonesian Metal Products Industry (ISIC 38)

Having discussed TFP growth and its components in the Indonesian food, textile and chemical industries, this section discusses TFP growth and its components in the Indonesian metal products industry (ISIC 38). Table 6.13 shows the average annual rates of growth for TFP and its components in three sub-sectors and at the industry level of the Indonesian chemical industry. The results of the average annual TFP growth rates in this table are calculated based on the levels/scores for TFP and its components from DPIN 3.0. The levels of TFP growth and its component for selected years and the calculation of total change over each sub-period are presented in Appendix 6.13. The firm-specific, time-varying results are not presented here due to space limitations but can be obtained from the author upon request.

From the estimates, TFP grew by annual average of 2.56% over the observed years in the Indonesian metal products industry. The main driver of TFP growth in this industry was technical progress, with annual average growth rate of 2.52% per year. Technical efficiency grew by 0.81% per year, but scale mix efficiency contributed negatively, with an annual average growth rate of -0.77%. The finding of positive TFP growth in the Indonesian metal products supports the findings of Ikhsan (2007) but contradicts the findings of Margono and Sharma (2006) and Suyanto (2010)**,** who find negative TFP growth in the Indonesian metal products industry.[39]

Dividing the observed years into four sub-periods, Table 6.13 shows that the highest annual average TFP growth was achieved in the further reform period (1992-1996). The main driver of TFP growth in this period was scale mix efficiency, with an annual growth rate of 8.99%. Technical progress and technical efficiency contributed negatively to TFP growth, with annual growth rates of -2.86% and -2.25%, respectively. The finding of positive TFP growth rate during the further reform contradicts the findings of Margono and Sharma (2006), Ikhsan (2007) and Suyanto (2010), who find negative annual TFP growth rates during this period.

[39] See footnote 26.

Table 6.13: Average Annual Rates of Growth in TFP and Components (%) in the Indonesian Metal Products Industry (ISIC 38)

Industry	1981 – 1985 (inward oriented)	1985 – 1992 (early reform)	1992 – 1996 (further reform)	1996 – 2000 (economic crisis)	1981 - 2000
ISIC 38: Metal Products Industry					
TFP	3.77	3.12	3.88	-0.94	2.56
TP	0.23	4.10	-2.86	7.44	2.52
OTE	-3.31	2.76	-2.25	4.57	0.81
OSME	6.84	-3.74	8.99	-12.95	-0.77

Source: Author's calculation from the output of DPIN 3.0

Table 6.13 also shows that annual TFP growth decreased by an average of -0.94% per year. This negative productivity growth was driven by scale mix efficiency. Although technical progress and technical efficiency growth rates were positive during this period, with average growth rates of 7.44% and 4.57% per annum, respectively, a relatively large decrease in scale mix efficiency, with an average growth rate of -12.95% per year, drove down TFP growth. The finding of negative TFP growth in the Indonesian metal products industry during the economic crisis supports the finding of Margono and Sharma (2006) and Suyanto (2010) but contradicts the finding of Ikhsan (2007), who shows a positive TFP growth rate in the metal products industry during the economic crisis.

Similar to the industries discussed previously, the F-test and t-test are also used for this industry. Both of these tests use the means of the levels of TFP and its components. The results of the F-test are presented in Appendix 6.14. Using the hypothesis in Equation 6.12, H_0 is rejected for TFP, TP and OSME, meaning that the means of TFP, TP and OSME are not equal over the sub-periods.

To test which means of sub-periods are different from those of other sub-periods, t-test as written in Equations 6.14 to 6.17 are used. The results of this test are presented in Appendix 6.15. The results vary across sub-periods and across TFP and its components. H_0 is rejected for TFP in the inwardly oriented and further reform periods. While in the inwardly oriented period, the mean of TFP is lower than the overall mean, in the further reform period, it is higher than the overall mean of TFP. The results are shown in Table 6.14.

Table 6.14: Example of the first t-test, which compares the means of TFP in all other sub-periods in the Indonesian Metal Products Industry (ISIC 38), at the 5% significance level

Year	Hypothesis $H_0 : \mu_1 = \mu$, $H_a : \mu_1 \# \mu$		Hypothesis $H_0 : \mu_3 = \mu$, $H_a : \mu_3 \# \mu$	
	Inward Oriented	Other	Further Reform	Other
1981	0.0461			0.0461
1982	0.0466			0.0466
1983	0.0472			0.0472
1984	0.0497			0.0497
1985	0.0536			0.0536
1986		0.0482		0.0482
1987		0.0570		0.0570
1988		0.0615		0.0615
1989		0.0689		0.0689
1990		0.0708		0.0708
1991		0.0673		0.0673
1992		0.0667		0.0667
1993		0.0706	0.0706	
1994		0.0726	0.0726	
1995		0.0732	0.0732	
1996		0.0779	0.0779	
1997		0.0805		0.0805
1998		0.0603		0.0603
1999		0.0605		0.0605
2000		0.0750		0.0750
Mean	0.0487	0.0674	0.0629	0.0626
t stat	-7.1686		0.0679	
t critical value two tail	2.1009		2.1098	
Conclusion	Reject the null hypothesis		Reject the null hypothesis	

Source: Author's calculation from the output of DPIN 3.0

H_0 are also rejected for TP and OSME in the further reform and the economic crisis periods. In TP, the means of TP are below and above the overall mean of TP in the further reform and the economic crisis periods, respectively. In OSME, the means of OSME are above and below the overall mean of OSME in the further reform and the economic crisis periods, respectively. In OTE, however, H_0 is accepted across sub-periods, meaning that there is no significantly different between the mean of OTE in each sub-periods and the overall mean of OTE.

The last t-test is used to compare the mean of TFP and its components in different sub-periods. The results of this test are presented in Appendix 6.16. Equations 6.18 to 6.20 are used to test the hypotheses. The results vary across TFP and its components, the mean of TFP and its components in one sub-period can be above or below the mean of TFP and its components in other sub-period. Hypotheses in Equations 6.18 and 6.19 are rejected for TFP, where the mean of TFP in the inwardly period is below the mean of TFP in the early reform period and the mean of TFP in the early reform period is below the mean of TFP in the further reform period. Table 6.15 shows these results.

The results in Table 6.15 are different from Table 6.13. While the calculation of the t-test in Table 6.15 is based on the mean of levels of TFP, the calculation Table 6.13 is based on the average of growth rates of the levels of TFP. As mentioned in the previous sub-section, unlike the method of the average annual growth rates that calculates the annual growth rates based on two points of data and does not accommodate the fluctuation of each year between the two points of data, the evaluation of policy reform is based on the means of the levels of TFP and its components, which accommodates the fluctuation of the levels of TFP and its components each year. The evaluation of policy reform using this method can add more perspective of the drivers of productivity and efficiency.

For example, in terms of levels (Table 6.15) the means of TFP in the inwardly oriented and early reform periods are 0.0487 and 0.0629, respectively, which means that the mean of TFP in the inwardly oriented was below the mean of TFP in the early reform period and the t-test result shows that the means of both sub-periods are statistically different.[40] In terms of growth rates (Table 6.13), TFP increased by an average of 3.77% and 3.12% per annum in the inwardly oriented and early reform periods, respectively, which means that the average of annual growth rate of TFP in the early period was higher than the average of annual growth rate of TFP in the early reform period.[41] In this example the lower mean of TFP in the inwardly oriented period than in the early reform period does not mean that the average annual growth of TFP in the inwardly oriented period was lower than the average annual growth of TFP in the early reform period.

[40] The mean of TFP in the inwardly oriented period (1981-1985) is 0.0487 = (0.0461+0.0466+0.0472+0.0497+0.0536)/5 and the mean of TFP in the early reform period is 0.0629 = (0.0482+0.0570+0.0615+0.0689+0.0708+0.0673+0.0667)/7.

[41] The average annual growth rate of TFP in the inwardly oriented period (1981-1985) is $\Delta TFP = \frac{\ln(TFP_{1985}/TFP_{1981})}{1985-1981} = \frac{\ln(0.0536/0.0461)}{4} = 0.0377$ or 3.77% per annum. The average annual growth rate of TFP in the early reform period (1985-1992) period is $\Delta TFP = \frac{\ln(TFP_{1992}/TFP_{1985})}{1992-1985} = \frac{\ln(0.0667/0.0536)}{7} = 0.0312$ or 3.12% per annum.

Table 6.15: Example of the second t-test, which compares the means of TFP for one sub-period with another sub-period in the Indonesian Metal Products Industry (ISIC 38), at the 5% significance level

TFP Hypothesis $H_0 : \mu_1 = \mu_2, H_a : \mu_1 \# \mu_2$			
Year	Inward Oriented	Year	Early Reform
1981	0.0461	1986	0.0482
1982	0.0466	1987	0.0570
1983	0.0472	1988	0.0615
1984	0.0497	1989	0.0689
1985	0.0536	1990	0.0708
		1991	0.0673
		1992	0.0667
Mean	0.0487		0.0629
t stat			-4.2854
t critical value two tail			2.3060
Conclusion			Reject the null hypothesis

Source: Author's calculation from the output of DPIN 3.0

Hypothesis in Equation 6.20 is also rejected for TP, where the mean of TP in the further reform period is below the mean of TP in the economic crisis period. In addition, hypotheses in Equations 6.19 and 6.20 are rejected for OSME, where the mean of OSME in the early period is lower than the mean of OSME in the further reform period and the mean of OSME in the further reform period is higher than the mean of OSME in the economic crisis period. The summary of these results is presented in Appendix 6.16.

6.6 Conclusion

This chapter discusses the decomposition of TFP growth and its components over the period from 1981 to 2000 in four selected Indonesian manufacturing industries at the three-digit and two-digit level. The method used is the Färe-Primont productivity index (O'Donnell 2010a, O'Donnell 2012). The Färe-Primont estimates are calculated based on the assumption that production technology exhibits variable returns to scale (VRS). In addition, the production possibilities frontier is allowed to both expand and contract, which means that technical progress can occur in some periods and technical regress can occur in other periods.

At the two digit industry level, the results of estimations show that in general, over the full period (1981-2000), the average annual growth of TFP was mainly driven by technological change, except in the chemical industry (ISIC 35), where the main driver of TFP growth was technical efficiency. The average annual growth of OTE and OSME were generally negative over the full period, except the annual average growth rates of OTE in the chemical (ISIC 35) and metal products (ISIC 38) industries, where the annual average growth rates for OTE were positive.

At the sub-sector level, similar to the decomposition results from the two-digit industry level, over the full period (1981-2000), the main driver of the annual productivity growth rates was technical progress, except in three-digit level chemical industry, where the main driver of the annual productivity growth was technical efficiency. The average annual growth rates were generally negative over the full period, except in three sub-sectors, namely the food products n.e.c industry (ISIC 312), sewing thread industry (ISIC 32112) and rubber products industry (ISIC 355).

Comparing the average annual growth rates of TFP in the four trade reform periods, the results show that in general, technological progress was the main driver of annual average of TFP growth, at both the two-digit and the sub-sector levels.

To empirically investigate the mean of TFP and its components across sub-periods, two statistical tests are used: the F-test and the t-test. The F test is used to test whether the mean of TFP and its components are equal. The tests are performed separately for each TFP and its components. At the two-digit and sub-sector level industry, the results generally show that at least one of the means TFP and its components are not equal, suggesting that the means of TFP and its components are not equal across sub-periods. An exception, however, is found in the food products (ISIC 311) industry, where the means of TFP, TP, OTE and OSME are equal.

There are two t-tests used in this study. The first t-test is to examine whether the mean of TFP and its components is equal to the overall mean of TFP and its components. At the two-digit and sub-sector level industry, most of the results show that null hypotheses are accepted, suggesting that there is no statistically significant difference between the mean TFP and its components in each sub-sector and the overall mean of TFP and its components. However, several null hypotheses are rejected, suggesting that there are significant differences between the mean of TFP and its components in sub-sector and the overall mean of TFP and its components. For TFP and its components, where the null hypotheses are rejected, results vary.

The mean of TFP and its components each sub-sector is sometimes above or sometimes below the overall mean of TFP and its components.

The second t-test is used to test whether the mean of TFP and its components in one sub-period is equal to the mean of TFP and its components in other sub-period. Similar to the results of the first t-test, at the two-digit and sub-sector industry level, most of the results show that null hypotheses are accepted, suggesting that there is no significant difference between the mean of TFP and its components in one sub-period and the mean of TFP or its components in other sub-period. For TFP and its components, where the null hypotheses are rejected, the results also vary. The mean of TFP and its components in one sub-period can be above or below the mean of TFP and its components in other sub-period.

To summarize, in productivity analysis, it is common to estimate reduced-form relationship between TFP growth and series of environment variables that influence productivity growth and efficiency (O'Donnell 2011). Regarding the main topic of this thesis, the following chapter estimates the relationships between variables that affect TFP growth and its components, including the effect of trade reform on TFP growth.

Chapter 7
The Effects of Trade Reform on Productivity Growth

7.1 Introduction

Topics related to total factor productivity (TFP) are discussed in the two previous chapters. Chapter 5 discusses the effects of trade reform on firm-level technical efficiency. A one-stage estimation method with a stochastic production frontier is used, following Battese and Coelli (1995). Chapter 6 discusses the decomposition of TFP growth into various finer measures, including technical change, technical efficiency change and scale mix efficiency change using the Färe-Primont productivity index proposed by O'Donnell (2012).

This chapter continues the previous chapters' discussion by focusing the effects of trade reform in four selected manufacturing industries. The findings from Chapter 5 show that trade reform variables (ERP and the ratio of imports) have different effects on technical efficiency across four selected industries, in terms of their direction and magnitude. Technical efficiency is only one source of TFP growth. It is important to empirically investigate the relationship between trade reform and TFP growth along with all its components.

The remainder of this chapter is organized in the following order. Section 7.2 briefly discusses the empirical model. Section 7.3 describes the data sources and measurement of variables, followed by a discussion of results and empirical analysis in Section 7.4. Section 7.5 compares the results of technical efficiency analysis from this chapter to those from Chapter 5. Finally, Section 7.6 concludes the chapter.

7.2 Empirical Model

Empirical studies on trade reform effects and sources of TFP growth in Indonesian manufacturing firms have been very limited. This thesis attempts to contribute to this literature by using updated data and methodology. The analysis involves two steps. First, the framework developed in Section 4.3 of Chapter 4 is used to decompose TFP growth, with results reported in Chapter 6. Second, the panel data model in Equation 4.41 is employed in this chapter to test the trade reform effects on productivity growth and its components. The empirical model for testing the effects of trade reform on productivity is specified as follows:

$$\Delta Y_{it} = \propto_i + TRE_{it}\beta + L_{it}\delta + \varphi_{it} \quad \textbf{7.1}$$

where ΔY_{it} is a measure of productivity growth or its components for firm i at time t, i denotes firm i; t denotes time period (t = 1, 2, …, T); TRE is a vector of trade reform variables; L is a vector of firm-specific variables; $\propto$, β and δ are parameters to be estimated; and φ denotes an error term.

Productivity growth is estimated in this study using the Färe-Primont productivity index proposed by O'Donnell (2012). There are several reasons for using this method. First, as explained in Chapter 4, this index satisfies all economically relevant axioms and tests from index number theory, including the transitivity axiom, and is reliable for comparing multi-temporal (many periods) and/or multi-lateral (many firms) indices of TFP and efficiency (O'Donnell 2011). Second, this method does not require strong assumptions related to the functional form of the production technology or the nature of technological change. Third, this method does not require any assumptions concerning either the degree of competition in product markets or the optimizing behaviour of firms. Fourth, this method decomposes the productivity growth into more sources of TFP components, then the two (technological change and technical efficiency change) commonly presented in the literature. Fifth, this method can be applied when price data on inputs and outputs are not available.[42]

Recalling Equation 4.20 from Chapter 4:

$$TFP_{it} = TFP_{it}^{*} \times TFPE_{it} \quad \textbf{7.2}$$

where TFP_{it} is total factor productivity of firm i at time t, $TFP_{it}^{*} = Y_t^{*}/X_t^{*}$ denotes the maximum TFP possible using the technology available in period t and $TFPE_{it}$ denotes TFP efficiency of firm i at time t. $TFP_{it}^{*} = Y_t^{*}/X_t^{*}$ is a measure of technical change or technological progress (TP). The efficiency component can be further decomposed into various measures of efficiency, such as pure technical efficiency, pure scale efficiency and mix efficiency, as in Equations 4.30 and 4.31 in Chapter 4:

$$TFPE_{it} = \frac{TFP_{it}}{TFP_t^{*}} = \frac{Y_{it}/X_{it}}{Y_t^{*}/X_t^{*}} = OTE_{it} \times OME_{it} \times ROSE_{it} \quad \textbf{7.3}$$

and

[42] In Indonesian case studies, there is only one study conducted by Widodo (2013) which uses this method. Other studies on productivity growth in Indonesia are available but these studies use different methods. Thus, employing this method will enrich previous studies.

$$TFPE_{it} = \frac{TFP_{it}}{TFP_t^*} = \frac{Y_{it}/X_{it}}{Y_t^*/X_t^*} = OTE_{it} \times OSE_{it} \times RME_{it} \quad \mathbf{7.4}$$

where OTE, OME, ROSE, OSE, and RME are output-oriented measures of pure technical, mix, residual scale, scale, and residual mix efficiency.

Recalling Equation 7.2 and rephrasing 7.3 and 7.4, TFP can be written as:

$$TFP_{it} = TFP_t^* \times TFPE_{it} = TFP_{it}^* \times (OTE_{it} \times OME_{it} \times ROSE_{it}) \mathbf{7.5}$$

and

$$TFP_{it} = TFP_t^* \times TFPE_{it} = TFP_{it}^* \times (OTE_{it} \times OSE_{it} \times RME_{it}) \mathbf{7.6}$$

The decomposition implied by Equations 7.5:[43]

$$TFP_{it} = TFP_t^* \times TFPE_{it} = TFP_{it}^* \times (OTE_{it} \times OSME_{it}) \ \mathbf{7.7}$$

where OSME is an output-oriented measure of scale mix efficiency and other components of TFP are previously defined. DPIN 3.0 is used to compute the TFP and its components.

Recall Equation 7.2 where ΔY_{it} is a measure of productivity for firm i at time t, which is represented by a firm's productivity growth, such that ΔY = (ΔTFP, ΔTP ΔTFPE, ΔOTE, ΔOSME).

The estimation procedure for Equation 7.1 can be described as follows:

1. Trade reform variables (ERP and the ratio of imports) and other related variables (age of firm, capital intensity, ratio of non-production workers, ownership status and time) are regressed on the firm's productivity growth (TFP). In this case, Equation 7.1 can be rewritten as:

$$\Delta TFP_{it} = \\ \propto_0 + \beta_1 ERP_{it} + \beta_2 IMP_{it} + \delta_1 AGE_{it} + \delta_2 CI_{it} + \delta_3 NPW_{it} + \delta_4 FOREIGN_{it} + \\ + \delta_5 t + \varphi_{it} \quad \mathbf{7.8}$$

The estimated β indicates trade reform effects on firm's TFP growth.

[43] A parallel expression exists for Equation 7.6. However, only the decomposition from Equation 7.5 is used in the regression analysis below as the results would be hardly distinguishable.

2. Trade reform variables and other related variables are regressed on each component of TFP growth (TP, OTE, OSME) separately. Thus, Equation 7.7 can be rewritten in three different equations as follows:

$$\Delta TP_{it} = \propto_0 + \beta_1 ERP_{it} + \beta_2 IMP_{it} + \delta_1 AGE_{it} + \delta_2 CI_{it} + \delta_3 NPW_{it} + \delta_4 FOREIGN_{it} + \delta_5 t + \varphi_{it} \quad \mathbf{7.9}$$

$$\Delta OTE_{it} = \propto_0 + \beta_1 ERP_{it} + \beta_2 IMP_{it} + \delta_1 AGE_{it} + \delta_2 CI_{it} + \delta_3 NPW_{it} + \delta_4 FOREIGN_{it} + \delta_5 t + \varphi_{it} \quad \mathbf{7.10}$$

$$\Delta OSME_{it} = \propto_0 + \beta_1 ERP_{it} + \beta_2 IMP_{it} + \delta_1 AGE_{it} + \delta_2 CI_{it} + \delta_3 NPW_{it} + \delta_4 FOREIGN_{it} + \delta_5 t + \varphi_{it} \quad \mathbf{7.11}$$

The estimated parameter β_1 in Equations 7.9 to 7.11 indicates the effect of ERP on technological progress, pure technical efficiency change and scale mix efficiency change, respectively. The estimated parameter β_2 in Equations 7.9 to 7.11 indicates the effect of the ratio of imports on technological progress, pure technical efficiency change and scale mix efficiency change, respectively.

Two-stage procedures are used to estimate the best-suited model in each regression:

1. Similar to Chapter 5, this study considers the economic crisis by including the dummy for the economic crisis and the variables that interact with the dummy in Equations 7.9 to 7.11 as follows:

$$\Delta TFP_{it} = \propto_0 + \beta_1 ERP_{it} + \beta_2 IMP_{it} + \delta_1 AGE_{it} + \delta_2 CI_{it} + \delta_3 NPW_{it} + \delta_4 FOREIGN_{it} + \delta_5 t + \delta_6 D + \delta_7 (ERP_{it} * D) + \delta_8 (IMP_{it} * D) + \delta_9 (AGE_{it} * D) + \delta_{10} (CI_{it} * D) + \delta_{11} (NPW_{it} * D) + \delta_{12} (FOREIGN_{it} * D) + \delta_{12} (t * D) + \varphi_{it} \quad \mathbf{7.12}$$

$$\Delta TP_{it} = \propto_0 + \beta_1 ERP_{it} + \beta_2 IMP_{it} + \delta_1 AGE_{it} + \delta_2 CI_{it} + \delta_3 NPW_{it} + \delta_4 FOREIGN_{it} + \delta_5 t + \delta_6 D + \delta_7 (ERP_{it} * D) + \delta_8 (IMP_{it} * D) + \delta_9 (AGE_{it} * D) + \delta_{10} (CI_{it} * D) + \delta_{11} (NPW_{it} * D) + \delta_{12} (FOREIGN_{it} * D) + \delta_{12} (t * D) + \varphi_{it} \quad \mathbf{7.13}$$

$$\Delta OTE_{it}= \propto_0 + \beta_1 ERP_{it} + \beta_2 IMP_{it} + \delta_1 AGE_{it} + \delta_2 CI_{it} + \delta_3 NPW_{it} + \delta_4 FOREIGN_{it} + \delta_5 t + \delta_6 D + \delta_7 (ERP_{it} * D) + \delta_8 (IMP_{it} * D) + \delta_9 (AGE_{it} * D) + \delta_{10} (CI_{it} * D) + \delta_{11} (NPW_{it} * D) + \delta_{12} (FOREIGN_{it} * D) + \delta_{12} (t * D) + \varphi_{it} \qquad \mathbf{7.14}$$

$$\Delta OSME_{it} = \propto_0 + \beta_1 ERP_{it} + \beta_2 IMP_{it} + \delta_1 AGE_{it} + \delta_2 CI_{it} + \delta_3 NPW_{it} + \delta_4 FOREIGN_{it} + \delta_5 t + \delta_6 D + \delta_7 (ERP_{it} * D) + \delta_8 (IMP_{it} * D) + \delta_9 (AGE_{it} * D) + \delta_{10} (CI_{it} * D) + \delta_{11} (NPW_{it} * D) + \delta_{12} (FOREIGN_{it} * D) + \delta_{12} (t * D) + \varphi_{it} \mathbf{7.15}$$

Three panel data models are used to regress Equations 7.12 to 7.15: the common effect (or pooled ordinary least square/OLS), fixed effect within transformation model (or FEM within) and random effect model (or Generalized Least Squares, GLS). As discussed in Section 4.3.5 in Chapter 4, three tests can be used to determine which of these three models is appropriate for representing the dataset: the *Chow* test, the *Hausman* test and the *Breusch-Pagan* (BP) test. The *Chow* test is used to determine whether the pooled OLS or fixed-effect model is appropriately represents the dataset. The *Hausman* test is performed to test whether fixed effect or random effect is appropriate, and the *Breusch-Pagan* (BP) method is used to test whether a pooled OLS or random effect model is appropriate.

2. The results from the most appropriate model in stage 1 are used to test the null hypothesis whether no-effect of crisis is an appropriate model for the dataset, imposing the following restriction on Equations 7.12 to 7.15:

$$\delta_6 = \delta_7 = \delta_8 = \delta_9 = \delta_{10} = \delta_{11} = \delta_{12} = 0 \qquad \mathbf{7.16}$$

The restricted least-squares F test is used to test the hypothesis 7.16. This ratio statistic is written as follows:

$$F = \frac{(R_{UR}^2 - R_R^2)/m}{(1 - R_{UR}^2)/(n-k)} \qquad \mathbf{7.17}$$

where $R_{UR}^2 - R_R^2$, respectively, the R^2 values obtained from the unrestricted regressions (Equations 7.12 to 7.15) and restricted regressions (Equations 7.8 to 7.11). This test follows the F distribution with *m*, *(n-k)* degrees of freedom, where *m* is the number of linear restrictions, *k* is the number of parameters in the unrestricted variables and *n* is the number of observations. If the null hypothesis is accepted, pooling regression (*i.e.*, including all the observations in one regression) is an appropriate model representing the dataset.

The computer program DPIN 3.0 is used to generate TFP and its components. The results from DPIN 3.0, then, are regressed with the independent variables using STATA 13.0.

7.3 Data and Measurement Variables

The main data used in this analysis are provided by the Indonesian Central Board of Statistics (*Badan Pusat Statistik* or BPS), as explained in Chapter 5. All independent variables used in the estimation, including ERP (the effective rate of protection), IMP (the ratio of imports), AGE (age of firm), CI (the ratio of capital intensity), NPW (the ratio of non-production workers), FOREIGN (ownership status) and t (time), have been explained in Chapter 5. The dependent variables, total factor productivity (TFP) growth and its components, are measured using the Färe-Primont productivity index proposed by O'Donnell (2012) and estimated from firm-level data. Table 7.1 lists a summary of the expected signs between the dependent variables and independent variables used in this thesis.

Table 7.1: Expected Signs of Parameter Estimates of the Regression Analysis

Variables	Symbol	Expected Sign
Dependent Variables		
Total factor productivity	TFP	
Technological progress	TP	
Technical efficiency	OTE	
Scale mix efficiency	OSME	
Independent Variables		
Effective rate of protection	ERP	-
The ratio of imports	IMP	+
Age	AGE	+/-
Capital intensity	CI	+/-
The ratio of non-production workers	NPW	+/-
The status of ownership	FOREIGN	+/-
Time	t	+/-

Note: + indicates positive effect, - indicates negative effect, +/- indicates no expectation for effect.

The estimation of Equations 7.12 to 7.15 is performed for the period between 1982 and 2000. A large number of capital values are missing. To obtain a sufficient number of observations, this study applies the back-casting method to estimate missing values. This method has been used in previous studies such as Vial (2006), Ikhsan (2007) and Suyanto (2010). The details of the methodology are presented in Appendix 5.1. In addition, the approach used to create a balanced panel dataset is the same as the method used in Chapter 5.

The descriptive summary statistics of the final data for the relevant variables are presented in Table 7.2. This table illustrates the differences in average productivity growth and their sources across firms from two-digit selected industry groups. For example: firms in textile industry (ISIC 32) have higher TFP, OTE and OSME growth than firms in food (ISIC 31), chemical (ISIC 35) and metal products (ISIC 38) industries. Table 7.2 also shows that the average of ERP is the highest in the metal products (ISIC 38) industry. It can also be seen that firms in chemical industry (ISIC 35) have the highest average ratio of imports compared with the firms in the other three selected industries. Table 7.2 further shows that firms in chemical and metal products industries have higher average capital intensity than the firms in the food and textile industries.

Table 7.2: Descriptive Summary of Four Sample Indonesian Manufacturing Industries, 1982-2000

	ISIC 31 (Food Products)				ISIC 32 (Textile)			
	Mean	**Std Dev**	**Min**	**Max**	**Mean**	**Std Dev**	**Min**	**Max**
Dependent Variables								
TFP	1.23	4.25	0.01	235.00	1.43	13.34	0.00	897.00
TP	1.10	0.45	0.41	2.63	1.12	0.51	0.47	2.75
OTE	1.11	0.79	0.03	47.95	1.57	33.64	0.00	2,500.00
OSME	1.18	1.94	0.01	108.70	1.43	19.23	0.00	1,428.57
Independent Variables								
ERP	68.80	18.61	46.36	108.46	86.91	41.91	23.76	155.98
Import ratio	3.80	13.00	0.00	100.00	14.37	27.75	0.00	100.00
Age	28.60	16.61	2.00	99.00	22.73	10.95	2.00	74.00
Capital intensity	24,774.59	39,660.88	218.88	969,010.60	27,325.56	28,321.08	101.73	1,142,980.00
Non-production workers ratio	17.72	17.89	0.00	96.77	11.57	10.41	0.00	88.44
Ownership	0.03	0.17	0.00	1.00	0.08	0.28	0.00	1.00
Crisis	0.21	0.41	0.00	1.00	0.21	0.41	0.00	1.00
Number of observations				9,899				5,529
Number of panel firms				521				291
	ISIC 35 (Chemical)				**ISIC 38 (Metal Products)**			
	Mean	**Std Dev**	**Min**	**Max**	**Mean**	**Std Dev**	**Min**	**Max**
Dependent Variables								
TFP	1.29	3.07	0.01	130.80	1.23	1.84	0.02	63.29
TP	1.16	0.70	0.33	3.62	1.05	0.22	0.65	1.42
OTE	1.27	1.40	0.06	39.22	1.10	0.55	0.07	7.13
OSME	1.24	1.58	0.02	52.63	1.18	2.07	0.02	80.65
Independent Variables								
ERP	61.78	33.84	16.93	109.50	114.03	84.82	16.85	245.21
Import ratio	37.84	38.22	0.00	100.00	29.53	36.91	0.00	100.00
Age	21.78	11.04	2.00	81.00	21.00	10.51	2.00	71.00
Capital intensity	87,002.07	75,014.29	2,124.27	1,009,006.00	72,343.56	91,284.58	3,245.96	813,081.10
Non-production workers ratio	24.30	18.76	0.00	100.00	18.45	14.20	0.00	89.66
Ownership	0.20	0.40	0.00	1.00	0.18	0.38	0.00	1.00
Crisis	0.21	0.41	0.00	1.00	0.21	0.41	0.00	1.00
Number of observations				4,579				1,767
Number of panel firms				241				93

Source: Author's calculation.

7.4 Analysis of Empirical Results

As explained in Section 7.2, there is a two-stage procedure for choosing the model specification. The first step is to choose which panel data model best represents the data set for TFP and for its components. The *Chow* test, the *Hausman* test and the *Breusch-Pagan* (BP) test are used to determine which of the three models (pooled OLS, fixed effect model and random effects model) appropriately represents the dataset. The results of these tests are presented in Appendix 7.1 and Appendix 7.2.

The second step is to test the null hypothesis whether no-effect of crisis is an appropriate model. The results of this test are presented in Appendix 7.3. If the null hypothesis is accepted, pooling regression (i.e., including all the observations in one regression) is an appropriate model representing the dataset. If the null hypothesis is rejected, it is justified to split the observations into two sub-periods: pre-crisis (1982-1996) and post-crisis (1997-2000).

The regression results based on the second step are then tested for heteroscedasticity and serial correlation. The results of the test for heteroscedasticity and autocorrelation are presented in Appendix 7.4. To overcome heteroscedasticity and autocorrelation problems, the regressions are corrected by incorporating correction techniques. Estimations of standard error in the pooled OLS and FEM are adjusted using the cluster-robust inference method (Cameron and Trivedi 2009).

The interpretation of the estimated parameters for TFP growth and its sources presented in each table in this chapter are based on the final results after the estimations are corrected for any heteroscedasticity and autocorrelation problems.

7.4.1 Trade Reform Effects on Productivity Growth in the Indonesian Food Industry (ISIC 31)

Table 7.3 presents the estimations results for the Indonesian food industry. Tests results from stage 1 and 2, as presented in Appendix 7.1 to Appendix 7.3 show different models for different TFP and its components. When dividing observations into two sub-periods, the fixed effect model (FEM within) is a better model for TFP and OSME. When dividing observations into two sub-periods, pooled OLS is well suited for TP and OTE.

Table 7.3: Trade Reform Effects and Sources of Productivity Growth in the Indonesian Food Industry (ISIC 31)

	TFP FEM (within)		TP Pooled OLS	
	Pre-crisis (1982-1996)	Post-crisis (1997-2000)	Pre-crisis (1982-1996)	Post-crisis (1997-2000)
ERP	-0.006	-1.154	-0.005***	-8.065***
Import Ratio	0.006*	0.010	0.001***	0.000
Age	-0.004	-0.037**	0.000*	-0.001
Capital Intensity	-0.026***	-0.082***	0.000*	0.000
Non-production Workers	-0.001	-0.013	0.000	0.001**
Foreign	0.371	1.701	-0.023*	-0.044
Time	-0.008	-3.536	-0.016***	-24.917***
F-test	1.24	5.20***	198.02***	73.59***
R^2	0.0126	0.2425	0.0126	0.1786
No. of Observations	7,815	2,084	7,815	2,084
No. of Panel Firms	521	521	521	521

	OTE Pooled OLS		OSME FEM (within)	
	Pre-crisis (1982-1996)	Post-crisis (1997-2000)	Pre-crisis (1982-1996)	Post-crisis (1997-2000)
ERP	-0.002*	2.589***	-0.003	0.863
Import Ratio	0.000	0.002	0.002	-0.009
Age	-0.001*	0.000	0.002	-0.024**
Capital Intensity	-0.002***	-0.001***	-0.010***	-0.033***
Non-production Workers	0.000	0.003***	-0.001	-0.001
Foreign	0.068**	-0.096	-0.027	1.082
Time	-0.005	7.945***	-0.008	2.802
F-test	3.23***	6.47***	1.52	20.81***
R^2	0.0044	0.0214	0.0088	0.2279
No. of Observations	9,899	2,084	7,815	2,084
No. of Panel Firms	521	521	521	521

Note: ***,**,* denote significance at the 1% level, the 5% level and the 10% level. OLS stands for ordinary least square, FEM is fixed effect model. All estimations include a constant.

The outcomes show that regression models are able to explain the TFP and its components, with the F test showing significance at the 5% level. These results imply that all explanatory variables are jointly significant, even though not all explanatory variables are individually significant. However, exceptions include TFP in the pre-crisis and OSME in the post-crisis, where F-statistic values are not significant. R^2 values for all regressions are low, indicating that a large proportion of inter-firm variation in productivity growth remains unexplained. The results also reveal that the coefficients vary under different models and different estimation periods.

Table 7.3 shows that the coefficients of ERP play various roles and have different effects on TFP and its components under different models and estimations periods. The coefficients of ERP are negative statistically significant at the 1% level both the pre-crisis and post-crisis periods regarding the rate of technological progress (TP). These results support the idea that trade reform increases productivity, especially through technical progress.

The finding that ERP has a negative effect on TP is consistent with the finding of Mahadevan (2002) in Australian manufacturing, although she uses different method to calculate TFP and tests the regressions at the aggregated industry level.[44]

While the coefficients of ERP have consistent signs and significant effects on TP in the Indonesian food industry in both sub-periods, the coefficients of ERP have different signs and different levels of significance on technical efficiency (OTE) in the pre- and post-crisis periods. In the pre-crisis period, ERP has a negative effect and is statistically significant at the 10% level. However, a positive and statistically significant effect of the estimated coefficient of ERP is observed at the 1% level in the post-crisis period. This finding suggests that the economic crisis interferes with the positive effect of trade reform on technical efficiency confirms the theoretical argument in Rodrik (1992), that during the economic crisis, there may be a large degree of indeterminacy with respect to the success of reform.

Regarding the findings on OTE, similar results on OTE are found by Salim (1999) in the Bangladeshi food processing industry.[45] He finds that the ERP has also different

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[44] In her study, Mahadevan uses ERA (effective rate of assistance) and NRA (nominal rate of protection) as proxies for trade reform variables.

signs and levels of significance on productive capacity realization (PCR) during three periods. The coefficient of ERP is observed to have a significant positive influence before reforms, a negative influence in the transition period and a significant negative influence on PCR. He interprets these results that, at least in the short run, protection increases PCR. When protection is continued, however, it has potential to produce a negative effect on PCR.

In Indonesia, as expected, in the pre-crisis period, ERP has negative effects on both TP and OTE. While the coefficient of ERP is statistically significant at the 1% level on TP, it is significant at the 10% level on OTE. These results can be interpreted that the reduction in ERP significantly improves both TP and OTE. It appears that trade reform brings incentives to firms to use better technology to compete efficiently in both domestic and international market. At the same time, trade reform encourages firms in the Indonesian food industry to use technology and input more efficiently. These findings are also consistent with the argument of Grossman and Helpman (1990) and Young (1991) that trade reform may increase efficiency through technological know-how and learning by doing gains.

Unlike the effects of ERP, which are statistically significant on TP and OTE, there is no evidence that ERP has any effect on TFP and scale mix efficiency (OSME) in the Indonesian food industry. These results are shown by the insignificance of the coefficient of ERP for TFP and OSME in the pre-crisis period and in the post-crisis period.

Several international studies also find insignificant coefficient of ERP on TFP, such as the findings of Jenkins (1995) in Sri Lanka, Jenkins (1995) in Bolivia, Mulaga and Weiss (1996) in Malawi and Sharma *et al.* (2000) in India, although they estimate ERP on the aggregated industry level. The finding that trade reform does not have any effect on scale economies confirm previous studies in Chile, Columbia and Morocco referred by Tybout (1992) and Berry (1991) in LDC (less developed country) manufacturing, which find no evidence that trade opening leads to efficiency gains through the exploitation of plant-level scale of economies.

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[45] Similar to Mahadevan, Salim also uses ERA as a trade reform variable. For TE, Salim uses PCR (productive capacity realization), which is defined as the movement firms towards or away from frontier, *i.e.*, the firm's ability to 'catch up'.

The next variable that represents trade reform is the ratio of imports. The results in Table 7.3 show that in the pre-crisis period, the coefficients of the ratio of imports are positive and statistically significant at 10% level for TFP and 1% level for TP, respectively, suggesting that in the pre-crisis period, the improvement of TFP growth stems from TP. These results support the idea that trade liberalization improves productivity through technological progress through greater access to technology and more varieties of inputs. The ratio of imports, however, does not have any significant effect on the other components of TFP growth.

The finding that the ratio of import has a positive effect on TFP is line with the findings of İşcan (1998) in Mexico, Paus *et al.* (2003) in several Latin American countries and Chu (2011) in Vietnam, although they use different methods in calculating TFP and estimate on the aggregated industrial level.

Results from firm-specific variables not associated with trade reform variables show that there are mixed signs and significance of these variables under different models and different sub-periods. An exception, however, is for capital intensity. Most of the coefficients of capital intensity are negative statistically significant at the 1% level, except for TP, which is statistically significant at the 10% level in the pre-crisis period only.

The negative coefficients of capital intensity may occur when the cost of capital becomes relatively inexpensive due to subsidized credit or low-interest rate. Under these conditions, firms may accumulate more capital than is required for production (Salim 2008). In addition, Sharma *et al.* (2000) note that in the case of developing countries, the use of capital can be inefficient because of the lack of a conducive environment, such as the lack of skilled labour and the availability of efficient infrastructure, and small market which constrain the effect of economic of scale.

The negative coefficients of capital intensity are also found in a number of previous studies on developing countries, although they use different definition of TFP and their regressions are conducted by using a pool of observations for various industries. These studies include Perkins *et al.* (1993) for China, Okuda (1994) for Taiwan, Kwak (1994) for Korea and Chu (2011) for Vietnam.

Based on the findings, trade reform variables have significant effects only on TFP, TP and OTE. While ERP has significant effects on TP and OTE only, and the ratio of imports has a significant positive effect on TFP and TP in the pre-crisis period only. The opposite effects of ERP on OTE are found in the different sub-periods, suggesting that the economic crisis interferes with the positive effect of trade reform on OTE.

7.4.2 Trade Reform Effects on Productivity Growth in the Indonesian Textile Industry (ISIC 32)

Having discussed the estimation results in the Indonesian food industry, this section continues with a discussion of the Indonesian textile industry. Based on the two-stage results as presented in Appendix 7.1 to Appendix 7.3, pooled OLS is well suited for TFP, TP, OTE and OSME. With all observations, pooled OLS turns out to be a better model for TFP and OSME. Additionally, when dividing observations into the pre- and post-crisis periods, pooled OLS is preferred for TP and OTE.

Table 7.4 shows that only TP and OTE in the pre-crisis period have significant F-statistics. These results mean that for these two components, all independent variables are jointly significantly different from zero implying that their inclusion in the model is valid. Both F-statistics for TP and OTE in the post-crisis period, however, are missing.[46] The results also show that F-statistics for TFP and OSME in the post-crisis period are not significant. The explanatory power of the regressions is very low, as shown by the values of R^2, suggesting that other important variables are omitted from the regressions, which may lead to bias in the estimated coefficients of the included variables.

Similar to the results of the regressions in the Indonesian food industry, the coefficient of each variable in the Indonesian textile industry also has different results under different periods. In this industry, ERP has a negative significant at 10% level for TFP, suggesting that trade reform leads to an increase in TFP growth over the observed years.[47] This finding is consistent with a previous study conducted by Aswicahyono and Hill (2002) although they use different method of TFP. They

[46] The values of F-statistic are reported as missing because, to correct heteroscedasticity and autocorrelation in TP and OTE in the post-crisis period, cluster-robust estimate of the variance-covariance matrix of the estimator (VCE) is applied (Cameron and Trivedi 2009). This approach uses F test, distributed as F(k, d-k+1), where k is the number of constraints and d is the number of cluster. Because the rank of VCE is at most d and the model test reserves 1 degree of freedom for the constant, at most d-1, constraint can be tested, so k must be less than d. The regressions of TP and OTE in the post-crisis period do not meet this requirement. As long as the standard errors are not missing, there is no mechanical problem with the models (www.stata.com).

[47] See footnote 46.

find that a reduction in ERP contributes to accelerated TFP growth in the Indonesian manufacturing industry. Similar to the results of this thesis, their study also has a low R-squared, suggesting that the result has a limited explanatory level.

The negative effects of ERP on TFP are also consistent with the empirical findings in several other countries, such as Urata and Yokota (1994) in Thailand, İşcan (1998) in Mexico, Mahadevan (2002) in Australia, Goldar and Kumari (2003) in India, Njikam and Cockburn (2011) in Cameroon and Chu (2011) in Vietnam, although these studies use different method of calculating TFP and estimate on the aggregated level of industry.

The estimated coefficients of ERP in the Indonesian textile industry, however, have varying effects and significance levels on the components of TFP growth. The estimated coefficients of ERP are statistically significant at the 1% level for TP in the pre- and post-crisis. The signs, however, are different pre- and post-crisis. While in the pre-crisis period, the sign of the coefficient is positive, which means that an increase in protection increases TP, in the post-crisis period, it is negative, which suggests that an increase in protection decreases TP. Thus, the economic crisis changes the direction of the coefficients.

The finding of positive signs of the ERP on both TP and OTE in the pre-crisis period in the textile industry may suggest that protection stimulates TFP growth. In the earlier phase of industrial policy, to protect the Indonesian textile industry, a high protection is needed to encourage firms to invest in the advanced technology of capital. Thus, protection opens opportunity to access more varieties of technology that will lead to an increase in TP and OTE. These results empirically demonstrate the theoretical argument in Rodrik (1988).

Table 7.4: Trade Reform Effects and Sources of Productivity Growth in the Indonesian Textile Industry (ISIC 32)

	TFP Pooled OLS	TP Pooled OLS	
	Total (1982-2000)	Pre-crisis (1982-1996)	Post-crisis (1997-2000)
ERP	-0.083*	0.037***	-106.618***
Import Ratio	0.006	0.000**	0.000
Age	0.040	0.000*	0.000
Capital Intensity	-0.013**	0.000	0.000
Non-production Workers	0.002	0.000	0.002***
Foreign	0.021	0.007	0.055**
Time	-0.640*	0.322***	-668.095***
F-test	1.15	356.4***	.
R^2	0.0024	0.0734	0.2217
No. of Observations	5,528	4,365	1,164
No. of Panel Firms	291	291	291

	OTE Pooled OLS		OSME Pooled OLS
	Pre-crisis (1982-1996)	Post-crisis (1997-2000)	Total (1982-2000)
ERP	0.016*	1339.805	-0.086
Import Ratio	0.000	0.158	0.011
Age	-0.004	0.746	0.088
Capital Intensity	-0.003*	-0.045	-0.009*
Non-production Workers	0.006*	-0.005	-0.016
Foreign	-0.050*	-2.636	0.036
Time	-0.125*	8395.294	-0.705*
F-test	3.45***	.	0.64
R^2	0.0048	0.0142	0.0028
No. of Observations	4,365	1,164	5,528
No. of Panel Firms	291	291	291

Note: ***,**,* denote significance at the 1% level, the 5% level and the 10% level. OLS stands for ordinary least square, FEM is fixed effect model. All estimations include a constant.

Turning to the ratio of import, similar to the effect of the ratio of imports on TP in the food industry, the effect of the ratio of imports on TP in the textile sector is also statistically significant. However, the coefficients of the ratio of imports for TP in these two industries are different, in terms of their signs and levels of significance. While in the food industry, the coefficient is positive and statistically significant at the 1% level, in the textile industry, it is negative and statistically significant at the 5% level. In the textile industry, however, the magnitude is smaller than in the food industry. The findings for the textile industry show that an increase in the ratio of imports decreases technological progress. The results also show that the estimated coefficients of the ratio of import do not have any significant effect on OTE, OSME and TFP.

As in the case of the Indonesian food industry, the coefficients of firm-specific variables in the Indonesian textile industry also show that there are mixed signs and significance, except for capital intensity. There are, however, different levels of significance results of capital intensity between these two industries. While in the food industry, they are mostly negative statistically significant at the 1% level, in the textile industry they are negative but vary in the level of significance. In the textile industry, the coefficients of capital intensity are statistically significant at the 5% level for TFP and at the 10% level for OTE and OSME.

The finding that the coefficients of capital intensity are negatively significant on TFP, OTE and OSME supports the finding of Pangestu (1997). As indicated by Pangestu (1997), a large investment occurred during 1988-1990 when the importing of textile machinery increased rapidly. This investment created excess capacity in the textile industry. The second round of large investment occurred during 1990-1993, that, again, created excess capacity. Further, the finding of the negative coefficients of capital intensity update the finding of Aswicahyono (1998), who finds that negative TFP growth is observed despite technological revolution in the textile industry during 1975-1980.

The results for the Indonesian textile industry show that only ERP has a negative effect on TFP during the observed period, which provides some evidence that trade reform increases TFP growth. However, it is significant only at the 10% level.

7.4.3 Trade Reform Effects on Productivity Growth in the Indonesian Chemical Industry (ISIC 35)

This section discusses the effects of trade reform on productivity growth in the Indonesian chemical industry. Test results in Appendix 7.1 to Appendix 7.3 show that FEM (within) is an appropriate model representing the data set for TFP, and pooled OLS is a better model for TP, OTE and OSME. The F test for the crisis dummy as presented in Appendix 7.3 shows that TFP and its components should be divided into the pre-and post-crisis periods.

The regression results in Table 7.5 show that the F-statistics values for all models are statistically significant at the 1% level. These results indicate that inclusion all the independent variables in these models can explain some sources of productivity, technical progress, technical efficiency and scale mix efficiency.[48] R^2 values, however, are low, indicating that a large proportion of the variation of TFP growth and its components cannot be explained by the independent variables in these models.

Table 7.5 shows that trade reform variables have significant effects on the components of TFP growth, but not on overall TFP growth. The effects of ERP on TP, OTE and OSME are all statistically significant at the 1% level and mostly positive, but the effects on TP and OTE are negative in the pre-crisis period.

The negative effect of ERP on OTE in the pre-crisis period, which suggests that trade reform increases technical efficiency, is also found by Salim (1999) in the Bangladeshi chemical industry. The coefficient of ERP is found to have a negative statistically significant effect at the 10% level on TE in the pre-reform in the Bangladeshi chemical industry.

The results also reveal negative coefficients of ERP on TP and OTE and a positive coefficient on OSME. Again, these results confirm the previous results found in the Indonesian food and textile industry that the signs are not always in the same direction on TFP and its component, suggesting that trade reform can have different effects on different components of TFP.

[48] An exception is for OTE in the post-crisis period, for which F-statistics are missing, because this model applies robust cluster standard errors to address heteroscedasticity. This approach may cause the variance and covariance matrix to not be of full rank, and the F numerator degree of freedom is less than the number of regressors. However, as long as the standard errors are not missing, there is no mechanical problem with the model (www.stata.com).

Table 7.5: Trade Reform Effects and Sources of Productivity Growth in the Indonesian Chemical Industry (ISIC 35)

	TFP FEM (within)		TP Pooled OLS	
	Pre-crisis (1982-1996)	Post-crisis (1997-2000)	Pre-crisis (1982-1996)	Post-crisis (1997-2000)
ERP	0.007	19.143	-0.006***	12.045***
Import Ratio	-0.002	0.004	0.001***	0.000**
Age	0.028	-0.057**	0.000	0.000
Capital Intensity	-0.015***	-0.015***	-0.0001***	0.000
Non-production Workers	0.000	-0.005	0.001*	0.000
Foreign	-0.081	0.0031	0.077***	0.000
Time	0.041	63.907	-0.019***	-0.002
F-test	3.76***	7.61***	348.39***	131.53***
R^2	0.0245	0.1629	0.0188	0.195
No. of Observations	3,615	964	3,615	964
No. of Panel Firms	241	241	241	241

	OTE Pooled OLS		OSME Pooled OLS	
	Pre-crisis (1982-1996)	Post-crisis (1997-2000)	Pre-crisis (1982-1996)	Post-crisis (1997-2000)
ERP	-0.014***	90.410***	0.007***	114.300***
Import Ratio	0.001***	0.000	0.000	0.001
Age	0.006*	0.004	-0.004**	0.000
Capital Intensity	-0.002***	-0.001***	-0.002***	-0.002***
Non-production Workers	0.001	0.003*	0.003**	0.001
Foreign	0.068*	0.002	0.059	0.057
Time	-0.143***	301.440***	0.043***	-381.251
F-test	16.09***	.	4.3***	21.31***
R^2	0.0385	0.0606	0.0093	0.1249
No. of Observations	3,615	964	3,615	964
No. of Panel Firms	241	241	241	241

Note: ***,**,* denote significance at the 1% level, the 5% level and the 10% level. OLS stands for ordinary least square, FEM is fixed effect model. All estimations include a constant.

The results also reveal negative coefficients of ERP on TP and OTE and a positive coefficient on OSME. Again, these results confirm the previous results found in the Indonesian food and textile industry that the signs are not always in the same direction on TFP and its component, suggesting that trade reform can have different effects on different components of TFP.

In the post-crisis period, coefficients of ERP are found to be positive and statistically significant at the 1% level on each TFP components. This suggests that in the post-crisis period, an increase in protection does provide a stimulus to an increase in TP, OTE and OSME. This finding is consistent with the theory in Rodrik (1988). Protection may increase technological growth, technical efficiency growth and scale of economies.

It is also noted that unlike in the two previous industries (food and textile), where the estimated coefficients of ERP are insignificant on OSME, in the Indonesian chemical industry, the estimated coefficients of ERP are positive and statistically significant at the 1% level in both pre-and post-crisis periods, suggesting that protection increases scale mix efficiency.

Moving to the second variable of trade reform, the effects of the ratio of imports on TP and OTE are positive and statistically significant. However, they have different significance levels under different periods. While the coefficients of the ratio of import are statistically significant at 1% level for TP and OTE in the pre-crisis period, the ratio of import is statistically significant at 5% level for TP and not significant for OTE in the post-crisis period. The positive coefficients of the ratio of import suggest that trade liberalization leads to better technological progress and technical efficiency through greater access to intermediate inputs and capital goods. However, similar to ERP, although the ratio of imports has effects on the components of TFP growth (TP and OTE), there is no evidence that it has a significant effect on overall TFP growth.

7.4.4 Trade Reform Effects on Productivity Growth in the Indonesian Metal Products Industry (ISIC 38)

Having discussed the effects of trade reform in the Indonesian food, textile, and chemical industries, this section discusses the effect of trade reform in the Indonesian metal products industry, the last selected industry in this thesis. The test results in Appendix 7.1 to Appendix 7.3 show that pooled OLS turns out to be a better model for TFP and its sources. The F test for the crisis dummy, as presented in Appendix 7.3, shows that TP is the only component of productivity growth that needs to be divided according to the pre- and post-economic crisis periods.

The regression results in Table 7.6 show that the F-statistics are all statistically significant. However, they have different levels of significance. While the F test for TFP growth is statistically significant at the 5% level, the F-statistics for OTE and OSME are statistically significant at the 1% level. These results mean that all the regression models explain at least some sources of productivity, technical efficiency and scale mix efficiency, even though the overall fit of regressions (R^2) is low. Exceptions are for the regression results for TP, both pre- and post-crisis, which have missing F-statistics.[49]

As shown in Table 7.6, trade reform variables have different signs and significance under different periods. The estimated coefficients of ERP are statistically significant for TP and TFP growth only. However, these coefficients have opposite effects in different periods. On TP, the effect of ERP is positive in the pre-crisis period, which means that protection increases technological progress. The economic crisis changes the effect of ERP on TP, which is negative in the post-crisis period, indicating that trade reform increases TP.

The effect of ERP on TFP, however, is positive and statistically significant at the 5% level. This finding indicates that in the Indonesian metal products industry, trade protection increases TFP growth. This result contradicts the argument that trade reform increases TFP growth.

Unlike in the Indonesian textile industry, where trade reform increases TFP, in the Indonesian metal products, trade reform decreases TFP growth, *i.e.*, protection increases TFP. Basically, the evolution of the metal products industry is similar to that of the textile industry. They start from import substitution activity.[50] However, both industries have different responses, as shown as different signs of ERP on TFP. The Indonesian metal industry seems to enjoy the protection given by the government.

[49] See the explanation in footnote 46.

[50] The metal products and machinery industries have become priority sectors with a policy target of self-sufficiency in the capital goods industry since the second five-year development plan (1979/80-1984/1985) by implementing an import substitution strategy behind high protection.

Table 7.6: Trade Reform Effects and Sources of Productivity Growth in the Indonesian Metal Industry (ISIC 38)

	TFP Pooled OLS	TP Pooled OLS	
	Total (1982-2000)	Pre-crisis (1982-1996)	Post-crisis (1997-2000)
ERP	0.005**	0.001***	-56.529***
Import Ratio	-0.004	0.000	0.000
Age	0.015	0.000	0.000
Capital Intensity	-0.007***	0.000	0.000***
Non-production Workers	0.022*	0.000	0.000*
Foreign	-0.083	-0.001	-0.003
Time	0.068***	0.008***	-341.875***
F-test	2.15**	.	.
R^2	0.0503	0.0212	0.6181
No. of Observations	1,767	1,395	372
No. of Panel Firms	93	93	93

	OTE Pooled OLS	OSME Pooled OLS
	Total (1982-2000)	Total (1982-2000)
ERP	0.000	0.002
Import Ratio	-0.001***	-0.001
Age	-0.001*	-0.007
Capital Intensity	-0.001***	-0.002***
Non-production Workers	0.003***	0.015*
Foreign	0.029	-0.042
Time	0.008	0.034
F-test	4.1***	5.92***
R^2	0.0201	0.0154
No. of Observations	1,767	1,767
No. of Panel Firms	93	93

Note: ***,**,* denote significance at the 1% level, the 5% level and the 10% level. OLS stands for ordinary least square, FEM is fixed effect model. All estimations include a constant.

The coefficient of the ratio of imports has an effect on OTE only. The effect, however, is negative and statistically significant at the 5% level. This finding suggests that the increase in imported inputs, which is not followed by technology mastery, does not lead to an increase in technical efficiency. This finding is line with the finding of UNIDO (2000) that in general, neither FDI (foreign direct investment) projects nor Indonesian private conglomerates and SOEs (state-owned enterprises) were able to acquire the foreign technologies and know-how to improve the efficiency and competitiveness of domestic manufacturing production.

Moving to the firm-specific variables, similar to results from the three industries (food, textile and chemical products) discussed in this chapter, in the Indonesian metal product industry, firm-specific variables vary in signs and significance. Consistent with the three industries previously discussed, the coefficients of capital intensity are generally found to be negative and statistically significant at the 1% level.

7.5 A Comparison of Technical Efficiency Regressions using the One-stage Stochastic Frontier Model and the Färe-Primont Decomposition Method

This section compares the findings regarding the technical efficiencies of the four selected Indonesian manufacturing using two different models: the one-stage stochastic frontier model of Battese and Coelli (1995) and regression using Färe-Primont data envelopment analysis (DEA) linear programming (LP) decomposition method. The discussion in this section is based on technical efficiency results of the model of Battese and Coelli (1995) presented in Section 5.5 and those based on the Färe-Primont decomposition method presented in Section 7.4.

It is worth mentioning that the discussion in this section is based on two important points. First, as noted in Section 5.5 and Section 7.4, the regression results in Section 5.5 and Section 7.4 are interpreted in terms of technical inefficiency and technical efficiency, respectively. In this section, to facilitate understanding of the discussion, the comparison between the two models is in terms of technical efficiency. Thus, the results of the regression from Section 5.5 are interpreted in terms of technical efficiency. In Table 7.7, the results from Section 5.5 are presented as the same as the results from Section 5.5; however, in this section, they are interpreted in terms of technical efficiency. The signs in the parentheses below each of coefficients in the technical inefficiency results are to show the signs in terms of technical efficiency.

The second important point is for the results of technical efficiency regression from the Färe-Primont decomposition method. As discussed in Section 7.2, TFP efficiency (TFPE) based on the Färe-Primont decomposition method consists of pure technical efficiency (OTE) and scale mix efficiency (OSME). In this section, the results of technical efficiency based on the one-stage stochastic frontier from Section 5.5 are compared with the results of technical efficiency (OTE) from Section 7.4 because of the similarity of technical efficiency definition from both models. Both models measure technical efficiency (inefficiency) as movements towards or away from the frontier production function.[51] However, there are differences in the statistical methods used. While in Section 5.5, effects on technical efficiency are estimated using the one-stage stochastic frontier, in Section 7.4, technical efficiency is estimated using a two-stage procedure. Technical efficiency is calculated first using the Färe-Primont decomposition method. Second, the result from the first stage is used to regress technical efficiency on trade reform variables and other firm-specific variables.

A summary of regression results based on these two models is shown in Table 7.7 Estimates in Table 7.7 show different results under different methods and different periods across the four selected industries. The differences are in both the significance and signs of various coefficients. These differences are observed for all variables.

The first variable representing trade reform is ERP. Generally, in terms of technical efficiency, the estimated coefficients of ERP are negative significant at the 1% level and indicate that, as expected, protection reduces technical efficiency under the one-stage stochastic frontier model. Exceptions, however, are found in the food product industry (ISIC 31) in the post-crisis period and in the metal products industry (ISIC 38) in the pre-crisis period, where the coefficients of ERP are positive and statistically significant at the 1% level and indicate that protection leads to an increase in technical efficiency. Under the Färe-Primont regressions model, however,

[51] The regression results of scale mix efficiency (OSME) are not included in the comparison because OSME has its own definition based on the Färe-Primont decomposition method. OSME is defined as a measure of the changes in productivity as firms move around the frontier surface when restrictions on the input and output mixes are relaxed.

the estimated coefficients of ERP vary in sign and significance across industries and sub-periods.

For the Indonesian food industry (ISIC 31), the results show the same directions of ERP in both sub-periods under the two models. In the pre-crisis period, the coefficients of ERP are found to have negative signs in both models, indicating that an increase in protection leads to decrease technical efficiency. There is, however, a change in significance. While in the one-stage stochastic frontier model, it is significant at 1% level, in the Färe-Primont regression model, it is significant at the 10% level. In the post-crisis period, the relationship between ERP and technical efficiency is positive under both models, and the level of significance remains at the 1% level. Thus, the directions of ERP on technical efficiency under the two models are consistent. The difference is in terms of significance in the pre-crisis period only.

For the Indonesian textile industry (ISIC 32), ERP has different effects and significance across the models. Under the one-stage stochastic frontier model, ERP is not significant in the pre-crisis period. It is, however, positive and statistically significant at the 10% level under the Färe-Primont regression model. In the post-crisis period, ERP is found to have a negative relationship with technical efficiency and is statistically significant at the 1% level under the one-stage stochastic frontier model. Under the Färe-Primont regression model, however, it is insignificant.

For the Indonesian chemical industry (ISIC 35), the results of the two models show that the estimated coefficients of ERP are negative and statistically significant at the 1% level in the pre-crisis period. In the post-crisis period, however, the results show that the signs are different. Using the one-stage stochastic frontier, ERP has a negative effect on technical efficiency and a positive effect on technical efficiency based on the Färe-Primont regression model.

Table 7.7: Regression Results of Technical Efficiency using the One-stage Stochastic Frontier Model and the Färe-Primont Decomposition

	Food (ISIC 31)		Textile (ISIC 32)	
	Technical Inefficiency SFA	Technical Efficiency F-P	Technical Inefficiency SFA	Technical Efficiency F-P
ERP				
Pre-crisis	0.009*** (-)	-0.002*	0.001 (-)	0.016*
Post-crisis	-0.305*** (+)	2.589***	0.025*** (-)	1339.805
Import				
Pre-crisis	-0.021*** (+)	0.000	-0.016*** (+)	0.000
Post-crisis	0.006*** (-)	0.002	0.013*** (-)	0.158
Age				
Pre-crisis	-0.015*** (+)	-0.001*	0.005** (-)	-0.004
Post-crisis	-0.024*** (+)	0.000	0.121*** (-)	0.746
Capital Intensity				
Pre-crisis	0.010*** (-)	-0.002***	0.009*** (-)	-0.003*
Post-crisis	0.010*** (-)	-0.001***	0.032*** (-)	-0.045
Ratio of non-production workers				
Pre-crisis	-0.008*** (+)	0.000	-0.002* (+)	0.006*
Post-crisis	-0.009*** (+)	0.003***	0.009*** (-)	-0.005
Status of Ownership				
Pre-crisis	-0.775*** (+)	0.068**	-0.074** (+)	-0.050*
Post-crisis	-1.398*** (+)	-0.096	-0.938** (+)	-2.636

Table 7.7 continued on the next page

Table 7.7: Regression Results of Technical Efficiency using the One-stage Stochastic Frontier Model and the Färe-Primont Decomposition(continued from the previous page)

	Chemical (ISIC 35)		Metal Products (ISIC 38)	
	Technical Inefficiency SFA	Technical Efficiency F-P	Technical Inefficiency SFA	Technical Efficiency F-P
ERP				
Pre-crisis	0.003*** (-)	-0.014***	-0.002*** (+)	
Post-crisis	0.073*** (-)	90.410***		
Total				0.000
Import				
Pre-crisis	-0.001*** (+)	0.001***	-0.015*** (+)	
Post-crisis	-0.021*** (+)	0.000		
Total				-0.001**
Age				
Pre-crisis	0.000	0.006*	-0.072*** (+)	
Post-crisis	0.013*** (-)	0.004		
Total				-0.001*
Capital Intensity				
Pre-crisis	0.002*** (-)	-0.002***	0.003* (-)	
Post-crisis	0.009*** (-)	-0.001***		
Total				-0.001***
Ratio of non-production workers				
Pre-crisis	-0.005*** (+)	0.001	0.008 (-)	
Post-crisis	-0.008*** (+)	0.003*		
Total				0.003***
Status of Ownership				
Pre-crisis	-0.140*** (+)	0.068*	-2.143*** (+)	
Post-crisis	-2.032*** (+)	0.002		
Total				0.029

Note: In the parenthesis is the sign of coefficient in terms of technical efficiency. ***, **and * denote 1%, 5% and 10% significance level, respectively.

For the Indonesian metal products industry (ISIC 38), the results cannot be compared directly because both models use different regression samples. In the one-stage stochastic frontier, the regression model used in the pre-crisis period is different from the regression used in the post-crisis period.[52] In the Färe-Primont regression model, pooling all samples (1982-2000) creates a better model. However, the result of the Färe-Primont regression model shows that during the observed years (1982-2000), ERP has no effect on technical efficiency.

The second variable representing trade reform is the ratio of imports. The estimates in Table 7.7 show that under both models, in terms of signs, generally, the coefficients of the ratio of imports are found to have positive effects on technical efficiency across the four selected industries and across periods. Exceptions are in the food (ISIC 31) and textile (ISIC 32) industries in the post-crisis period and in the metal industry (ISIC 38) during the whole period, where the coefficients of the ratio of imports are found to have negative effects on technical efficiency. In terms of levels of significance, however, it is found that under both models, the estimated coefficients of the ratio of imports vary across the four selected industries and across periods. Under the one-stage stochastic frontier model, all the coefficients of the ratio of import are statistically significant at the 1% level across the four selected industries and across sub-periods. Estimates of the ratio of imports from the Färe-Primont regression model are generally insignificant, except in the chemical industry (ISIC 35) in the pre-crisis period, where the coefficient of the ratio of imports is statistically significant at 1% level, and in the metal products industry (ISC 38), where the ratio of imports is statistically significant at the 5% level.

The coefficients of firm-specific variables vary in term of signs and significance under the two models across the four selected industries, except the coefficients of capital intensity. The coefficients of capital intensity are mostly negative and statistically significant at the 1% level under both models across the four selected industries. Exceptions are in the textile products industry under the Färe-Primont regression model and in the metal products industry under the one-stage stochastic frontier model. These findings show that generally, the results from both models show that an increase in capital intensity leads to a decrease in technical efficiency.

[52] As discussed in Chapter 5, in the Indonesian metal industry, in the post-crisis period Frontier 4.1 fails to iterate and does not produce maximum likelihood regression results.

7.6 Conclusion

This chapter empirically investigates the effects of trade reform on TFP growth and its sources in the four selected Indonesian manufacturing industries. It highlights the importance of considering technological progress, technical efficiency and scale mix efficiency in examining the effects of trade reform on productivity growth.

Using firm-level panel data between 1982 and 2000, the investigation is conducted in two stages. In the first stage, O'Donnell's approach of a multiplicatively complete TFP index is used to decompose TFP growth into technical change, technical efficiency and scale mix efficiency change. The advantage of this approach over other productivity indices is that it can be estimated without any restrictive assumptions related to the structure of technology, competition in the input and output markets or the optimizing behaviour of firms. In addition, this approach can be applied when price data on inputs and outputs are not available.

In the second stage, two phases are conducted. In the first phase, panel data regressions are employed to test the effects of trade reform on firms' productivity growth. Three panel data models are estimated, and the *Chow* test, the *Hausman* test and *Breusch-Pagan* LM test are used to choose the appropriate model. In the second phase, the results from the tests in phase 1 are used to test the null hypothesis whether no-effect of crisis is an appropriate model for the dataset. The results from the second test are used to estimate the effects of trade reform variables and other contributing variables on the calculated TFP growth and on each component of TFP growth, separately. Estimating trade reform variables for each component of TFP growth makes it possible to identify from which component the gains from trade reform come.

The regression results show that almost all the F-statistic values are statistically significant. These results indicate that all independent variables included in the model are jointly significant, even though not all independent variables are individually statistically significant. R^2 values are, however, are low, suggesting that a large portion of inter-firm variation in TFP growth and its components remains unexplained and constitutes a potential for bias in the estimated coefficients for the included variables.

Regarding trade reform variables, the empirical estimates of the trade reform on TFP growth show that there is no strong evidence that trade reform variables consistently affects TFP growth across the four selected industries. The coefficient of the ratio of imports has a negative statistically significant effect in the food industry (ISIC 31) in the pre-crisis only and the estimated coefficients of ERP are significant only in the Indonesian textile (ISIC 32) and metal products (ISIC 38) industries. The effects, however, do not always support the initial hypothesis that protection reduces TFP growth. While in the textile industry, the coefficient of ERP is negative and statistically significant at 10% level, in the metal products industry, it is positive and statistically significant at 5% level. Thus, as expected, trade reform leads to increase TFP growth in the textile industry. In the metal products industry, however, protection increases TFP growth.

The empirical results show, however, that trade reform variables have effects on the components of TFP growth. The effects of trade reform on the components of TFP are mixed across the four selected industries in the different periods, in terms of their signs and significance. It is evident that ERP contributes significantly to TP and OTE in the food (ISIC 31) and chemical (ISIC 35) industries in the pre-crisis period. These findings validate the argument that trade liberalization increases the incentive to use better technology and improves technical efficiency.

In the textile industry (ISIC 32) in the pre-crisis period, the effects of ERP are in the same direction on technological progress and technical efficiency. The coefficient of ERP is positive, suggesting that in this industry, protection increases TP and OTE. These results empirically support the policy of the Government of Indonesia to protect the Indonesian textile industry, as an infant industry in early industrialization, by providing high protection for this industry.

In the metal products industry (ISIC 38) during the pre-crisis period, ERP has an effect on technological progress only. This effect is positive, suggesting that in this industry, protection increases technological progress, as in the case of the textile industry.

ERP has positive effects on scale mix efficiency both pre-and post-crisis in the chemical industry (ISIC 35) only. These results suggest that in this industry, an increase in protection leads to an increase in scale mix efficiency.

In the post-crisis period, the effects of ERP also have different results across the four selected industries, in terms of their signs and significance. In the Indonesian food product industry (ISIC 31), in the post-crisis period, the coefficients of ERP are negative and positive for technological progress and technical efficiency, respectively.

In the chemical industry (ISIC 35) during the post-crisis period, the effects of ERP move in the same direction for the all three components of TFP growth. The estimated coefficients of ERP are found to be positive and statistically significant at 1% level for TP, OTE and OSME, indicating that during the economic crisis, protection do provide stimulus to increase TP, OTE and OSME.

In the textile and metal product industries during the post-crisis period, the coefficients of ERP have negative effects on technological progress. There is no effect of ERP on technical efficiency or scale mix efficiency, as suggested by the insignificance of the coefficients of ERP on these components.

Regarding the effect of the ratio of imports on TFP growth and its components, the ratio of imports is positive and statistically significant at 10% for TFP in the Indonesian food product industry (ISIC 31) only, indicating that an increase in the ratio of import increases TFP growth. This finding confirms the hypothesis that trade liberalization improves productivity. There is no statistically significant effect of the ratio of import on TFP in the other three selected industries.

The coefficients of the ratio of imports, however, have varying effects on TP and OTE, in terms of signs and significance across the four selected industries and sub-periods. There is no effect of the ratio of import on OSME across industries and across sub-periods, as shown by the insignificance of the ratio of import on OSME.

In the food product industry (ISIC 31), a positive significant effect of the ratio of imports at 1% level is found on TP in the pre-crisis only. There is no effect of the ratio of import on TP in the post-crisis. The insignificance effects of the ratio of imports are also found on TFP, OTE and OSME both pre-and post-crisis periods.

In the textile products industry (ISIC 32), a negative statistically significant at 5% level is found for TF in the pre-crisis only. The ratio of imports is also found to have no significant effect on TFP, OTE and OSME.

In the chemical products industry (ISIC 35), the ratio of imports has positive and statistically significant effects at 1% level on TP and OTE during the pre-crisis period. In the post-crisis period, the ratio of imports has a positive effect at 1% level for TP only. The ratio of import has no effect on TFP and OSME, as is the case in the food and textile industries.

In the metal products industry (ISIC 38), the ratio of import has a negative statistically significant effect at 5% on OTE during the whole period. There is no statistically significant effect of the ratio of imports on TFP, TP and OSME in this industry.

Firm-specific variables (age, the ratio of non-production workers, the status of ownership and time) also have different effects on TFP growth and its components across the four selected industries in both sub-periods, in terms of their signs and significance. Regularities, however, are found in the estimated coefficient of capital intensity. Most of the coefficients of the ratio of capital intensity are negative and statistically significant for TFP growth and its components, indicating that an increase in the ratio of capital intensity generally leads to a decrease in TFP growth and its components.

There is a limitation to the empirical estimates, especially regarding the results of the comparison of the technical efficiency measures used in Section 5.5 and Section 7.4. As discussed in this chapter, the results of the technical efficiency measures are different under different methods. The effects of trade reform from different methods used in the estimation can be different across industries. Comparing the results from Section 5.5 and Section 7.4, differences are found in both signs and significance of the trade reform variables (ERP and the ratio of imports) and other firm-specific variables. Therefore, the findings of this chapter should be treated with caution and subjected to further detailed analysis.

Consistent results are found for some variables in some industries under both models. First, related to ERP, the negative significant effects of ERP on technical efficiency with different significance levels are evident in the Indonesian food industry (ISIC 31) in the pre-crisis period. In addition, the negative significant effects of ERP on technical efficiency with the same significance levels are found in the Indonesian chemical industry (ISIC 35) in the pre-crisis period. These findings support the idea that trade reform increases technical efficiency.

The second consistency is regarding the effects of the ratio of import on technical efficiency. Under both models, positive significant effects of the ratio of import on technical efficiency with the same significance level are only in the Indonesian chemical industry (ISIC 35) in the pre-crisis period. This finding supports the view that trade liberalization increases technical efficiency.

The third consistency is related to the effects of the economic crisis and the estimated coefficients of capital intensity. Under both models, it is found that the economic interferes with the effect of trade reform (ERP) on technical efficiency in the Indonesian food industry (ISIC 31). The estimated coefficients of ERP show a positive impact of liberalization on technical efficiency before the crisis but switch to opposite signs in the post-crisis period under both models, but the levels of significance are different.

A final consistency is that the estimated coefficients of capital are mostly negative and statistically significant at 1% level under both models. These results indicate that an increase in the ratio of capital intensity generally leads to a decrease in technical efficiency.

The results from productivity analysis in this chapter show that there is no strong evidence that trade reform consistently affects TFP growth across the four selected industries. In addition, the effects of trade reform variables vary across industries and across sub-periods. Thus, the government may need to consider the characteristics of firms in each industry when formulating trade reform policies. The next chapter discusses policy implications arise from these findings.

Chapter 8
Conclusion and Policy Implications

8.1 Introduction

The effects of trade reform on firms' productivity growth have been a growing interest for policy makers and researchers in the last few decades. A wide range of trade reform policies have been formulated by many developing countries, including Indonesia, to obtain benefits from trade reform. So far, theoretical literature provides optimistic arguments for the positive effects of trade reform on firms' productivity growth. Empirical studies, however, provide mixed results. Thus, the relationship between trade reform and firms' productivity remains an issue for further empirical examination.

This thesis develops a framework, based on two productivity analysis methodologies, to examine whether trade reform improves the productivity of the four selected Indonesian manufacturing industries. By decomposing productivity growth into three components, namely, technological change, technical efficiency change and scale mix efficiency change, this thesis empirically shows that trade reform can affect firms' productivity growth through the components of productivity growth.

Total factor productivity (TFP) growth as a measure of an analysis of the effect of trade reform on firms' performance has recently gained attention by researchers and policy makers. The effects of trade reform on TFP growth comprise three components: technological progress, technical efficiency improvement and scale mix efficiency. However, technical efficiency and scale efficiency are often ignored in empirical studies. Several earlier studies are conducted at an aggregate level (industry, sector or national level) under a conventional production function, in which industries, sectors or countries are assumed to be producing at full efficiency, full capacity and with constant returns to scale, implying that gains from trade reform are contributed by technological progress only. Furthermore, there are very limited studies that examine the determinants of technical efficiency and, in particular, the effects of the 1980s trade and industrial policy reforms on firms' technical efficiency.

This thesis makes contributions to economic analysis and economic modelling of the effects of trade reform by addressing the issues previously neglected. The major contributions can be summarized as follows: (1) it examines the effect of trade reform on firm-level productive efficiency under the stochastic production frontier framework, which allows the identification of trade reform effects on technical efficiency; (2) it is one of the first studies the effect of trade reform on TFP growth and its components for the Indonesian economy; (3) it decomposes productivity growth in both the aggregated manufacturing sector and disaggregated sub-sectors from selected Indonesian manufacturing industries; (4) it includes the period of economic crisis to capture the change in magnitude of the effects of trade reform before and after the crisis.

8.2 Major Findings of the Study

This thesis provides an empirical analysis of the effects of trade reform on firm-level productivity efficiency and productivity growth in four selected Indonesian manufacturing industries. The selected industries are food (ISIC 31), textile (ISIC 32), chemical (ISIC 35) and metal products (ISIC 38). The main source of the data is the annual manufacturing survey conducted by the Indonesian Central Board of Statistics (BPS). Two productivity analysis methods, namely, the stochastic frontier method and the Färe-Primont productivity index method, are used to achieve the objectives of this thesis.

There are several interesting findings from this study. Some findings match the established theory in the literature and are consistent with the findings of similar studies for other developing countries. However, this study also offers some new perspectives and may provide valuable insights for researchers and policy makers in Indonesia as well as other developing countries that pursue trade liberalization in their development strategy. These findings are summarized in the following sub-sections.

8.2.1 The Effects of Trade Liberalization on Firm-level Technical Efficiency

The empirical results show that the effects of trade reform on technical efficiency are different across industries and across sub-periods (Chapter 5). By splitting observations into the pre-crisis and post-crisis period, the different effects of both trade reform variables, effective rate of protection (ERP) and the ratio of imports (IMP), are found across industries and across sub-periods. More specifically, ERP has positive effects on technical inefficiency in the Indonesian food (ISIC 31), textile (ISIC 32) and chemical (ISIC 35) industries in the pre-crisis period. These results suggest that an increase in ERP increases technical inefficiency (decreases technical efficiency). These effects are statistically significant in the food and chemical industries only. In the textile industry, ERP is not statistically significant. In contrast, the effect of ERP on technical inefficiency in the metal products (ISIC 38) industry is negative and statistically significant, suggesting that an increase in ERP decreases technical inefficiency (or increases technical efficiency).

ERP has also different effects across the four selected industries in the post-crisis period. While in the textile, chemical and metal products ERP has positive effects on technical inefficiency, in the food industry, ERP has negative effects on technical inefficiency. The change of direction of the effect of ERP on inefficiency in the food industry from pre-crisis to post-crisis suggests that the crisis alters the impact of trade reform on efficiency.

Regarding the effect of IMP on technical inefficiency, IMP has negative effects on technical inefficiency and is statistically significant across all four selected industries. The effect of protection measured by IMP on technical inefficiency is thus more consistent than for the corresponding effect measured by ERP and suggest that in the pre-crisis period, an increase in IMP decreases technical inefficiency (or increases technical efficiency).

In the post-crisis period, IMP has different effects on technical inefficiency across the four selected industries. The effects of IMP on technical inefficiency are positive in the Indonesian food and textile industries, suggesting that an increase in the ratio of import increases technical inefficiency (or decreases technical efficiency). In the Indonesian chemical and metal product industries, however, IMP has negative effects on technical inefficiency. As in the case of the effect of ERP on technical inefficiency, the findings of the effect of IMP also suggest that the crisis interferes with the impact of trade reform on efficiency.

8.2.2 The Decomposition of Total Factor Productivity Growth

The decomposition analysis is performed using the Färe-Primont productivity index at the two-digit, three-digit and some five-digit levels to examine more detailed components of productivity growth in the four selected industries and sub-sectors (Chapter 6). The results reveal that in the two-digit industries, technical change is the main source of productivity growth over the full observed period, except in the

Indonesian chemical industry (ISIC 35), where technical efficiency is the main driver of productivity growth. Similarly, the main source of productivity growth at the three-digit level is also technical change. Exceptions, however, are found in food products not elsewhere classified (ISIC 312), sewing thread (ISIC 32112) and rubber products (ISIC 355) industries.

To test whether the mean of TFP and its components are equal across sub-periods, an F-test is used. The results show that generally, the means of TFP and its components are not equal across sub-periods, except in the food products (ISIC 311) industry, where the means of TFP, TC, OTE and OSME are equal across sub-periods cannot be rejected. Furthermore, a t-test is used to test whether the means of TFP and its components are equal to the overall mean of TFP and its components. The results of the t-test show that at the two-digit and three-digit levels, most of the means of TFP and its components are equal to the overall means of TFP and its components. For TFP and its components, where the means of TFP are not equal to the overall mean, the results vary. The mean of TFP and its components are sometimes above and sometimes below the overall means of TFP and its components.

A t-test is also used to investigate empirically whether the means of TFP and its components in one sub-period are significantly different from the mean of TFP and its components in another sub-period. Similar to the results of the previous t-test, at the three-digit and two-digit levels, most of the results show that there is no significant difference between the means of TFP and its components in one sub-period and the means of TFP and its components in another sub-period. For sub-sectors/industries where the means of TFP and its components in one sub-period are significantly different from the means of TFP and its components in another sub-period, the means of TFP and its components are sometimes below and sometimes above the mean of TFP and its components in another sub-period.

8.2.3 The Effect of Trade Reform on Productivity Growth

Using the results of the decomposition of productivity growth reported in Chapter 6, panel data analysis is employed to estimate the effect of trade reform on productivity growth in Chapter 7. The results from the analysis show that there is no strong evidence that trade reform consistently affect TFP growth across the four selected industries. The coefficient of the ratio of imports has a statistically significant negative effect in the food industry (ISIC 31) in the pre-crisis only, and the estimated coefficients of ERP are significant only in the Indonesian textile (ISIC 32) and metal products (ISIC 38) industries. In the textile industry, the coefficient of ERP is negative and statistically significant for TFP growth, while in the metal products industry it is positive and statistically significant. Thus, as expected, trade reform leads to increase TFP growth in the textile industry. In the metal products industry, however, protection increases TFP growth.

The findings show that trade reform variables have effects on the components of TFP growth. The effects of trade reform variables, ERP and the ratio of imports, on the components of TFP vary across industries and sub-periods, in terms of their signs and significance.

8.3 Policy Implications

Based on these findings, this study offers several policy recommendations. First, this study finds that the effects of trade reform on technical efficiency are different across industries and across sub-periods. Generally, trade reform improves technical efficiency, at least in the pre-crisis period. This suggests that the government of Indonesia can continue policies aimed at deregulating trade. However, the government needs to consider that the economic crisis has interfered with the effects of both trade reform variables (ERP and the ratio of imports) on technical inefficiency. For example, in the Indonesian food industry (ISIC 31, both variables switch to opposite signs in the post-crisis. Further, these findings need to be interpreted cautiously by the government before formulating trade reform policies because recent data are not included in this thesis. The lack of recent data may alter the results of the findings and policy implications accordingly.

Second, outcomes from the productivity analysis show that there is no strong evidence that trade reform consistently affect TFP growth across the four selected industries. Indeed, the effects of trade reform variables vary across industries and across sub-periods. The government may need to consider the characteristics of firms in each industry when formulating trade reform policies. In an industry where trade reform increases TFP growth, such as food products (ISIC 31) and textile (ISIC 32) industries, the government should continue to reduce protection for this industry. The government, however, should consider other industries where protection rather than trade reform increases productivity, such as the Indonesian metal products industry (ISIC 38).

Further, the results from productivity analysis show that the effects of trade reform can be channelled through technological progress, technical efficiency or scale mix efficiency. The effects vary across TFP components and across sub-periods. Positive trade reform effects occur through technical efficiency, such as in the pre-crisis period in the food (ISIC 31) and chemical (ISIC 35) industries, and technological progress, such as in the pre-crisis period in the food (ISIC 31) and chemical (ISIC 35) industries, and in the post-crisis period in the food (ISIC 31), textile (ISIC 32), chemical (ISIC 35) and metal products (ISIC 38) industries. In these industries, the government should continue the reform process.

The government, however, needs to be aware because protection is needed in several industries in the early phases of development as it brings positive effects in TFP components, such as in the textile (ISIC 32) and metal products (ISIC 38) industries, where protection increases technological progress and technical efficiency, and in the chemical (ISIC 35), where protection increases scale mix efficiency.

Third, results from technical efficiency and productivity analysis show that there is a negative relationship between capital intensity and technical efficiency and productivity. This may be due to the lack of supporting infrastructures needed for firm operations. Therefore, a more active role of the government is needed to mobilize resources in physical infrastructures and to provide other more general policies, such as creating a good institutional environment and building a more transparent legal and political system

8.4 Limitations and the Focus of Further Research

The empirical findings in this thesis provide some important insights for researchers and policy makers on trade reform policies and productivity growth in Indonesia. However, this thesis has some limitations that need to be considered in interpreting the findings and in conducting further empirical research.

First, the main limitation of this thesis is the lack of data, which is relatively difficult to overcome. Several sources of data that should be used cautiously are described as follows. (1) Data on capital are not available continuously in the Annual Survey of

Medium and Large Manufacturing Firms (*Survei Tahunan Statistik Industri Perusahaan Menengah dan Besar* or SI). The missing values are estimated using a methodology similar to that of Vial (2006), Ikhsan (2007) and Suyanto (2010). (2) Ideally, labour input is measured using both quality and quantity of labour. The quality of labour includes education levels, type of work, age and sex, whereas quantity of labour comprises the number of workers and the number of hours worked. Unfortunately, the qualitative data of labour are not available in the SI data and this study therefore relies on quantitative data on labour. The SI data classify labour input into production, non-production and family workers. These data cover employees directly or indirectly involved in the production process. (3) Ideally, to obtain the real values of electricity inputs, the monetary values of electricity inputs are deflated using the wholesale electricity price index provided by PLN. Unfortunately, the wholesale electricity price index data are not available before 1985, and in this study, therefore, the WPI index of electrical machinery, apparatus, appliances and supplies for two-digit ISIC product codes at 1993 constant price is used to deflate the monetary values of electricity inputs. (4) Ideally, data on ERP used are calculated yearly. Unfortunately, yearly data for ERP are not available. This thesis uses three major published studies of protection rate. These are World Bank (1981), Warr (1992) and Widodo (2008). ERP estimates provided by these studies are for 1976, 1987, 1991, 1995, and 2001. For data that are not available, ERP are constructed using a standard linear interpolation. These data limitation may lead to bias in the estimates of TFP growth decomposition and in the estimated coefficients of the included variables.

Second, the empirical analysis covers only established and surviving firms during the period of 1981 to 2000. New firms and "non-surviving" firms, which exist at the beginning but disappear during the period of study, are left out of the analysis. Excluding "non-surviving" firms may not create problems, but omitting new firms may omit some information related to the learning by doing process, technology adaption and managerial skills. Thus, the coverage of this thesis does not include new firms, which likely have some important information.

Third, regarding the method used in the decomposition analysis in Chapter 6 (that generates the data used in Chapter 7 as well), this thesis uses DEA methodology to decompose the Färe-Primont productivity index. A problem with DEA is that it does not accommodate any statistical noise, so any measurement errors in data are reflected in estimates TFP and its components. In this thesis, the measurement error is complicated by the fact that the decomposition is exhaustive. So, for example, if one component of TFP change is estimated poorly (e.g., technical change), then, at least one other component is also be estimated poorly (e.g., technical efficiency). Not surprisingly, using an econometric methodology that allows statistical noise, as with the stochastic frontier analysis of O'Donnell (2010 and 2011) used in Chapter 5, generates somewhat different results.

Fourth, this thesis focuses its analysis only on the period from 1981 to 2000. This period is important because there were some trade reform and industrial policies during this period. However, leaving out the period after 2000 may omit important information on trade reform policies in those periods, which could be compared with the period of study. Lack of recent data is particularly important in considering the implications of the findings from this study for current trade policy.

Despite these limitations, this thesis provides important contributions to the empirical literature of the effects of trade reform on productivity growth. This is one of the first studies that employ decomposition analysis to investigate the effects of trade reform on firm productivity. Additionally, this study represents a significant attempt to analyse the components of productivity growth from trade reform in the four selected Indonesian manufacturing firms. The empirical findings in this study offer valuable input for future studies and policy making in Indonesia, especially for policies related to trade reform and industrial policies.

Appendices

Appendix to Chapter 5

Appendix 5.1: A Methodology for Back-casting the Missing Values of Capital

In this thesis, the missing values of firms' capital are back-casted using the following regression (Vial 2006, Ikhsan 2007, Suyanto 2012):

$$\ln k_{it} = \delta_0 + \delta_1 lny_{it-1} + \mu_{it} + v_{it} \qquad \text{A5.1}$$

Where k_{it} is the replacement value of firm i at time t , y_{it} is the gross-output of firm i at time t-1, δ_0 and δ_1 are the parameters to be estimated, μ_{it} is the firm-specific effect, and v_{it} is the remainder disturbance. The one-year lag of gross-output is selected as the independent variable is to control for a potential endogeneity that may arise if using the gross-output at time t.

Following Vial (2006), Equation A5.1 is estimated using a random effect generalised least square (GLS). The random effect model is chosen instead of fixed effect model because of two reasons. First, the random effect may avoid an enormous loss of degree of freedom (Greene, 2008). Second, the random effect model is preferred than the fixed effect model as the number of firms are larger compared to the time period (Baltagi, 2008).

Equation A5.1 is estimated using STATA13 computer program. To allow for a serial correlation and to ensure a homoscedasticity in the model, Equation A5.1 is then estimated using the feasible GLS estimator proposed by Baltagi and Wu (1999). This estimator reduces the autocorrelation problem by accommodating first-order autoregression (AR1) in a residual structure. Thus, the residual in Equation A5.1 is further explained by $v_{it} = \rho\varepsilon v_{it-1} + \omega_{it}$, where -1<ρ<1 and ω_{it} is independent and identically distributed with mean 0 and variance σ_{ω}^2 .

The feasible GLS estimates for each sector are given the tables below:

Table A5.1: The Random Effect Feasible GLS Estimates of Capital and the One-year Lag of Output for Food Industry (ISIC 31), Dependent Variable: ln *k*

Variable	Coefficient	Standard Error	z-statistics	P>|z|
constant	-.065	.265	37.35	0.000
ln y_{it-1}	.723	.019	-0.25	0.805
R2 within	0.0299			
R2 between	0.7841			
R2 overall	0.6599			

Source: Author's calculation

Table A5.2: The Random Effect Feasible GLS Estimates of Capital and the One-year Lag of Output for Textile Industry (ISIC 32), Dependent Variable: ln *k*

Variable	Coefficient	Standard Error	z-statistics	P>|z|
constant	-.663	.345	-1.92	0.055
ln y_{it-1}	.798	.023	33.55	0.000
R2 within	0.0246			
R2 between	0.8540			
R2 overall	0.7179			

Source: Author's calculation

Table A5.3: The Random Effect Feasible GLS Estimates of Capital and the One-year Lag of Output for Chemical Industry (ISIC 35) , Dependent Variable: ln *k*

Variable	Coefficient	Standard Error	z-statistics	P>|z|
constant	2.849	.441	6.46	0.000
ln y_{it-1}	.584	.028	20.26	0.000
R2 within	0.0424			
R2 between	0.6697			
R2 overall	0.5314			

Source: Author's calculation

Table A5.4: The Random Effect Feasible GLS Estimates of Capital and the One-year Lag of Output for Metal Products (ISIC 38), Dependent Variable: ln *k*

Variable	Coefficient	Standard Error	z-statistics	P>|z|
constant	.320	.615	0.52	0.603
ln y_{it-1}	.739	.041	17.91	0.000
R2 within	0.1214			
R2 between	0.7897			
R2 overall	0.6515			

Source: Author's calculation

The estimates from the feasible GLS of the random effect, as given above, are used to calculate the missing values of capital in each sector.

Appendix 5.2: Descriptive Statistics (Mean Values and Standard Deviations)

	Food (31)	Textile (32)	Chemical (35)	Metal Products (38)
lnY	13.38 (2.23)	14.05 (2.15)	14.85 (2.06)	14.47 (2.11)
lnL	4.52 (1.31)	5.19 (1.41)	5.04 (1.11)	4.91 (1.19)
lnK	9.58 (1.61)	10.50 (1.71)	11.49 (1.21)	10.98 (1.55)
lnM	12.62 (2.40)	13.61 (2.18)	14.06 (2.30)	13.85 (2.27)
lnE	9.91 (2.13)	10.65 (2.68)	11.11 (1.95)	10.80 (1.86)
Effective Rate of Protection	71.07 (20.69)	90.70 (44.07)	64.26 (34.70)	120.96 (88.02)
Ratio of Import	3.96 (13.33)	14.74 (28.13)	38.45 (38.42)	30.72 (37.47)
No. of Firms Observation	521 10,420	291 5,820	241 4,820	93 1,860

Source: Author's calculation from the final balanced dataset.
Note: the numbers in parentheses under each coefficient are standard deviations.

Appendix 5.3: Full Set of Parameter Estimates of Stochastic Production Frontier in the Indonesian Manufacturing Firm

Table A5.5: Maximum Likelihood Estimates of the Stochastic Production Frontiers in the Food Industry (ISIC 31)

Variable	With Dummy	
	Coefficient	**t-ratio**
Production Frontier *(Dependent Variable: lnY)*		
Constant	1.777	14.51***
lnL	0.252	6.89***
lnK	0.066	1.43*
lnM	0.450	17.76***
lnE	0.320	16.97***
T	0.003	0.57
$[lnL]^2$	0.001	0.12
$[lnK]^2$	0.410	33.81***
$[lnM]^2$	0.199	53.12***
$[lnE]^2$	0.062	22.82***
T^2	-0.001	-2.13**
lnL* lnK	0.054	5.37***
lnL* lnM	-0.033	-6.22***
lnL* lnE	-0.024	-6.21***
lnK* lnM	-0.242	-47.63***
lnK* lnE	-0.064	-14.44***
lnM* lnE	-0.006	-6.59***
lnL* T	-0.001	-1.12
lnK* T	0.001	1.44*
lnM* T	0.000	0.53
lnE* T	-0.002	-4.22***
D	8.918	7.72***
lnL* D	0.059	0.73
lnK* D	0.283	2.34***
lnM* D	-0.162	-2.81***
lnE* D	-0.043	-1.04
T* D	-1.037	-8.13***
$[lnL]^2$*D	0.007	0.31
$[lnK]^2$*D	-0.051	-2.02**
$[lnM]^2$*D	0.020	2.49***
$[lnE]^2$*D	-0.027	-4.42***
T^2*D	0.062	8.36***
lnL* lnK*D	0.003	0.16
lnL* lnM*D	-0.013	-1.33*
lnL* lnE*D	0.005	0.60
lnK* lnM*D	-0.002	-0.19
lnK* lnE*D	0.032	3.19***
lnM* lnE*D	-0.002	-0.54
lnL* T*D	0.001	0.67
lnK* T*D	-0.010	-2.36**
lnM* T*D	0.002	1.23
lnE* T*D	0.002	2.59***
Log-likelihood		-1,620.17
No. of Firms		521
Observation		10,420

Source: Author's calculation using the model specified in Equations 5.1 and 5.2. The t-statistics are in parenthesis. *** denotes 1% significance level, ** denotes 5% significance level and * denotes 10% significance level.

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Table A5.6: Estimates of Technical Inefficiency Parameters in the Food Industry (ISIC 31)

Variable	With Dummy	
	Coefficient	t-ratio
Inefficiency Function *(Dependent Variable: u)*		
Constant	-6.813	-19.31***
ERP	**0.012**	**9.71*** **
Import Ratio	**-0.017**	**-15.13*** **
AGE	-0.010	-6.49***
Capital Intensity	0.012	23.81***
Non-Production Workers	-0.010	-10.13***
Foreign Ownership	-0.723	-8.76***
ERP*D	**-0.305**	**-32.93*** **
Import Ratio*D	**0.018**	**8.30*** **
AGE*D	-0.018	-11.11***
Capital Intensity*D	-0.003	-6.97***
Non-Production Workers*D	0.003	1.083
Foreign Ownership*D	-0.672	-4.70***
D	17.611	35.14***
Sigma-squared	1.022	26.79***
Gamma	0.947	392.85***
No. of Firms	521	
Observation	10,420	

Source: Author's calculation using the model specified in Equation 5.2. The t-statistics are in parenthesis. *** denotes 1% significance level, ** denotes 5% significance level and * denotes 10% significance level.

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Table A5.7: Maximum Likelihood Estimates of the Stochastic Production Frontiers on the Trade Reform Effects in the Textile Industry (ISIC 32)

Variable	With Dummy	
	Coefficient	**t-ratio**
Production Frontier *(Dependent Variable: lnY)*		
Constant	3.675	14.35***
lnL	0.469	6.56***
lnK	0.037	0.45
lnM	0.296	5.59***
lnE	0.058	1.91**
T	0.072	8.79***
$[\ln L]^2$	0.050	2.68***
$[\ln K]^2$	0.181	14.22***
$[\ln M]^2$	0.167	23.92***
$[\ln E]^2$	0.021	6.06***
T^2	-0.001	-2.79***
lnL* lnK	0.082	6.81***
lnL* lnM	-0.081	-8.83***
lnL* lnE	-0.033	-5.37***
lnK* lnM	-0.150	-17.54***
lnK* lnE	0.001	0.20
lnM* lnE	-0.002	-1.35*
lnL* T	0.001	0.94
lnK* T	-0.003	-1.30*
lnM* T	-0.000	-0.21
lnE* T	-0.001	-1.64**
D	13.166	13.14***
lnL* D	-0.079	-0.47
lnK* D	0.264	1.38*
lnM* D	0.050	0.44
lnE* D	-0.210	-2.92***
T* D	-1.504	-12.17***
$[\ln L]^2$*D	0.041	0.84
$[\ln K]^2$*D	0.003	0.10
$[\ln M]^2$*D	0.050	3.55***
$[\ln E]^2$*D	-0.013	-1.43
T^2*D	0.078	10.17***
lnL* lnK*D	0.014	0.42
lnL* lnM*D	-0.005	-0.26
lnL* lnE*D	-0.025	-1.64**
lnK* lnM*D	-0.064	-4.25***
lnK* lnE*D	0.040	2.67***
lnM* lnE*D	0.001	0.26
lnL* T*D	-0.000	-0.17
lnK* T*D	0.008	1.47*
lnM* T*D	-0.001	-0.45
lnE* T*D	0.001	0.70
Log-likelihood		-647.85
No. of Firms		291
Observation		5,820

Source: Author's calculation using the model specified in Equations 5.1 and 5.2. The t-statistics are in parenthesis. *** denotes 1% significance level, ** denotes 5% significance level and * denotes 10% significance level.

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Table A5.8: Estimates of Technical Inefficiency Parameters in the Textile Industry (ISIC 32)

Variable	With Dummy	
	Coefficient	t-ratio
Inefficiency Function *(Dependent Variable: u)*		
Constant	-7.22	-28.07***
ERP	**-0.002**	**-1.93***
Import Ratio	**-0.003**	**-3.53*****
AGE	0.051	28.44***
Capital Intensity	0.010	18.60***
Non-Production Workers	0.008	5.50***
Foreign Ownership	0.082	1.43*
ERP*D	**0.030**	**5.61*****
Import Ratio*D	**0.016**	**14.12*****
AGE*D	0.059	12.46***
Capital Intensity*D	0.020	19.85***
Non-Production Workers*D	-0.006	-1.73**
Foreign Ownership*D	-1.543	-16.11***
D	-3.059	-11.21***
Sigma-squared	0.853	41.29***
Gamma	0.941	462.28***
No. of Firms	291	
Observation	5,820	

Source: Author's calculation using the model specified in Equation 5.2. The t-statistics are in parenthesis. *** denotes 1% significance level, ** denotes 5% significance level and * denotes 10% significance level.

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Table A5.9:Maximum Likelihood Estimates of the Stochastic Production Frontiers in Chemical Industry (ISIC 35)

Variable	**With Dummy**	
	Coefficient	**t-ratio**
Production Frontier *(Dependent Variable: lnY)*		
Constant	1.844	2.461***
lnL	-0.024	-0.202
lnK	-0.145	-0.633
lnM	0.546	7.291***
lnE	0.442	6.626***
T	-0.065	-3.618***
$[\ln L]^2$	0.090	4.482***
$[\ln K]^2$	0.292	8.565***
$[\ln M]^2$	0.131	20.666***
$[\ln E]^2$	0.048	7.027***
T^2	-0.004	-5.630***
lnL* lnK	0.061	2.852***
lnL* lnM	-0.064	-6.347***
lnL* lnE	-0.015	-1.772***
lnK* lnM	-0.143	-12.831***
lnK* lnE	-0.073	-6.385***
lnM* lnE	0.001	0.686
lnL* T	-0.002	-1.405*
lnK* T	0.016	5.165***
lnM* T	-0.005	-2.969***
lnE* T	-0.002	-2.810***
D	13.746	13.819***
lnL* D	0.729	2.721***
lnK* D	-1.096	-2.561***
lnM* D	0.305	1.692**
lnE* D	-0.420	-2.830***
T* D	-0.938	-4.877***
$[\ln L]^2$*D	0.152	3.415***
$[\ln K]^2$*D	0.069	1.053
$[\ln M]^2$*D	0.004	0.254
$[\ln E]^2$*D	-0.036	-2.545***
T^2*D	0.053	5.194***
lnL* lnK*D	-0.104	-2.198***
lnL* lnM*D	-0.003	-0.141
lnL* lnE*D	-0.033	-1.834**
lnK* lnM*D	-0.021	-0.768
lnK* lnE*D	0.095	3.678***
lnM* lnE*D	-0.007	-1.052
lnL* T*D	0.004	1.422*
lnK* T*D	-0.010	-1.244*
lnM* T*D	0.006	1.460*
lnE* T*D	0.001	0.435
Log-likelihood		-1993.98
No. of Firms		241
Observation		4,820

Source: Author's calculation using the model specified in Equations 5.1 and 5.2. The t-statistics are in parenthesis. *** denotes 1% significance level, ** denotes 5% significance level and * denotes 10% significance level.

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Table A5.10: Estimates of Technical Inefficiency Parameters in the Chemical Industry (ISIC 35)

Variable	With Dummy	
	Coefficient	**t-ratio**
Inefficiency Function *(Dependent Variable: u)*		
Constant	0.066	9.19***
ERP	0.002	18.75***
Import Ratio	-0.001	-2.61***
AGE	0.000	0.43
Capital Intensity	0.0016	9.59***
Non-Production Workers	-0.006	-10.78***
Foreign Ownership	-0.171	-12.92***
ERP*D	0.011	1.97**
Import Ratio*D	-0.002	-2.84***
AGE*D	-0.003	-1.69**
Capital Intensity*D	0.0003	0.92
Non-Production Workers*D	0.004	9.94***
Foreign Ownership*D	-0.044	-1.42*
D	0.025	3.78***
Sigma-squared	0.132	83.72***
Gamma	0.004	2.28**
No. of Firms		241
Observation		4,820

Source: Author's calculation using the model specified in Equation 5.2 The t-statistics are in parenthesis. *** denotes 1% significance level, ** denotes 5% significance level and * denotes 10% significance level.

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Table A5.11: Maximum Likelihood Estimates of the Stochastic Production Frontiers in the Metal Products Industry (ISIC 38)

Variable	With Dummy	
	Coefficient	**t-ratio**
Production Frontier *(Dependent Variable: lnY)*		
Constant	2.033	4.63***
lnL	0.271	2.49***
lnK	0.535	3.14***
lnM	0.174	2.00**
lnE	0.195	2.82***
T	-0.029	-1.90**
$[\ln L]^2$	-0.030	-1.04
$[\ln K]^2$	0.269	6.85***
$[\ln M]^2$	0.244	15.84***
$[\ln E]^2$	0.018	1.41*
T^2	0.001	1.18
lnL* lnK	0.110	3.93***
lnL* lnM	-0.100	-5.96***
lnL* lnE	0.018	1.11
lnK* lnM	-0.232	-11.22***
lnK* lnE	-0.035	-2.88***
lnM* lnE	-0.001	-0.32
lnL* T	-0.001	-0.61
lnK* T	0.004	1.03
lnM* T	0.000	0.00
lnE* T	-0.002	-1.15
D	27.066	19.04***
lnL* D	-0.016	-0.05
lnK* D	-0.725	-1.76**
lnM* D	0.513	2.39***
lnE* D	-0.276	-1.83**
T* D	-2.668	-12.90***
$[\ln L]^2$*D	0.104	1.59*
$[\ln K]^2$*D	-0.022	-0.30
$[\ln M]^2$*D	-0.079	-3.03***
$[\ln E]^2$*D	0.002	0.10
T^2*D	0.140	9.62***
lnL* lnK*D	-0.075	-1.24
lnL* lnM*D	0.070	1.89**
lnL* lnE*D	-0.066	-1.94**
lnK* lnM*D	0.036	1.12
lnK* lnE*D	0.060	2.60***
lnM* lnE*D	-0.007	-0.70
lnL* T*D	0.002	0.50
lnK* T*D	-0.004	-0.34
lnM* T*D	0.006	0.95
lnE* T*D	-0.001	-0.33
Log-likelihood		-364.06
No. of Firms		93
Observation		1,860

Source: Author's calculation using the model specified in Equations 5.1 and 5.2. The t-statistics are in parenthesis. *** denotes 1% significance level, ** denotes 5% significance level and * denotes 10% significance level.

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Table A5.12: Estimates of Technical Inefficiency Parameters in the Metal Products Industry (ISIC 38)

Variable	With Dummy	
	Coefficient	t-ratio
Inefficiency Function *(Dependent Variable: u)*		
Constant	-2.240	-8.198***
ERP	-0.001	-2.670***
Import Ratio	-0.015	-7.013***
AGE	-0.053	-9.442***
Capital Intensity	0.003	8.250***
Non-Production Workers	0.010	3.469***
Foreign Ownership	-2.084	-9.952***
ERP*D	0.163	19.578***
Import Ratio*D	-0.008	-4.460***
AGE*D	0.003	0.434
Capital Intensity*D	-0.003	-3.316***
Non-Production Workers*D	-0.009	-2.049**
Foreign Ownership*D	2.272	7.673***
D	-3.708	-9.524***
Sigma-squared	0.751	11.013***
Gamma	0.924	91.967***
No. of Firms		93
Observation		1,860

Source: Author's calculation using the model specified in Equation 5.2. The t-statistics are in parenthesis. *** denotes 1% significance level, ** denotes 5% significance level and * denotes 10% significance level.

Appendix to Chapter 6

Appendix 6.1: The Levels and Ratios of TFP and Components in the Indonesian Food Industry (ISIC 31), selected years

Sub-sector/Industry	Levels					Ratio				
	1981	1985	1992	1996	2000	1985/1981	1992/1985	1996/1992	2000/1996	2000/1981
ISIC 311: Food Products										
TFP = TP x TFPE	0.02	0.02	0.02	0.02	0.02	1.13	1.05	0.98	1.00	1.17
TP	0.07	0.07	0.09	0.13	0.17	1.02	1.22	1.50	1.33	2.48
TFPE = OTE x OSME	0.30	0.33	0.29	0.19	0.14	1.12	0.86	0.65	0.75	0.47
OTE	0.62	0.56	0.51	0.38	0.35	0.91	0.92	0.74	0.92	0.57
OSME	0.49	0.60	0.56	0.49	0.40	1.23	0.93	0.89	0.82	0.83
ISIC 312: Food Products n.e.c										
TFP = TP x TFPE	0.04	0.05	0.04	0.05	0.05	1.17	0.94	1.06	1.00	1.17
TP	0.19	0.15	0.22	0.13	0.17	0.79	1.43	0.61	1.31	0.90
TFPE = OTE x OSME	0.21	0.31	0.20	0.35	0.27	1.48	0.65	1.76	0.77	1.30
OTE	0.51	0.65	0.43	0.76	0.57	1.29	0.66	1.77	0.75	1.12
OSME	0.41	0.47	0.47	0.47	0.48	1.14	1.00	1.00	1.02	1.16
ISIC 313 + 314: Beverage+Tobacco										
TFP = TP x TFPE	0.01	0.02	0.02	0.02	0.02	1.30	1.04	1.05	0.96	1.36
TP	0.21	0.32	0.26	0.37	0.38	1.49	0.83	1.43	1.02	1.80
TFPE = OTE x OSME	0.06	0.05	0.07	0.05	0.05	0.88	1.25	0.73	0.94	0.76
OTE	0.40	0.42	0.30	0.33	0.37	1.03	0.73	1.07	1.14	0.92
OSME	0.15	0.13	0.22	0.15	0.12	0.85	1.71	0.69	0.82	0.82
ISIC 31: Food Industry										
TFP = TP x TFPE	0.02	0.03	0.03	0.03	0.03	1.20	1.01	1.03	0.99	1.23
TP	0.14	0.15	0.17	0.19	0.23	1.06	1.13	1.09	1.21	1.59
TFPE = OTE x OSME	0.16	0.18	0.16	0.15	0.12	1.13	0.89	0.95	0.81	0.77
OTE	0.50	0.53	0.41	0.45	0.42	1.06	0.76	1.12	0.92	0.84
OSME	0.31	0.33	0.39	0.33	0.29	1.06	1.17	0.85	0.88	0.93

Notes: Levels are generated using DPIN 3.0, ratio is author's calculation using levels.

Appendix 6.2: The Results of F-test in the Indonesian Food Industry (ISIC 31)

Recalling Equations 6.12 and 6.13, the hypothesis tested as follows:

$H_0 : \mu_1 = \mu_2 = \mu_3 = \mu_4$ A6.1

H_a : the means are not equal A6.2

The test statistic for testing A6.1 is:

$$F_{stat} = \frac{\sum n_j \left(\bar{X}_j - \bar{X}\right)^2 / (k-1)}{\sum\sum \left(X - \bar{X}_j\right)^2 / (N-K)} \qquad \text{A6.3}$$

The decision rule for the F-test depends on the level of significance and the degrees of freedom. The F statistic has two degrees of freedom. These are denoted df_1 and df_2, called the numerator and denominator degrees of freedom, respectively. The degrees of freedom are defined as follows:

$df_1 = k - 1$ and $df_2 = N - K$ A6.4

The null hypothesis is rejected at 5% significance level if $F_{stat} > F_{crit}$.

where:

μ_1 = the mean of TFP/TP/OTE/OSME for period 1981-1985 (inwardly oriented policy)

μ_2= the mean of TFP/TP/OTE/OSME for period 1986-1992 (early reform)

μ_3= the mean of TFP/TP/OTE/OSME for period 1993-1996 (further reform)

μ_4= the mean of TFP/TP/OTE/OSME for period 1997-2000 (economic crisis period)

n_j= the sample size in the j^{th} group(e.g., j = 1,2,3, and 4 when there are four comparison groups

$\bar{X}_j$ = the sample mean in the j^{th} group

$\bar{X}$ = the overall mean

X = individual observation

k = the number of independent groups (in this thesis, k = 4)

N = the total number of observations in the analysis (in this thesis, the sum of sample sizes in the comparison groups, e.g., $N = n_1 + n_2 + n_3 + n_4$)

Appendix 6.2: The Results of F-test in the Indonesian Food Industry (ISIC 31)

	F stat	F critical value (α=0.05)	Decision
ISIC 311: Food Products			
TFP	2.166	3.239	Accept H_0
TP	1.831	3.239	Accept H_0
OTE	1.456	3.239	Accept H_0
OSME	2.184	3.239	Accept H_0
ISIC 312: Food Products n.e.c			
TFP	3.438	3.239	Reject H_0
TP	2.311	3.239	Accept H_0
OTE	3.441	3.239	Reject H_0
OSME	0.294	3.239	Accept H_0
ISIC 313 + 314: Beverage+Tobacco			
TFP	7.365	3.239	Reject H_0
TP	7.179	3.239	Reject H_0
OTE	2.671	3.239	Accept H_0
OSME	10.449	3.239	Reject H_0
ISIC 31: Food Industry			
TFP	5.211	3.239	Reject H_0
TP	12.392	3.239	Reject H_0
OTE	2.924	3.239	Accept H_0
OSME	4.819	3.239	Reject H_0

Source: Author's calculation.

Appendix 6.3: The Results of t-test between the means of TFP and its components in one period and all other sub-periods in the Indonesian Food Industry (ISIC 31)

Recalling Equations 6.14 to 6.17:

$H_0 : \mu_1 = \mu$, $H_a : \mu_1 \# \mu$ A6.5

$H_0 : \mu_2 = \mu$, $H_a : \mu_2 \# \mu$ A6.6

$H_0 : \mu_3 = \mu$, $H_a : \mu_3 \# \mu$ A6.7

$H_0 : \mu_4 = \mu$, $H_a : \mu_4 \# \mu$ A6.8

The test statistic for testing A6.5 to A6.8 is:

$$t_{stat} = \frac{(\mu_t - \mu)}{[\text{std err}(\mu_t - \mu)]} \qquad \text{A6.9}$$

where μ_t is the mean for μ_1, μ_2, μ_3, or μ_4 as previously defined; μ is the means for all other sub periods.

The decision rule for the t-test depends on the level of significance and the degrees of freedom. The degree of freedom of t is at ($n_1 + n_2 - 2$). For the two-sided t on this thesis, the null hypothesis is rejected at 5% significance level if $|t_{stat}| > t_{crit}$.

Appendix 6.3: The Results of t-test between the means of TFP and its components in one period and all other sub-periods in the Indonesian Food Industry (ISIC 31)

TFP/Sub-sectors	t stat	t critical value (α=0.05)	Decision	TFP/Sub-sectors	t stat	t critical value (α=0.05)	Decision
ISIC 311: Food Products				**ISIC 313 + 314:**			
TFP				**Beverage+Tobacco**			
$H_0 : \mu_1 = \mu$	|-2.404|	2.306	Reject H_0	**TFP**			
$H_0 : \mu_2 = \mu$	0.381	2.160	Accept H_0	$H_0 : \mu_1 = \mu$	|-3.381|	2.571	Reject H_0
$H_0 : \mu_3 = \mu$	2.537	2.262	Reject H_0	$H_0 : \mu_2 = \mu$	0.912	2.101	Accept H_0
$H_0 : \mu_4 = \mu$	0.063	2.770	Accept H_0	$H_0 : \mu_3 = \mu$	2.779	2.109	Reject H_0
TP				$H_0 : \mu_4 = \mu$	1.633	2.364	Accept H_0
$H_0 : \mu_1 = \mu$	|-3.532|	2.119	Reject H_0	**TP**			
$H_0 : \mu_2 = \mu$	0.186	2.228	Accept H_0	$H_0 : \mu_1 = \mu$	|-2.117|	2.201	Accept H_0
$H_0 : \mu_3 = \mu$	1.526	2.776	Accept H_0	$H_0 : \mu_2 = \mu$	|-1.934|	2.145	Accept H_0
$H_0 : \mu_4 = \mu$	0.297	2.447	Accept H_0	$H_0 : \mu_3 = \mu$	1.797	2.228	Accept H_0
OTE				$H_0 : \mu_4 = \mu$	4.355	2.365	Reject H_0
$H_0 : \mu_1 = \mu$	2.619	2.101	Reject H_0	**OTE**			
$H_0 : \mu_2 = \mu$	0.396	2.179	Accept H_0	$H_0 : \mu_1 = \mu$	3.051	2.120	Reject H_0
$H_0 : \mu_3 = \mu$	|-0.861|	2.776	Accept H_0	$H_0 : \mu_2 = \mu$	|-0.135|	2.306	Accept H_0
$H_0 : \mu_4 = \mu$	|-1.177|	2.776	Accept H_0	$H_0 : \mu_3 = \mu$	|-4.429|	2.110	Reject H_0
OSME				$H_0 : \mu_4 = \mu$	1.009	2.101	Accept H_0
$H_0 : \mu_1 = \mu$	2.611	2.145	Reject H_0	**OSME**			
$H_0 : \mu_2 = \mu$	|-0.255|	2.262	Accept H_0	$H_0 : \mu_1 = \mu$	|-0.970|	2.262	Accept H_0
$H_0 : \mu_3 = \mu$	0.475	2.262	Accept H_0	$H_0 : \mu_2 = \mu$	4.070	2.110	Reject H_0
$H_0 : \mu_4 = \mu$	|-2.739|	2.364	Reject H_0	$H_0 : \mu_3 = \mu$	0.658	2.179	Accept H_0
				$H_0 : \mu_4 = \mu$	|-4.683|	2.365	Reject H_0

Appendix 6.3 continued on the next page

Appendix 6.3: The Results of t-test between the means of TFP and its components in one period and all other sub-periods in the Indonesian Food Industry (ISIC 31) (continued from the previous page)

TFP/Sub-sectors	t stat	t critical value (α=0.05)	Decision	TFP/Sub-sectors	t stat	t critical value (α=0.05)	Decision
ISIC 312: Food Products n.e.c				**ISIC 31: Food Industry**			
TFP				**TFP**			
$H_0 : \mu_1 = \mu$	|-1.989|	2.570	Accept H_0	$H_0 : \mu_1 = \mu$	|-2.817|	2.571	Reject H_0
$H_0 : \mu_2 = \mu$	|-0.374|	2.101	Accept H_0	$H_0 : \mu_2 = \mu$	0.433	2.110	Accept H_0
$H_0 : \mu_3 = \mu$	2.287	2.447	Accept H_0	$H_0 : \mu_3 = \mu$	2.976	2.160	Reject H_0
$H_0 : \mu_4 = \mu$	1.349	2.447	Accept H_0	$H_0 : \mu_4 = \mu$	1.120	2.447	Accept H_0
TP				**TP**			
$H_0 : \mu_1 = \mu$	|-1.202|	2.101	Accept H_0	$H_0 : \mu_1 = \mu$	|-4.538|	2.110	Reject H_0
$H_0 : \mu_2 = \mu$	0.063	2.120	Accept H_0	$H_0 : \mu_2 = \mu$	|-0.707|	2.145	Accept H_0
$H_0 : \mu_3 = \mu$	|-2.375|	1.260	Reject H_0	$H_0 : \mu_3 = \mu$	0.088	2.110	Accept H_0
$H_0 : \mu_4 = \mu$	1.423	3.182	Accept H_0	$H_0 : \mu_4 = \mu$	7.509	2.201	Reject H_0
OTE				**OTE**			
$H_0 : \mu_1 = \mu$	0.891	2.228	Accept H_0	$H_0 : \mu_1 = \mu$	4.214	2.110	Reject H_0
$H_0 : \mu_2 = \mu$	|-0.363|	2.179	Accept H_0	$H_0 : \mu_2 = \mu$	|-0.010|	2.262	Accept H_0
$H_0 : \mu_3 = \mu$	2.543	2.447	Reject H_0	$H_0 : \mu_3 = \mu$	|-1.099|	2.571	Accept H_0
$H_0 : \mu_4 = \mu$	|-3.314|	2.365	Reject H_0	$H_0 : \mu_4 = \mu$	|-2.388|	2.306	Reject H_0
OSME				**OSME**			
$H_0 : \mu_1 = \mu$	|-0.918|	2.201	Accept H_0	$H_0 : \mu_1 = \mu$	0.089	2.110	Accept H_0
$H_0 : \mu_2 = \mu$	0.062	2.229	Accept H_0	$H_0 : \mu_2 = \mu$	1.354	2.228	Accept H_0
$H_0 : \mu_3 = \mu$	1.567	2.101	Accept H_0	$H_0 : \mu_3 = \mu$	2.118	2.110	Reject H_0
$H_0 : \mu_4 = \mu$	|-0.082	2.776	Accept H_0	$H_0 : \mu_4 = \mu$	|-4.910|	2.365	Reject H_0

Source: Author's calculation

Appendix 6.4: The Results of t-test between the means of TFP and its components in one period and another sub-period in the Indonesian Food Industry (ISIC 31)

Recalling Equations 6.18 to 6.20:

$H_0 : \mu_1 = \mu_2,\ H_a : \mu_1 \# \mu_2$ A6.10

$H_0 : \mu_2 = \mu_3,\ H_a : \mu_2 \# \mu_3$ A6.11

$H_0 : \mu_3 = \mu_4,\ H_a : \mu_3 \# \mu_4$ A6.12

The test statistic for testing to is:

$$t = \frac{(\mu_1 - \mu_2)}{[\text{std err}(\mu_1 - \mu_2)]} \qquad \text{A6.13}$$

$$t = \frac{(\mu_2 - \mu_3)}{[\text{std err}(\mu_2 - \mu_3)]} \qquad \text{A6.14}$$

$$t = \frac{(\mu_3 - \mu_4)}{[\text{std err}(\mu_3 - \mu_4)]} \qquad \text{A6.15}$$

where μ_1, μ_2, μ_3 and μ_4 are as previously defined.

Appendix 6.4: The Results of t-test between the means of TFP and its components in one period and another sub-period in the Indonesian Food Industry (ISIC 31)

TFP/Sub-sectors	t stat	t critical value (α=0.05)	Decision	TFP/Sub-sectors	t stat	t critical value (α=0.05)	Decision
ISIC 311: Food Products				**ISIC 313 + 314:**			
TFP				**Beverage+Tobacco**			
$H_0 : \mu_1 = \mu_2$	|-1.742|	2.228	Accept H_0	**TFP**			
$H_0 : \mu_2 = \mu_3$	|-1.386|	2.262	Accept H_0	$H_0 : \mu_1 = \mu_2$	|-2.832|	2.447	Reject H_0
$H_0 : \mu_3 = \mu_4$	1.106	2.776	Accept H_0	$H_0 : \mu_2 = \mu_3$	|-1.631|	2.306	Accept H_0
TP				$H_0 : \mu_3 = \mu_4$	0.234	3.182	Accept H_0
$H_0 : \mu_1 = \mu_2$	|-1.735|	2.447	Accept H_0	**TP**			
$H_0 : \mu_2 = \mu_3$	|-0.081|	2.262	Accept H_0	$H_0 : \mu_1 = \mu_2$	|-0.219|	2.228	Accept H_0
$H_0 : \mu_3 = \mu_4$	|-0.907|	2.571	Accept H_0	$H_0 : \mu_2 = \mu_3$	|-2.538|	2.262	Reject H_0
OTE				$H_0 : \mu_3 = \mu_4$	|-1.768|	2.447	Accept H_0
$H_0 : \mu_1 = \mu_2$	1.137	2.306	Accept H_0	**OTE**			
$H_0 : \mu_2 = \mu_3$	0.792	2.447	Accept H_0	$H_0 : \mu_1 = \mu_2$	1.309	2.447	Accept H_0
$H_0 : \mu_3 = \mu_4$	0.211	2.447	Accept H_0	$H_0 : \mu_2 = \mu_3$	1.692	2.365	Accept H_0
OSME				$H_0 : \mu_3 = \mu_4$	|-6.222|	2.447	Reject H_0
$H_0 : \mu_1 = \mu_2$	1.436	2.306	Accept H_0	**OSME**			
$H_0 : \mu_2 = \mu_3$	|-0.423|	2.262	Accept H_0	$H_0 : \mu_1 = \mu_2$	|-2.781|	2.365	Reject H_0
$H_0 : \mu_3 = \mu_4$	2.387	2.447	Accept H_0	$H_0 : \mu_2 = \mu_3$	2.065	2.306	Accept H_0
				$H_0 : \mu_3 = \mu_4$	4.045	2.447	Reject H_0

Appendix 6.4 continued on the next page.

Appendix 6.4: The Results of t-test between the means of TFP and its components in one period and another sub-period in the Indonesian Food Industry (ISIC 31)(continued from the previous page)

TFP/Sub-sectors	t stat	t critical value (α=0.05)	Decision	TFP/Sub-sectors	t stat	t critical value (α=0.05)	Decision
ISIC 312: Food Products n.e.c				**ISIC 31: Food Industry**			
				TFP			
TFP				$H_0 : \mu_1 = \mu_2$			
$H_0 : \mu_1 = \mu_2$	$\lvert -1.305 \rvert$	2.571	Accept H_0	$H_0 : \mu_2 = \mu_3$	$\lvert -2.245 \rvert$	2.447	Accept H_0
$H_0 : \mu_2 = \mu_3$	$\lvert -2.115 \rvert$	2.571	Accept H_0	$H_0 : \mu_3 = \mu_4$	$\lvert -2.051 \rvert$	2.262	Accept H_0
$H_0 : \mu_3 = \mu_4$	0.601	2.447	Accept H_0	**TP**	0.833	2.571	Accept H_0
TP				$H_0 : \mu_1 = \mu_2$			
$H_0 : \mu_1 = \mu_2$	$\lvert -0.907 \rvert$	2.306	Accept H_0	$H_0 : \mu_2 = \mu_3$	$\lvert -2.001 \rvert$	2.365	Accept H_0
$H_0 : \mu_2 = \mu_3$	1.738	2.262	Accept H_0	$H_0 : \mu_3 = \mu_4$	$\lvert -0.609 \rvert$	2.306	Accept H_0
$H_0 : \mu_3 = \mu_4$	$\lvert -1.865 \rvert$	3.182	Accept H_0	**OTE**	$\lvert -6.159 \rvert$	2.447	Reject H_0
OTE				$H_0 : \mu_1 = \mu_2$			
$H_0 : \mu_1 = \mu_2$	0.774	2.228	Accept H_0	$H_0 : \mu_2 = \mu_3$	1.758	2.365	Accept H_0
$H_0 : \mu_2 = \mu_3$	$\lvert -1.824 \rvert$	2.262	Accept H_0	$H_0 : \mu_3 = \mu_4$	0.676	2.306	Accept H_0
$H_0 : \mu_3 = \mu_4$	4.084	2.447	Reject H_0	**OSME**	0.967	2.447	Accept H_0
OSME				$H_0 : \mu_1 = \mu_2$			
$H_0 : \mu_1 = \mu_2$	$\lvert -0.552 \rvert$	2.228	Accept H_0	$H_0 : \mu_2 = \mu_3$	$\lvert -0.856 \rvert$	2.306	Accept H_0
$H_0 : \mu_2 = \mu_3$	$\lvert -0.735 \rvert$	2.365	Accept H_0	$H_0 : \mu_3 = \mu_4$	$\lvert -0.109 \rvert$	2.367	Accept H_0
$H_0 : \mu_3 = \mu_4$	0.56	3.182	Accept H_0		6.399	2.776	Reject H_0

Source: Author's calculation

Appendix 6.5: The Levels and Ratios of TFP and Components in the Indonesian Textile Industry (ISIC 32), selected years

Sub-sector/Industry	Levels					Ratio				
	1981	1985	1992	1996	2000	1985/1981	1992/1985	1996/1992	2000/1996	2000/1981
ISIC 32112: Sewing Thread										
TFP = TP x TFPE	0.03	0.03	0.04	0.04	0.04	1.09	1.10	0.99	1.10	1.30
TP	0.12	0.09	0.14	0.25	0.13	0.77	1.56	1.73	0.52	1.08
TFPE = OTE x OSME	0.26	0.37	0.26	0.15	0.31	1.40	0.71	0.57	2.12	1.20
OTE	0.63	0.64	0.57	0.39	0.51	1.02	0.88	0.69	1.32	0.82
OSME	0.42	0.57	0.46	0.38	0.61	1.37	0.80	0.83	1.61	1.47
ISIC 32111+32113+32114: Spinning and Weaving										
TFP = TP x TFPE	0.04	0.03	0.05	0.05	0.06	0.91	1.37	1.03	1.31	1.69
TP	0.14	0.18	0.13	0.18	0.25	1.32	0.70	1.40	1.40	1.83
TFPE = OTE x OSME	0.27	0.18	0.36	0.27	0.25	0.69	1.95	0.74	0.93	0.92
OTE	0.78	0.63	0.86	0.63	0.73	0.80	1.37	0.73	1.17	0.94
OSME	0.34	0.29	0.42	0.42	0.34	0.86	1.43	1.01	0.80	0.99
ISIC 32115 to 32290: Textile n.e.c										
TFP = TP x TFPE	0.03	0.04	0.06	0.07	0.08	1.20	1.42	1.25	1.10	2.32
TP	0.09	0.15	0.16	0.28	0.33	1.67	1.08	1.73	1.19	3.69
TFPE = OTE x OSME	0.38	0.27	0.36	0.26	0.24	0.72	1.32	0.72	0.92	0.63
OTE	0.68	0.62	0.74	0.58	0.70	0.92	1.19	0.78	1.21	1.03
OSME	0.55	0.43	0.48	0.44	0.34	0.78	1.10	0.93	0.76	0.61
ISIC 32: Textile Industry										
TFP = TP x TFPE	0.03	0.04	0.05	0.05	0.06	1.06	1.29	1.08	1.16	1.72
TP	0.11	0.14	0.14	0.23	0.22	1.19	1.06	1.61	0.96	1.94
TFPE = OTE x OSME	0.30	0.26	0.32	0.22	0.26	0.89	1.22	0.67	1.22	0.89
OTE	0.69	0.63	0.71	0.52	0.64	0.91	1.13	0.73	1.23	0.92
OSME	0.43	0.42	0.45	0.41	0.41	0.97	1.08	0.92	0.99	0.96

Notes: Levels are generated using DPIN 3.0, ratio is author's calculation using levels.

Appendix 6.6: The Results of F-test in the Indonesian Textile Industry (ISIC 32)

The F-test procedures follow Equations A6.1 to A6.4

	F stat	F critical value (α=0.05)	Decision
ISIC 32112: Sewing Thread			
TFP			
TP	11.774	3.239	Reject H_0
OTE	1.054	3.239	Accept H_0
OSME	1.321	3.239	Accept H_0
ISIC 32111+32113+32114: Spinning and Weaving	0.887	3.239	Accept H_0
TFP			
TP	25.527	3.239	Reject H_0
OTE	1.575	3.239	Accept H_0
OSME	1.989	3.239	Accept H_0
ISIC 32115 to 32290: Textile n.e.c	2.903	3.239	Accept H_0
TFP	47.693	3.239	Reject H_0
TP	12.464	3.239	Reject H_0
OTE	0.289	3.239	Accept H_0
OSME	3.304	3.239	Reject H_0
ISIC 32: Textile Industry			
TFP	40.769	3.239	Reject H_0
TP	7.684	3.239	Reject H_0
OTE	0.506	3.239	Accept H_0
OSME	5.865	3.239	Reject H_0

Source: Author's calculation

Appendix 6.7: The Results of t-test between the means of TFP and Components in one period and all other sub-periods in the Indonesian Textile Industry (ISIC 32)

The t-test procedures follow Equations A6.5 to A6.9.

TFP/Sub-sectors	t stat	t critical value (α=0.05)	Decision
ISIC 32112: Sewing Thread			
TFP			
$H_0 : \mu_1 = \mu$	|-5.518|	2.365	Reject H_0
$H_0 : \mu_2 = \mu$	0.768	2.101	Accept H_0
$H_0 : \mu_3 = \mu$	1.887	2.110	Accept H_0
$H_0 : \mu_4 = \mu$	2.513	2.447	Reject H_0
TP			
$H_0 : \mu_1 = \mu$	|-1.926|	2.110	Accept H_0
$H_0 : \mu_2 = \mu$	|-0.125|	2.160	Accept H_0
$H_0 : \mu_3 = \mu$	|-0.172|	2.776	Accept H_0
$H_0 : \mu_4 = \mu$	1.412	2.776	Accept H_0
OTE			
$H_0 : \mu_1 = \mu$	1.682	2.365	Accept H_0
$H_0 : \mu_2 = \mu$	|-0.292|	2.120	Accept H_0
$H_0 : \mu_3 = \mu$	0.061	2.776	Accept H_0
$H_0 : \mu_4 = \mu$	|-1.514|	2.571	Accept H_0
OSME			
$H_0 : \mu_1 = \mu$	|-2.736|	2.131	Reject H_0
$H_0 : \mu_2 = \mu$	0.608	2.160	Accept H_0
$H_0 : \mu_3 = \mu$	1.156	2.776	Accept H_0
$H_0 : \mu_4 = \mu$	|-0.500|	2.776	Accept H_0

TFP/Sub-sectors	t stat	t critical value (α=0.05)	Decision
ISIC 32115 to 32290: Textile n.e.c			
TFP			
$H_0 : \mu_1 = \mu$	|-6.387|	2.120	Reject H_0
$H_0 : \mu_2 = \mu$	|-1.212|	2.131	Accept H_0
$H_0 : \mu_3 = \mu$	2.706	2.120	Reject H_0
$H_0 : \mu_4 = \mu$	6.434	2.179	Reject H_0
TP			
$H_0 : \mu_1 = \mu$	|-4.810|	2.101	Reject H_0
$H_0 : \mu_2 = \mu$	|-0.320|	2.110	Accept H_0
$H_0 : \mu_3 = \mu$	0.058	2.365	Accept H_0
$H_0 : \mu_4 = \mu$	7.620	1.160	Reject H_0
OTE			
$H_0 : \mu_1 = \mu$	|-0.435|	2.120	Accept H_0
$H_0 : \mu_2 = \mu$	0.139	2.262	Accept H_0
$H_0 : \mu_3 = \mu$	0.675	2.776	Accept H_0
$H_0 : \mu_4 = \mu$	|-0.799|	2.447	Accept H_0
OSME			
$H_0 : \mu_1 = \mu$	1.230	2.447	Accept H_0
$H_0 : \mu_2 = \mu$	|-0.980|	2.145	Accept H_0
$H_0 : \mu_3 = \mu$	2.359	2.306	Reject H_0
$H_0 : \mu_4 = \mu$	|-3.760|	2.120	Reject H_0

Appendix 6.7 continued on the next page.

Appendix 6.7: The Results of t-test between the means of TFP and Components in one period and all other sub-periods in the Indonesian Textile Industry (ISIC 32) (continued from the previous page)

TFP/Sub-sectors	t stat	t critical value (α=0.05)	Decision	TFP/Sub-sectors	t stat	t critical value (α=0.05)	Decision
ISIC 32111+32113+32114: Spinning and Weaving				**ISIC 32: Textile Industry**			
TFP				**TFP**			
$H_0 : \mu_1 = \mu$	|-6.801|	2.101	Reject H_0	$H_0 : \mu_1 = \mu$	|-7.642|	2.110	Reject H_0
$H_0 : \mu_2 = \mu$	|-0.520|	2.101	Accept H_0	$H_0 : \mu_2 = \mu$	|-0.575|	2.110	Accept H_0
$H_0 : \mu_3 = \mu$	1.092	2.120	Accept H_0	$H_0 : \mu_3 = \mu$	2.234	2.101	Reject H_0
$H_0 : \mu_4 = \mu$	5.620	2.447	Reject H_0	$H_0 : \mu_4 = \mu$	6.256	2.179	Reject H_0
TP				**TP**			
$H_0 : \mu_1 = \mu$	|-2.067|	2.201	Accept H_0	$H_0 : \mu_1 = \mu$	|-4.556|	2.110	Reject H_0
$H_0 : \mu_2 = \mu$	|-0.421|	2.179	Accept H_0	$H_0 : \mu_2 = \mu$	|-0.451|	2.110	Accept H_0
$H_0 : \mu_3 = \mu$	0.752	2.776	Accept H_0	$H_0 : \mu_3 = \mu$	0.072	2.776	Accept H_0
$H_0 : \mu_4 = \mu$	1.370	2.776	Accept H_0	$H_0 : \mu_4 = \mu$	4.398	2.571	Reject H_0
OTE				**OTE**			
$H_0 : \mu_1 = \mu$	0.251	2.131	Accept H_0	$H_0 : \mu_1 = \mu$	1.287	2.131	Accept H_0
$H_0 : \mu_2 = \mu$	0.788	2.131	Accept H_0	$H_0 : \mu_2 = \mu$	0.350	2.228	Accept H_0
$H_0 : \mu_3 = \mu$	|-1.610|	3.182	Accept H_0	$H_0 : \mu_3 = \mu$	|-0.728|	2.776	Accept H_0
$H_0 : \mu_4 = \mu$	1.529	2.306	Accept H_0	$H_0 : \mu_4 = \mu$	|-0.545|	2.571	Accept H_0
OSME				**OSME**			
$H_0 : \mu_1 = \mu$	|-3.093|	2.101	Reject H_0	$H_0 : \mu_1 = \mu$	|-1.700|	2.306	Accept H_0
$H_0 : \mu_2 = \mu$	|-0.223|	2.201	Accept H_0	$H_0 : \mu_2 = \mu$	|-0.296|	2.120	Accept H_0
$H_0 : \mu_3 = \mu$	2.267	2.776	Accept H_0	$H_0 : \mu_3 = \mu$	3.162	2.776	Reject H_0
$H_0 : \mu_4 = \mu$	0.084	2.228	Accept H_0	$H_0 : \mu_4 = \mu$	|-2.162|	2.228	Accept H_0

Source: Author's calculation

Appendix 6.8: The Results of t-test between the means of TFP and components in one period and another sub-period in the Indonesian Textile Industry (ISIC 32)

The t-test procedures follow Equations A6.10 to A6.15.

TFP/Sub-sectors	t stat	t critical value (α=0.05)	Decision	TFP/Sub-sectors	t stat	t critical value (α=0.05)	Decision
ISIC 32112: Sewing Thread				**ISIC 32115 to 32290: Textile**			
TFP				**n.e.c**			
$H_0 : \mu_1 = \mu_2$	$\lvert -4.115 \rvert$	2.262	Reject H_0	**TFP**			
$H_0 : \mu_2 = \mu_3$	$\lvert -0.929 \rvert$	2.262	Accept H_0	$H_0 : \mu_1 = \mu_2$	$\lvert -4.577 \rvert$	2.262	Reject H_0
$H_0 : \mu_3 = \mu_4$	$\lvert -0.957 \rvert$	2.776	Accept H_0	$H_0 : \mu_2 = \mu_3$	$\lvert -4.475 \rvert$	2.365	Reject H_0
TP				$H_0 : \mu_3 = \mu_4$	$\lvert -2.859 \rvert$	2.447	Reject H_0
$H_0 : \mu_1 = \mu_2$	$\lvert -1.024 \rvert$	2.365	Accept H_0	**TP**			
$H_0 : \mu_2 = \mu_3$	0.076	2.571	Accept H_0	$H_0 : \mu_1 = \mu_2$	$\lvert -2.791 \rvert$	2.306	Reject H_0
$H_0 : \mu_3 = \mu_4$	$\lvert -0.922 \rvert$	2.447	Accept H_0	$H_0 : \mu_2 = \mu_3$	$\lvert -0.056 \rvert$	2.364	Accept H_0
OTE				$H_0 : \mu_3 = \mu_4$	$\lvert -3.964 \rvert$	2.776	Reject H_0
$H_0 : \mu_1 = \mu_2$	1.324	2.306	Accept H_0	**OTE**			
$H_0 : \mu_2 = \mu_3$	$\lvert -0.170 \rvert$	2.571	Accept H_0	$H_0 : \mu_1 = \mu_2$	$\lvert -0.310 \rvert$	2.306	Accept H_0
$H_0 : \mu_3 = \mu_4$	0.896	2.447	Accept H_0	$H_0 : \mu_2 = \mu_3$	$\lvert -0.390 \rvert$	2.365	Accept H_0
OSME				$H_0 : \mu_3 = \mu_4$	0.898	2.571	Accept H_0
$H_0 : \mu_1 = \mu_2$	$\lvert -1.339 \rvert$	2.228	Accept H_0	**OSME**			
$H_0 : \mu_2 = \mu_3$	$\lvert -0.487 \rvert$	2.571	Accept H_0	$H_0 : \mu_1 = \mu_2$	1.306	2.365	Accept H_0
$H_0 : \mu_3 = \mu_4$	0.933	2.447	Accept H_0	$H_0 : \mu_2 = \mu_3$	$\lvert -2.242 \rvert$	2.262	Accept H_0
				$H_0 : \mu_3 = \mu_4$	4.807	2.571	Reject H_0

Appendix 6.8 continued on the next page.

Appendix 6.8: The Results of t-test between the means of TFP and components in one period and another sub-period in the Indonesian Textile Industry (ISIC 32) (continued from the previous page)

TFP/Sub-sectors	t stat	t critical value (α=0.05)	Decision	TFP/Sub-sectors	t stat	t critical value (α=0.05)	Decision
ISIC 32111+32113+32114: Spinning and Weaving				**ISIC 32: Textile Industry**			
TFP				**TFP**			
$H_0 : \mu_1 = \mu_2$	|-4.530|	2.306	Reject H_0	$H_0 : \mu_1 = \mu_2$	|-5.318|	2.228	Reject H_0
$H_0 : \mu_2 = \mu_3$	|-1.570|	2.262	Accept H_0	$H_0 : \mu_2 = \mu_3$	|-3.089|	2.262	Reject H_0
$H_0 : \mu_3 = \mu_4$	|-3.597|	2.571	Reject H_0	$H_0 : \mu_3 = \mu_4$	|-3.736|	2.571	Reject H_0
TP				**TP**			
$H_0 : \mu_1 = \mu_2$	|-1.088|	2.262	Accept H_0	$H_0 : \mu_1 = \mu_2$	|-2.803|	2.365	Reject H_0
$H_0 : \mu_2 = \mu_3$	|-0.732|	2.447	Accept H_0	$H_0 : \mu_2 = \mu_3$	|-0.262|	2.571	Accept H_0
$H_0 : \mu_3 = \mu_4$	|-0.411|	2.447	Accept H_0	$H_0 : \mu_3 = \mu_4$	|-2.069|	2.571	Accept H_0
OTE				**OTE**			
$H_0 : \mu_1 = \mu_2$	|-0.365|	2.228	Accept H_0	$H_0 : \mu_1 = \mu_2$	0.479	2.262	Accept H_0
$H_0 : \mu_2 = \mu_3$	1.472	2.776	Accept H_0	$H_0 : \mu_2 = \mu_3$	0.658	2.571	Accept H_0
$H_0 : \mu_3 = \mu_4$	|-1.844|	2.776	Accept H_0	$H_0 : \mu_3 = \mu_4$	|-0.240|	2.571	Accept H_0
OSME				**OSME**			
$H_0 : \mu_1 = \mu_2$	|-1.406|	2.306	Accept H_0	$H_0 : \mu_1 = \mu_2$	|-0.942|	2.228	Accept H_0
$H_0 : \mu_2 = \mu_3$	|-1.636|	2.365	Accept H_0	$H_0 : \mu_2 = \mu_3$	|-2.439|	2.571	Accept H_0
$H_0 : \mu_3 = \mu_4$	1.713	2.571	Accept H_0	$H_0 : \mu_3 = \mu_4$	3.497	2.776	Reject H_0

Source: Author’s calculation

Appendix 6.9: The Levels and Ratios of TFP and Components in the Indonesian Chemical Industry (ISIC 35), selected years

Sub-sector/Industry	Levels					Ratio				
	1981	1985	1992	1996	2000	1985/1981	1992/1985	1996/1992	2000/1996	2000/1981
ISIC 352: Other Chemical										
TFP = TP x TFPE	0.01	0.01	0.01	0.01	0.01	1.29	1.01	1.24	1.02	1.63
TP	0.09	0.09	0.06	0.13	0.16	0.95	0.62	2.33	1.24	1.71
TFPE = OTE x OSME	0.07	0.10	0.16	0.09	0.07	1.35	1.61	0.53	0.82	0.95
OTE	0.18	0.53	0.44	0.54	0.51	2.97	0.84	1.22	0.94	2.85
OSME	0.42	0.19	0.37	0.16	0.14	0.46	1.93	0.43	0.88	0.34
ISIC 355: Rubber Products										
TFP = TP x TFPE	0.07	0.10	0.12	0.13	0.11	1.38	1.25	1.01	0.90	1.57
TP	0.47	0.35	0.44	0.43	0.41	0.74	1.26	0.99	0.95	0.88
TFPE = OTE x OSME	0.15	0.28	0.28	0.29	0.27	1.87	0.99	1.02	0.95	1.79
OTE	0.52	0.69	0.70	0.73	0.72	1.32	1.01	1.04	0.99	1.37
OSME	0.29	0.41	0.41	0.40	0.38	1.43	0.98	0.98	0.96	1.31
ISIC 351 + 356: Chemical and Plastic Products										
TFP = TP x TFPE	0.03	0.04	0.05	0.05	0.04	1.53	1.08	1.02	0.92	1.56
TP	0.23	0.28	0.25	0.24	0.33	1.25	0.88	0.95	1.40	1.47
TFPE = OTE x OSME	0.12	0.15	0.19	0.20	0.13	1.22	1.23	1.07	0.66	1.06
OTE	0.36	0.36	0.63	0.60	0.61	1.01	1.75	0.94	1.02	1.72
OSME	0.35	0.42	0.29	0.33	0.21	1.21	0.70	1.13	0.64	0.62
ISIC 35: Chemical Industry										
TFP = TP x TFPE	0.02	0.03	0.04	0.04	0.04	1.40	1.11	1.09	0.94	1.59
TP	0.22	0.21	0.18	0.24	0.28	0.96	0.88	1.30	1.18	1.30
TFPE = OTE x OSME	0.11	0.16	0.20	0.17	0.14	1.46	1.25	0.83	0.80	1.22
OTE	0.32	0.51	0.58	0.62	0.61	1.58	1.14	1.06	0.98	1.88
OSME	0.35	0.32	0.35	0.28	0.23	0.92	1.10	0.78	0.82	0.65

Notes: Levels are generated using DPIN 3.0, ratio is author's calculation using levels.

Appendix 6.10: The Results of F-test in the Indonesian Chemical Industry (ISIC 35)

The F-test procedures follow Equations A6.1 to A6.4

	F stat	F critical value (α=0.05)	Decision
ISIC 352: Other Chemical			
TFP	7.508	3.239	Reject H_0
TP	1.814	3.239	Accept H_0
OTE	1.343	3.239	Accept H_0
OSME	0.534	3.239	Accept H_0
ISIC 355: Rubber Products			
TFP	12.202	3.239	Reject H_0
TP	0.381	3.239	Accept H_0
OTE	1.775	3.239	Accept H_0
OSME	3.504	3.239	Reject H_0
ISIC 351 + 356: Chemical and Plastic Products			
TFP	6.792	3.239	Reject H_0
TP	2.033	3.239	Accept H_0
OTE	7.264	3.239	Reject H_0
OSME	2.028	3.239	Accept H_0
ISIC 35: Chemical Industry			
TFP	9.028	3.239	Reject H_0
TP	2.526	3.239	Accept H_0
OTE	5.312	3.239	Reject H_0
OSME	1.668	3.239	Accept H_0

Source: Author's calculation

Appendix 6.11: The Results of t-test between the means of TFP and its components in one period and all other sub-periods in the Indonesian Chemical Industry (ISIC 35)

The t-test procedures follow Equations A6.5 to A6.9.

TFP/Sub-sectors	t stat	t critical value (α=0.05)	Decision	TFP/Sub-sectors	t stat	t critical value (α=0.05)	Decision
ISIC 352: Other Chemical				**ISIC 351 + 356: Chemical**			
TFP				**and Plastic Products**			
$H_0 : \mu_1 = \mu$	$\lvert -4.661 \rvert$	2.201	Reject H_0	**TFP**			
$H_0 : \mu_2 = \mu$	$\lvert -0.346 \rvert$	2.101	Accept H_0	$H_0 : \mu_1 = \mu$			
$H_0 : \mu_3 = \mu$	1.869	2.776	Accept H_0	$H_0 : \mu_2 = \mu$	$\lvert -3.477 \rvert$	2.447	Reject H_0
$H_0 : \mu_4 = \mu$	2.127	2.365	Accept H_0	$H_0 : \mu_3 = \mu$	0.744	2.120	Accept H_0
TP				$H_0 : \mu_4 = \mu$	2.798	2.571	Reject H_0
$H_0 : \mu_1 = \mu$	0.057	2.447	Accept H_0	**TP**	0.088	2.571	Accept H_0
$H_0 : \mu_2 = \mu$	$\lvert -2.876 \rvert$	2.120	Reject H_0	$H_0 : \mu_1 = \mu$			
$H_0 : \mu_3 = \mu$	0.872	2.776	Accept H_0	$H_0 : \mu_2 = \mu$	$\lvert -0.481 \rvert$	2.131	Accept H_0
$H_0 : \mu_4 = \mu$	1.428	2.571	Accept H_0	$H_0 : \mu_3 = \mu$	$\lvert -1.429 \rvert$	2.201	Accept H_0
OTE				$H_0 : \mu_4 = \mu$	$\lvert -0.076 \rvert$	2.776	Accept H_0
$H_0 : \mu_1 = \mu$	$\lvert -1.014 \rvert$	2.776	Accept H_0	**OTE**	2.660	2.571	Reject H_0
$H_0 : \mu_2 = \mu$	1.637	2.110	Accept H_0	$H_0 : \mu_1 = \mu$			
$H_0 : \mu_3 = \mu$	1.493	2.131	Accept H_0	$H_0 : \mu_2 = \mu$	$\lvert -3.648 \rvert$	2.571	Reject H_0
$H_0 : \mu_4 = \mu$	$\lvert -0.809 \rvert$	2.571	Accept H_0	$H_0 : \mu_3 = \mu$	3.075	2.110	Reject H_0
OSME				$H_0 : \mu_4 = \mu$	0.777	2.447	Accept H_0
$H_0 : \mu_1 = \mu$	0.287	2.447	Accept H_0	**OSME**	0.235	2.365	Accept H_0
$H_0 : \mu_2 = \mu$	1.281	2.110	Accept H_0	$H_0 : \mu_1 = \mu$			
$H_0 : \mu_3 = \mu$	$\lvert -0.630 \rvert$	2.776	Accept H_0	$H_0 : \mu_2 = \mu$	0.411	2.447	Accept H_0
$H_0 : \mu_4 = \mu$	$\lvert -0.609 \rvert$	2.776	Accept H_0	$H_0 : \mu_3 = \mu$	0.482	2.160	Accept H_0
				$H_0 : \mu_4 = \mu$	2.170	2.101	Reject H_0
					$\lvert -2.254 \rvert$	2.776	Accept H_0

Appendix 6.11 continued on the next page.

Appendix 6.11: The Results of t-test between the means of TFP and its components in one period and all other sub-periods in the Indonesian Chemical Industry (ISIC 35)(continued from the previous page)

TFP/Sub-sectors	t stat	t critical value (α=0.05)	Decision	TFP/Sub-sectors	t stat	t critical value (α=0.05)	Decision
ISIC 355: Rubber Products				**ISIC 35: Chemical Industry**			
TFP							
$H_0 : \mu_1 = \mu$	|-4.527|	2.571	Reject H_0	**TFP**			
$H_0 : \mu_2 = \mu$	1.486	2.120	Accept H_0	$H_0 : \mu_1 = \mu$	|-4.296|	2.364	Reject H_0
$H_0 : \mu_3 = \mu$	2.341	2.447	Accept H_0	$H_0 : \mu_2 = \mu$	0.603	2.110	Accept H_0
$H_0 : \mu_4 = \mu$	1.100	2.101	Accept H_0	$H_0 : \mu_3 = \mu$	2.418	2.571	Accept H_0
TP				$H_0 : \mu_4 = \mu$	1.023	2.306	Accept H_0
$H_0 : \mu_1 = \mu$	0.237	2.571	Accept H_0	**TP**			
$H_0 : \mu_2 = \mu$	|-1.196|	2.131	Accept H_0	$H_0 : \mu_1 = \mu$	|-0.046|	2.447	Accept H_0
$H_0 : \mu_3 = \mu$	1.128	2.101	Accept H_0	$H_0 : \mu_2 = \mu$	|-2.698|	2.110	Reject H_0
$H_0 : \mu_4 = \mu$	0.320	2.776	Accept H_0	$H_0 : \mu_3 = \mu$	0.763	2.571	Accept H_0
OTE				$H_0 : \mu_4 = \mu$	2.365	2.447	Accept H_0
$H_0 : \mu_1 = \mu$	|-1.922|	2.365	Accept H_0	**OTE**			
$H_0 : \mu_2 = \mu$	|-0.060|	2.228	Accept H_0	$H_0 : \mu_1 = \mu$	|-3.084|	2.571	Reject H_0
$H_0 : \mu_3 = \mu$	0.710	2.306	Accept H_0	$H_0 : \mu_2 = \mu$	2.217	2.101	Reject H_0
$H_0 : \mu_4 = \mu$	2.985	2.101	Reject H_0	$H_0 : \mu_3 = \mu$	1.488	2.262	Accept H_0
OSME				$H_0 : \mu_4 = \mu$	0.129	2.571	Accept H_0
$H_0 : \mu_1 = \mu$	|-2.072|	2.447	Accept H_0	**OSME**			
$H_0 : \mu_2 = \mu$	2.796	2.131	Reject H_0	$H_0 : \mu_1 = \mu$	|-0.400|	2.306	Accept H_0
$H_0 : \mu_3 = \mu$	0.597	2.262	Accept H_0	$H_0 : \mu_2 = \mu$	2.402	2.101	Reject H_0
$H_0 : \mu_4 = \mu$	|-0.962|	2.571	Accept H_0	$H_0 : \mu_3 = \mu$	|-0.083|	2.776	Accept H_0
				$H_0 : \mu_4 = \mu$	|-1.269|	2.776	Accept H_0

Source: Author's calculation

Appendix 6.12: The Results of t-test between the means of TFP and its components in one period and another sub-period in the Indonesian Chemical Industry (ISIC 35)

The t-test procedures follow Equations A6.10 to A6.15.

TFP/Sub-sectors	t stat	t critical value (α=0.05)	Decision	TFP/Sub-sectors	t stat	t critical value (α=0.05)	Decision
ISIC 352: Other Chemical				**ISIC 351 + 356: Chemical**			
TFP				**and Plastic Products**			
$H_0 : \mu_1 = \mu_2$	$\lvert-3.091\rvert$	2.228	Reject H_0	**TFP**			
$H_0 : \mu_2 = \mu_3$	$\lvert-1.649\rvert$	2.776	Accept H_0	$H_0 : \mu_1 = \mu_2$			
$H_0 : \mu_3 = \mu_4$	0.211	2.571	Accept H_0	$H_0 : \mu_2 = \mu_3$	$\lvert-3.149\rvert$	2.571	Reject H_0
TP				$H_0 : \mu_3 = \mu_4$	$\lvert-1.972\rvert$	2.776	Accept H_0
$H_0 : \mu_1 = \mu_2$	1.107	2.776	Accept H_0	**TP**	1.628	2.447	Accept H_0
$H_0 : \mu_2 = \mu_3$	$\lvert-1.661\rvert$	3.182	Accept H_0	$H_0 : \mu_1 = \mu_2$			
$H_0 : \mu_3 = \mu_4$	$\lvert-0.110\rvert$	2.571	Accept H_0	$H_0 : \mu_2 = \mu_3$	0.660	2.262	Accept H_0
OTE				$H_0 : \mu_3 = \mu_4$	$\lvert-0.563\rvert$	2.447	Accept H_0
$H_0 : \mu_1 = \mu_2$	$\lvert-1.277\rvert$	2.776	Accept H_0	**OTE**	$\lvert-1.424\rvert$	2.571	Accept H_0
$H_0 : \mu_2 = \mu_3$	$\lvert-0.053\rvert$	2.365	Accept H_0	$H_0 : \mu_1 = \mu_2$			
$H_0 : \mu_3 = \mu_4$	1.429	2.776	Accept H_0	$H_0 : \mu_2 = \mu_3$	$\lvert-4.245\rvert$	2.571	Reject H_0
OSME				$H_0 : \mu_3 = \mu_4$	0.802	2.776	Accept H_0
$H_0 : \mu_1 = \mu_2$	$\lvert-0.341\rvert$	2.571	Accept H_0	**OSME**	0.398	2.447	Accept H_0
$H_0 : \mu_2 = \mu_3$	0.927	3.182	Accept H_0	$H_0 : \mu_1 = \mu_2$			
$H_0 : \mu_3 = \mu_4$	$\lvert-0.071\rvert$	2.447	Accept H_0	$H_0 : \mu_2 = \mu_3$	0.045	2.306	Accept H_0
				$H_0 : \mu_3 = \mu_4$	$\lvert-0.961\rvert$	2.364	Accept H_0
					2.902	3.182	Accept H_0

Appendix 6.12 continued on the next page.

Appendix 6.12: The Results of t-test between the means of TFP and its components in one period and another sub-period in the Indonesian Chemical Industry (ISIC 35)(continued from the previous page)

TFP/Sub-sectors	t stat	t critical value (α=0.05)	Decision	TFP/Sub-sectors	t stat	t critical value (α=0.05)	Decision
ISIC 355: Rubber Products				**ISIC 35: Chemical Industry**			
TFP							
$H_0 : \mu_1 = \mu_2$	$\lvert -4.169 \rvert$	2.571	Reject H_0	**TFP**			
$H_0 : \mu_2 = \mu_3$	$\lvert -1.185 \rvert$	2.776	Accept H_0	$H_0 : \mu_1 = \mu_2$	$\lvert -3.672 \rvert$	2.447	Reject H_0
$H_0 : \mu_3 = \mu_4$	1.427	2.776	Accept H_0	$H_0 : \mu_2 = \mu_3$	$\lvert -1.697 \rvert$	2.776	Accept H_0
TP				$H_0 : \mu_3 = \mu_4$	1.144	2.571	Accept H_0
$H_0 : \mu_1 = \mu_2$	0.604	2.447	Accept H_0	**TP**			
$H_0 : \mu_2 = \mu_3$	$\lvert -1.798 \rvert$	2.306	Accept H_0	$H_0 : \mu_1 = \mu_2$	1.009	2.571	Accept H_0
$H_0 : \mu_3 = \mu_4$	0.223	3.182	Accept H_0	$H_0 : \mu_2 = \mu_3$	$\lvert -1.897 \rvert$	2.571	Accept H_0
OTE				$H_0 : \mu_3 = \mu_4$	$\lvert -0.902 \rvert$	2.447	Accept H_0
$H_0 : \mu_1 = \mu_2$	1.090	2.228	Accept H_0	**OTE**			
$H_0 : \mu_2 = \mu_3$	0.454	2.262	Accept H_0	$H_0 : \mu_1 = \mu_2$	$\lvert -3.271 \rvert$	2.447	Reject H_0
$H_0 : \mu_3 = \mu_4$	1.395	2.776	Accept H_0	$H_0 : \mu_2 = \mu_3$	0.166	2.447	Accept H_0
OSME				$H_0 : \mu_3 = \mu_4$	0.789	2.571	Accept H_0
$H_0 : \mu_1 = \mu_2$	2.718	2.365	Reject H_0	**OSME**			
$H_0 : \mu_2 = \mu_3$	1.222	2.306	Accept H_0	$H_0 : \mu_1 = \mu_2$	$\lvert -1.565 \rvert$	2.447	Accept H_0
$H_0 : \mu_3 = \mu_4$	1.098	2.571	Accept H_0	$H_0 : \mu_2 = \mu_3$	1.027	2.776	Accept H_0
				$H_0 : \mu_3 = \mu_4$	0.792	2.447	Accept H_0

Source: Author's calculation

Appendix 6.13: The Levels and Ratios of TFP and Components in the Indonesian Metal Products Industry (ISIC 38), selected years

Sub-sector/Industry	Levels					Ratio				
	1981	1985	1992	1996	2000	1985/1981	1992/1985	1996/1992	2000/1996	2000/1981
ISIC 38: Metal Products Industry										
TFP = TP x TFPE	0.05	0.05	0.07	0.08	0.08	1.16	1.24	1.17	0.96	1.63
TP	0.25	0.25	0.34	0.30	0.41	1.01	1.33	0.89	1.35	1.61
TFPE = OTE x OSME	0.18	0.21	0.20	0.26	0.18	1.15	0.93	1.31	0.71	1.01
OTE	0.63	0.55	0.67	0.61	0.74	0.88	1.21	0.91	1.20	1.17
OSME	0.29	0.38	0.29	0.42	0.25	1.31	0.77	1.43	0.60	0.86

Notes: Levels are generated using DPIN 3.0, ratio is author's calculation using levels.

Appendix 6.14: The Results of F-test in the Indonesian Metal Products Industry (ISIC 38)

The F-test procedures follow Equations A6.1 to A6.4

ISIC 38: Metal Products	F stat	F critical value (α=0.05)	Decision
TFP	11.263	3.239	Reject H_0
TP	5.930	3.239	Reject H_0
OTE	1.256	3.239	Accept H_0
OSME	4.066	3.239	Reject H_0

Source: Author's calculation

Appendix 6.15: The Results of t-test between the means of TFP and its components in one period and all other sub-periods in the Indonesian Metal Products Industry (ISIC 38)

The t-test procedures follow Equations A6.5 to A6.9.

ISIC 38: Metal Products	t stat	t critical value (α=0.05)	Decision
TFP			
$H_0 : \mu_1 = \mu$	|-7.169|	2.101	Reject H_0
$H_0 : \mu_2 = \mu$	0.068	2.110	Accept H_0
$H_0 : \mu_3 = \mu$	4.341	2.110	Reject H_0
$H_0 : \mu_4 = \mu$	1.360	2.571	Accept H_0
TP			
$H_0 : \mu_1 = \mu$	|-2.196|	2.228	Accept H_0
$H_0 : \mu_2 = \mu$	0.537	2.145	Accept H_0
$H_0 : \mu_3 = \mu$	|-2.624|	2.131	Reject H_0
$H_0 : \mu_4 = \mu$	3.756	2.571	Reject H_0
OTE			
$H_0 : \mu_1 = \mu$	|-1.860|	2.179	Accept H_0
$H_0 : \mu_2 = \mu$	|-0.458|	2.262	Accept H_0
$H_0 : \mu_3 = \mu$	0.929	2.447	Accept H_0
$H_0 : \mu_4 = \mu$	1.520	2.571	Accept H_0
OSME			
$H_0 : \mu_1 = \mu$	|-1.089|	2.160	Accept H_0
$H_0 : \mu_2 = \mu$	0.282	2.306	Accept H_0
$H_0 : \mu_3 = \mu$	5.058	2.145	Reject H_0
$H_0 : \mu_4 = \mu$	|-2.484|	2.364	Reject H_0

Source: Author's calculation

Appendix 6.16: The Results of t-test between the means of TFP and its components in one period and another sub-period in the Indonesian Metal Products Industry (ISIC 38)

The t-test procedures follow Equations A6.10 to A6.15.

ISIC 38: Metal Products	t stat	t critical value (α=0.05)	Decision
TFP			
$H_0 : \mu_1 = \mu_2$	|-4.285|	2.306	Reject H_0
$H_0 : \mu_2 = \mu_3$	|-3.133|	2.306	Reject H_0
$H_0 : \mu_3 = \mu_4$	0.839	2.775	Accept H_0
TP			
$H_0 : \mu_1 = \mu_2$	|-1.753|	2.228	Accept H_0
$H_0 : \mu_2 = \mu_3$	2.076	2.306	Accept H_0
$H_0 : \mu_3 = \mu_4$	|-4.813|	2.570	Reject H_0
OTE			
$H_0 : \mu_1 = \mu_2$	|-0.681|	2.262	Accept H_0
$H_0 : \mu_2 = \mu_3$	|-0.818|	2.262	Accept H_0
$H_0 : \mu_3 = \mu_4$	|-0.478|	2.447	Accept H_0
OSME			
$H_0 : \mu_1 = \mu_2$	|-0.699|	2.262	Accept H_0
$H_0 : \mu_2 = \mu_3$	|-2.374|	2.306	Reject H_0
$H_0 : \mu_3 = \mu_4$	5.383	2.571	Reject H_0

Source: Author’s calculation

Appendix to Chapter 7

Appendix 7.1: The Effects of Trade Reform on TFP and Components in the Indonesian Manufacturing Firms (1982-2000)

A. Food Industry (ISIC 31): TFP

	TFP					
	Pooled OLS		FEM (within)		REM	
	coefficient	t	coefficier	t	coefficient	t
erp	-0.007	-0.830	-0.005	-0.870	-0.007	-1.100
rimport	0.003	0.960	0.010	1.680	0.003	0.640
age	-0.006	-2.160	-0.019	-0.440	-0.006	-1.940
ci	0.000	-2.910	0.000	-16.550	0.000	-2.970
rnpw	0.000	-0.290	-0.001	-0.250	0.000	-0.120
foreign	0.129	1.140	0.589	1.000	0.129	0.400
crisis	422.072	1.230	346.903	1.150	422.072	1.380
t	-0.022	-0.830	0.019	0.370	-0.022	-0.830
erpc	-3.928	-1.240	-3.227	-1.160	-3.928	-1.390
rimportc	0.002	0.260	-0.007	-0.760	0.002	0.260
agec	-0.003	-0.420	0.000	0.030	-0.003	-0.470
cic	0.000	1.070	0.000	7.000	0.000	0.750
rnpwc	0.011	1.260	0.008	1.340	0.011	1.880
foreignc	-0.333	-1.400	0.445	0.610	-0.333	-0.470
tc	-11.990	-1.230	-9.887	-1.150	-11.990	-1.380
_cons	2.201	2.210	2.916	2.790	2.201	3.130
Number of observations	9,899		9,899		9,899	
Number of panel firms	521		521		521	
F-test	3.51		20.52		25.29	
R-squared	0.0026		0.0318		0.0435	
Chow test	1.55>F-table:FE					
Hausman test			Prob Chi2=0.000: FE			
BP-LM Test						

Source: Author's calculation

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Appendix 7.1 continued from the previous page

Food Industry (ISIC 31): TP

	TP					
	Pooled OLS		FEM (within)		REM	
	coefficient	t	coefficient	t	coefficient	t
erp	-0.005	-27.110	-0.005	-7.500	-0.005	-7.660
rimport	0.001	3.260	0.001	1.270	0.001	1.320
age	0.000	1.570	-0.002	-0.410	0.000	0.640
ci	0.000	1.540	0.000	-0.650	0.000	0.600
rnpw	0.000	0.630	0.000	0.020	0.000	0.320
foreign	-0.023	-1.520	0.005	0.090	-0.023	-0.710
crisis	871.713	21.970	871.390	28.150	871.713	28.790
t	-0.016	-18.970	-0.014	-2.660	-0.016	-6.070
erpc	-8.060	-21.850	-8.057	-28.080	-8.060	-28.720
rimportc	-0.001	-0.840	-0.001	-0.690	-0.001	-0.700
agec	-0.001	-3.930	-0.001	-1.790	-0.001	-1.910
cic	0.000	-1.320	0.000	-0.380	0.000	-1.020
rnpwc	0.001	3.120	0.001	2.060	0.001	2.260
foreignc	-0.021	-0.390	-0.028	-0.370	-0.021	-0.300
tc	-24.901	-22.060	-24.892	-28.200	-24.901	-28.840
_cons	1.566	81.500	1.606	14.940	1.566	22.480
Number of observations	9,899		9,899		9,899	
Number of panel firms	521		521		521	
F-test	394.69		79.8		1253.19	
R-squared	0.1125		0.1133		0.0401	
Chow test	0.18<F-table: Pooled OLS					
Hausman test			Prob Chi2=0.3769: RE			
BP-LM Test	0.000<Chi2 table: Pooled OLS					

Source: Author’s calculation

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Food Industry: OTE (continued from the previous page)

	OTE					
	Pooled OLS		FEM (within)		REM	
	coefficient	t	coefficien	t	coefficient	t
erp	-0.002	-1.420	-0.002	-1.750	-0.002	-1.840
rimport	0.000	-0.860	0.001	0.540	0.000	-0.480
age	-0.001	-1.560	-0.003	-0.350	-0.001	-1.220
ci	0.000	-3.650	0.000	-8.790	0.000	-5.160
rnpw	0.000	-0.050	0.001	0.880	0.000	-0.030
foreign	0.068	1.840	0.148	1.330	0.068	1.130
crisis	-279.228	-4.970	-284.915	-5.000	-279.229	-4.940
t	-0.005	-0.900	0.000	-0.040	-0.005	-0.910
erpc	2.591	4.980	2.645	5.010	2.591	4.940
rimportc	0.002	1.090	0.001	0.840	0.002	1.120
agec	0.001	0.890	0.001	0.860	0.001	0.660
cic	0.000	1.640	0.000	3.600	0.000	1.310
rnpwc	0.003	1.770	0.003	2.450	0.003	2.670
foreignc	-0.164	-2.650	-0.128	-0.930	-0.164	-1.240
tc	7.950	4.960	8.109	4.990	7.950	4.930
_cons	1.365	7.710	1.423	7.190	1.365	10.480
Number of observations	9,899		9,899		9,899	
Number of panel firms	521		521		521	
F-test	3.86		8.63		78.11	
R-squared	0.0078		0.0136		0.0022	
Chow test	0.77<F-table: Pooled OLS					
Hausman test			Prob Chi2=0.0087: FE			
BP-LM Test	0.000<Chi2 table: Pooled OLS					

Source: Author's calculation

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Food Industry: OSME

	OSME					
	Pooled OLS		FEM (within)		REM	
	coefficient	t	coefficient	t	coefficient	t
erp	-0.003	-0.980	-0.003	-0.880	-0.003	-1.090
rimport	0.000	0.390	0.003	1.080	0.000	0.260
age	-0.002	-1.430	-0.011	-0.560	-0.002	-1.250
ci	0.000	-3.150	0.000	-14.390	0.000	-3.670
rnpw	-0.002	-2.430	-0.001	-0.530	-0.002	-1.400
foreign	0.075	1.210	0.107	0.400	0.075	0.500
crisis	18.587	0.130	-10.472	-0.080	18.587	0.130
t	-0.010	-0.740	0.010	0.440	-0.010	-0.820
erpc	-0.201	-0.150	0.070	0.050	-0.201	-0.160
rimportc	-0.003	-1.600	-0.007	-1.680	-0.003	-0.750
agec	-0.002	-0.690	-0.001	-0.280	-0.002	-0.670
cic	0.000	1.440	0.000	6.130	0.000	1.110
rnpwc	0.006	1.700	0.005	1.760	0.006	2.220
foreignc	0.033	0.420	0.385	1.160	0.033	0.100
tc	-0.451	-0.110	0.362	0.090	-0.451	-0.110
_cons	1.643	4.260	1.976	4.120	1.643	5.140
Number of observations	9,899		9,899		9,899	
Number of panel firms	521		521		521	
F-test	12.68		16.72		47.46	
R-squared	0.0048		0.0261		0.0193	
Chow test	1.32>F-table:FE					
Hausman test			Prob Chi2=0.000: FE			
BP-LM Test						

Source: Author’s calculation

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B. Textile Industry (ISIC 32): TFP

	TFP					
	Pooled OLS		FEM (within)		REM	
	coefficient	t	coefficient	t	coefficient	t
erp	-0.068	-1.190	-0.068	-1.010	-0.068	-1.020
rimport	0.006	0.770	0.008	0.720	0.006	0.840
age	0.051	0.730	0.022	0.070	0.051	2.330
ci	0.000	-1.660	0.000	-3.040	0.000	-2.020
rnpw	0.004	0.190	0.009	0.300	0.004	0.180
foreign	-0.034	-0.190	-0.246	-0.150	-0.034	-0.040
crisis	0.000	omitted	0.000	omitted	1.567	0.510
t	-0.518	-1.140	-0.469	-0.740	-0.518	-0.950
erpc	-0.005	-0.660	-0.002	-0.040	-0.015	-0.260
rimportc	-0.006	-0.740	-0.015	-0.800	-0.006	-0.340
agec	-0.055	-0.780	-0.047	-0.970	-0.055	-1.140
cic	0.000	1.050	0.000	0.280	0.000	0.650
rnpwc	-0.002	-0.130	0.004	0.110	-0.002	-0.060
foreignc	0.296	1.600	1.242	0.640	0.296	0.160
tc	0.066	0.730	0.057	0.440	0.000	omitted
_cons	12.268	1.310	12.597	1.030	12.268	1.050
Number of observations	5,528		5,528		5,528	
Number of panel firms	291		291		291	
F-test	4.16		1.12		15.84	
R-squared	0.0029		0.003		0.0137	
Chow test	1.04<F-table: Pooled OLS					
Hausman test			Prob Chi2=0.0028: FE			
BP-LM Test						

Source: Author's calculation

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Textile Industry: TP

	TP					
	Pooled OLS		FEM (within)		REM	
	coefficient	t	coefficient	t	coefficient	t
erp	0.037	40.660	0.037	14.650	0.037	15.080
rimport	0.000	-1.970	0.000	-0.830	0.000	-0.980
age	0.000	1.620	0.017	1.410	0.000	0.410
ci	0.000	-0.850	0.000	-0.400	0.000	-0.550
rnpw	0.000	-0.870	0.000	0.400	0.000	-0.500
foreign	0.007	0.470	0.069	1.100	0.007	0.230
crisis	0.000	omitted	0.000	omitted	-1.200	-10.570
t	0.321	38.590	0.304	12.600	0.321	15.880
erpc	0.010	12.240	0.010	5.560	0.018	7.980
rimportc	0.000	0.090	0.000	-0.080	0.000	0.050
agec	-0.001	-1.520	-0.001	-0.470	-0.001	-0.450
cic	0.000	0.810	0.000	0.550	0.000	0.530
rnpwc	0.002	3.130	0.003	1.650	0.002	1.670
foreignc	0.044	1.320	0.049	0.670	0.044	0.630
tc	-0.050	-17.760	-0.050	-10.250	0.000	omitted
_cons	-5.543	-33.180	-5.735	-12.330	-5.543	-12.800
Number of observations	5,528		5,528		5,528	
Number of panel firms	291		291		291	
F-test	13929.7		25.51		371.63	
R-squared	0.0631		0.064		0.0022	
Chow test	0.03<F-table: Pooled OLS					
Hausman test			Prob Chi2=0.9113: RE			
BP-LM Test	0.000<Chi2 table: Pooled OLS					

Source: Author's calculation
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Appendix 7.1 continued from the previous page

Textile Industry: OTE

	OTE					
	Pooled OLS		FEM (within)		REM	
	coefficient	t	coefficient	t	coefficient	t
erp	-0.016	-1.430	-0.013	-0.070	-0.016	-0.100
rimport	0.000	-0.190	0.022	0.770	0.000	0.000
age	-0.004	-1.180	-0.215	-0.270	-0.004	-0.080
ci	0.000	-1.620	0.000	-0.640	0.000	-0.150
rnpw	0.006	1.440	0.010	0.140	0.006	0.130
foreign	-0.050	-1.390	-0.343	-0.080	-0.050	-0.030
crisis	0.000	omitted	0.000	omitted	-19.173	-2.490
t	-0.123	-1.480	0.142	0.090	-0.123	-0.090
erpc	-0.144	-0.950	-0.135	-1.180	-0.016	-0.100
rimportc	0.160	1.030	0.144	3.030	0.160	3.500
agec	0.750	1.040	0.746	6.140	0.750	6.200
cic	0.000	-0.930	0.000	-1.260	0.000	-1.080
rnpwc	-0.065	-0.900	-0.068	-0.650	-0.065	-0.640
foreignc	-2.529	-0.820	-1.271	-0.260	-2.529	-0.530
tc	-0.806	-1.060	-0.793	-2.440	0.000	omitted
_cons	3.926	1.990	5.485	0.180	3.921	0.130
Number of observations	5,528		5,528		5,528	
Number of panel firms	291		291		291	
F-test	1.98		4.44		74.08	
R-squared	0.0133		0.0118		0.0445	
Chow test	0.97<F-table: Pooled OLS					
Hausman test			Prob Chi2=0.9494: RE			
BP-LM Test	0.000<Chi2 table: Pooled OLS					

Source: Author's calculation

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Textile Industry: OSME

	OSME					
	Pooled OLS		FEM (within)		REM	
	coefficient	t	coefficient	t	coefficient	t
erp	-0.078	-1.230	-0.076	-0.790	-0.078	-0.800
rimport	0.013	0.970	0.019	1.150	0.013	1.160
age	0.110	1.010	0.038	0.080	0.110	3.470
ci	0.000	-1.230	0.000	-1.490	0.000	-0.990
rnpw	-0.017	-1.020	-0.020	-0.480	-0.017	-0.600
foreign	0.091	0.490	-0.162	-0.070	0.091	0.080
crisis	0.000	omitted	0.000	omitted	4.007	0.910
t	-0.649	-1.210	-0.553	-0.600	-0.649	-0.820
erpc	-0.012	-4.350	-0.007	-0.110	-0.039	-0.450
rimportc	-0.013	-0.980	-0.030	-1.100	-0.013	-0.490
agec	-0.107	-0.980	-0.109	-1.570	-0.107	-1.540
cic	0.000	0.850	0.000	0.250	0.000	0.340
rnpwc	0.014	0.840	0.015	0.250	0.014	0.250
foreignc	-0.096	-0.490	0.883	0.320	-0.096	-0.040
tc	0.168	1.220	0.172	0.920	0.000	omitted
_cons	13.202	1.390	13.838	0.780	13.202	0.780
Number of observations	5,528		5,528		5,528	
Number of panel firms	291		291		291	
F-test	3.7		0.66		18.43	
R-squared	0.0033		0.0018		0.0355	
Chow test	0.96<F-table: Pooled OLS					
Hausman test			Prob Chi2=0.7558: RE			
BP-LM Test	0.000<Chi2 table: Pooled OLS					

Source: Author's calculation

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Appendix 7.1 continued from the previous page

C. Chemical Industry (ISIC 35): TFP

	TFP					
	Pooled OLS		FEM (within)		REM	
	coefficient	t	coefficient	t	coefficient	t
erp	0.006	0.890	0.007	1.000	0.006	0.890
rimport	0.000	-0.040	-0.001	-0.380	0.000	-0.040
age	0.014	2.500	0.003	0.050	0.014	2.500
ci	0.000	-5.000	0.000	-10.060	0.000	-5.000
rnpw	0.006	1.820	0.001	0.260	0.006	1.820
foreign	0.194	1.230	-0.008	-0.020	0.194	1.230
crisis	-424.965	-0.140	-934.599	-0.310	-424.963	-0.140
t	0.031	0.630	0.065	0.890	0.031	0.630
erpc	5.067	0.140	11.169	0.310	5.067	0.140
rimportc	0.001	0.420	0.002	0.570	0.001	0.420
agec	-0.007	-0.580	-0.006	-0.520	-0.007	-0.580
cic	0.000	1.340	0.000	3.350	0.000	1.340
rnpwc	-0.001	-0.140	-0.002	-0.290	-0.001	-0.140
foreignc	0.054	0.170	0.017	0.050	0.054	0.170
tc	16.961	0.140	37.257	0.310	16.961	0.140
_cons	0.482	0.500	1.262	1.130	0.482	0.500
Number of observations	4,579		4,579		4,579	
Number of panel firms	241		241		241	
F-test	3.01		7.79		45.13	
R-squared	0.0098		0.0263		0.0043	
Chow test	1.29>F-table:FE					
Hausman test			Prob Chi2=0.019: FE			
BP-LM Test						

Source: Author’s calculation

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Chemical Industry: TP

	TP					
	Pooled OLS		FEM (within)		REM	
	coefficient	t	coefficient	t	coefficient	t
erp	-0.006	-3.480	-0.005	-3.290	-0.006	-3.480
rimport	0.001	3.240	0.000	0.040	0.001	3.240
age	0.000	0.390	0.002	0.160	0.000	0.390
ci	0.000	-4.260	0.000	-4.260	0.000	-4.260
rnpw	0.001	1.070	-0.002	-1.950	0.001	1.070
foreign	0.077	2.170	-0.034	-0.390	0.077	2.170
crisis	-1009.985	-1.490	-991.604	-1.440	-1009.980	-1.490
t	-0.019	-1.710	-0.019	-1.150	-0.019	-1.710
erpc	12.051	1.490	11.832	1.440	12.051	1.490
rimportc	-0.001	-0.880	-0.001	-1.300	-0.001	-0.880
agec	-0.001	-0.340	-0.001	-0.410	-0.001	-0.340
cic	0.000	2.790	0.000	2.970	0.000	2.790
rnpwc	-0.001	-0.390	0.000	-0.210	-0.001	-0.390
foreignc	-0.079	-1.080	-0.086	-1.130	-0.079	-1.080
tc	40.298	1.490	39.563	1.440	40.297	1.490
_cons	1.745	8.070	1.873	7.280	1.745	8.070
Number of observations	4,579		4,579		4,579	
Number of panel firms	241		241		241	
F-test	9.51		8.68		142.67	
R-squared	0.0303		0.0292		0.2033	
Chow test	0.49<F-table: Pooled OLS					
Hausman test			Prob Chi2=1.000: RE			
BP-LM Test	0.000<Chi2 table: Pooled OLS					

Source: Author’s calculation

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Chemical Industry: OTE

	OTE					
	Pooled OLS		FEM (within)		REM	
	coefficient	t	coefficient	t	coefficient	t
erp	-0.014	-4.320	-0.013	-4.170	-0.014	-4.320
rimport	0.001	2.380	0.000	-0.080	0.001	2.380
age	0.006	2.440	-0.001	-0.050	0.006	2.440
ci	0.000	-5.260	0.000	-8.000	0.000	-5.260
rnpw	0.001	0.820	-0.002	-0.990	0.001	0.820
foreign	0.068	0.960	0.094	0.560	0.068	0.960
crisis	-7562.000	-5.590	-7679.154	-5.660	-7561.966	-5.590
t	-0.143	-6.390	-0.130	-3.930	-0.143	-6.390
erpc	90.424	5.590	91.828	5.660	90.424	5.590
rimportc	-0.002	-1.040	-0.001	-0.730	-0.002	-1.040
agec	-0.002	-0.400	-0.002	-0.370	-0.002	-0.400
cic	0.000	1.120	0.000	2.530	0.000	1.120
rnpwc	0.002	0.750	0.002	0.640	0.002	0.750
foreignc	-0.066	-0.450	-0.098	-0.650	-0.066	-0.450
tc	301.585	5.590	306.248	5.660	301.584	5.590
_cons	3.534	8.190	3.890	7.650	3.534	8.190
Number of observations	4,579		4,579		4,579	
Number of panel firms	241		241		241	
F-test	13.72		14.96		205.8	
R-squared	0.0432		0.0493		0.0743	
Chow test	0.90<F-table: Pooled OLS					
Hausman test			Prob Chi2=0.0087: RE			
BP-LM Test	0.000<Chi2 table: Pooled OLS					

Source: Author's calculation

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Chemical Industry: OSME

	OSME					
	Pooled OLS		FEM (within)		REM	
	coefficient	t	coefficient	t	coefficient	t
erp	0.007	1.830	0.007	1.880	0.007	1.830
rimport	0.000	-0.560	-0.001	-0.780	0.000	-0.560
age	-0.004	-1.410	-0.011	-0.410	-0.004	-1.410
ci	0.000	-5.320	0.000	-8.910	0.000	-5.320
rnpw	0.003	1.760	0.004	1.580	0.003	1.760
foreign	0.059	0.730	0.073	0.380	0.059	0.730
crisis	9560.839	6.230	9345.631	6.100	9560.797	6.230
t	0.043	1.680	0.057	1.540	0.043	1.680
erpc	-114.308	-6.230	-111.731	-6.100	-114.307	-6.230
rimportc	0.002	0.930	0.002	1.120	0.002	0.930
agec	0.004	0.720	0.005	0.850	0.004	0.720
cic	0.000	0.990	0.000	2.690	0.000	0.990
rnpwc	-0.001	-0.440	-0.003	-0.990	-0.001	-0.440
foreignc	-0.002	-0.010	0.026	0.150	-0.002	-0.010
tc	-381.296	-6.230	-372.724	-6.110	-381.294	-6.230
_cons	0.580	1.180	0.864	1.510	0.580	1.180
Number of observations	4,579		4,579		4,579	
Number of panel firms	241		241		241	
F-test	8.54		12.19		128.09	
R-squared	0.0273		0.0406		0.0009	
Chow test	1.09<F-table: Pooled OLS					
Hausman test			Prob Chi2=0.000: FE			
BP-LM Test						

Source: Author's calculation

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D. Metal Products Industry (ISIC 38): TFP

	TFP					
	Pooled OLS		FEM (within)		REM	
	coefficient	t	coefficient	t	coefficient	t
erp	0.005	1.630	0.005	2.230	0.005	2.440
rimport	-0.001	-0.720	-0.004	-1.710	-0.001	-0.760
age	-0.008	-1.260	0.018	0.330	-0.008	-1.350
ci	0.000	-2.330	0.000	-6.660	0.000	-3.860
rnpw	0.016	1.620	0.022	3.990	0.016	4.470
foreign	0.017	0.160	-0.114	-0.370	0.017	0.110
crisis	0.000	omitted	0.000	omitted	0.374	0.560
t	0.092	1.580	0.060	0.860	0.092	2.220
erpc	-0.010	-0.910	-0.005	-0.430	-0.012	-0.820
rimportc	0.000	0.140	0.000	-0.110	0.000	0.090
agec	-0.004	-0.490	-0.006	-0.500	-0.004	-0.300
cic	0.000	-0.390	0.000	0.440	0.000	-0.470
rnpwc	-0.003	-0.270	0.000	-0.040	-0.003	-0.360
foreignc	0.484	1.260	0.309	0.840	0.484	1.350
tc	0.016	0.650	0.014	0.470	0.000	omitted
_cons	-0.300	-0.330	-0.136	-0.150	-0.300	-0.440
Number of observations	1,767		1,767		1,767	
Number of panel firms	93		93		93	
F-test	2.06		6.48		57.72	
R-squared	0.0214		0.0518		0.0309	
Chow test	1.28>F-table:FE					
Hausman test			Prob Chi2=0.000: FE			
BP-LM Test						

Source: Author’s calculation

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Metal Products Industry: TP

	TP					
	Pooled OLS		FEM (within)		REM	
	coefficient	t	coefficier	t	coefficien	t
erp	0.001	3.050	0.001	2.940	0.001	3.050
rimport	0.000	0.020	0.000	0.110	0.000	0.020
age	0.000	0.020	-0.008	-1.180	0.000	0.020
ci	0.000	0.050	0.000	0.110	0.000	0.050
rnpw	0.000	0.070	0.000	0.010	0.000	0.070
foreign	-0.001	-0.080	0.019	0.510	-0.001	-0.080
crisis	0.000		0.000	omitted	-0.128	-1.640
t	0.008	1.640	0.016	1.910	0.008	1.640
erpc	0.008	5.350	0.008	5.270	0.008	4.820
rimportc	0.000	-0.260	0.000	-0.190	0.000	-0.260
agec	0.000	-0.250	0.000	-0.140	0.000	-0.250
cic	0.000	-0.600	0.000	-0.590	0.000	-0.600
rnpwc	0.000	-0.180	0.000	-0.220	0.000	-0.180
foreignc	0.038	0.900	0.043	0.950	0.038	0.900
tc	-0.006	-1.640	-0.006	-1.690	0.000	omitted
_cons	0.853	10.610	0.929	8.570	0.853	10.610
Number of observations	1,767		1,767		1,767	
Number of panel firms	93		93		93	
F-test	5.65		5.5		79.13	
R-squared	0.0432		0.0443		0	
Chow test	0.02<F-table: Pooled OLS					
Hausman test			Prob Chi2=0.9984: RE			
BP-LM Test	0.000<Chi2 table: Pooled OLS					

Source: Author's calculation

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Metal Products Industry: OTE

	OTE					
	Pooled OLS		FEM (within)		REM	
	coefficient	t	coefficient	t	coefficient	t
erp	0.000	0.010	0.000	-0.020	0.000	0.000
rimport	-0.001	-2.010	-0.001	-1.710	-0.001	-1.480
age	-0.001	-0.990	0.008	0.470	-0.001	-0.590
ci	0.000	-3.030	0.000	-4.800	0.000	-4.550
rnpw	0.003	3.200	0.001	0.680	0.003	2.850
foreign	0.028	0.960	-0.062	-0.660	0.028	0.600
crisis	0.000	omitted	0.000	omitted	0.222	1.120
t	0.001	0.130	-0.008	-0.380	0.001	0.110
erpc	-0.003	-1.440	-0.003	-0.760	-0.005	-1.020
rimportc	0.000	-0.510	0.000	-0.160	0.000	-0.310
agec	-0.001	-0.590	-0.001	-0.280	-0.001	-0.360
cic	0.000	0.580	0.000	1.070	0.000	0.450
rnpwc	-0.003	-1.620	-0.003	-1.250	-0.003	-1.080
foreignc	0.024	0.540	0.000	0.000	0.024	0.220
tc	0.010	1.910	0.009	1.000	0.000	omitted
_cons	1.125	6.030	1.150	4.250	1.125	5.540
Number of observations	1,767		1,767		1,767	
Number of panel firms	93		93		93	
F-test	3.09		2.36		38.36	
R-squared	0.0214		0.0195		0.2812	
Chow test	0.47<F-table: Pooled OLS					
Hausman test			Prob Chi2=0.365: RE			
BP-LM Test	0.000<Chi2 table: Pooled OLS					

Source: Author's calculation

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Metal Products Industry: OSME

	OSME					
	Pooled OLS		FEM (within)		REM	
	coefficient	t	coefficier	t	coefficien	t
erp	0.004	1.010	0.004	1.500	0.004	1.660
rimport	-0.001	-0.480	-0.004	-1.770	-0.001	-0.530
age	-0.006	-0.870	0.012	0.190	-0.006	-0.960
ci	0.000	-1.720	0.000	-5.090	0.000	-2.760
rnpw	0.016	1.260	0.026	4.070	0.016	3.950
foreign	-0.101	-0.970	-0.254	-0.730	-0.101	-0.580
crisis	0.000	omitted	0.000	omitted	0.061	0.080
t	0.072	1.010	0.045	0.570	0.072	1.540
erpc	-0.009	-1.400	-0.004	-0.300	-0.009	-0.540
rimportc	0.000	0.150	-0.001	-0.230	0.000	0.080
agec	-0.001	-0.150	-0.005	-0.330	-0.001	-0.080
cic	0.000	0.400	0.000	1.050	0.000	0.370
rnpwc	-0.009	-0.720	-0.006	-0.630	-0.009	-1.020
foreignc	0.356	1.960	0.165	0.390	0.356	0.880
tc	0.003	0.110	0.002	0.070	0.000	omitted
_cons	-0.013	-0.010	0.171	0.170	-0.013	-0.020
Number of observations	1,767		1,767		1,767	
Number of panel firms	93		93		93	
F-test	6.79		4.04		31.66	
R-squared	0.0178		0.0329		0.0123	
Chow test	1.17<F-table: Pooled OLS					
Hausman test			Prob Chi2=0.000: RE			
BP-LM Test	0.000<Chi2 table: Pooled OLS					

Source: Author's calculation

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Appendix 7.2: Breusch-Pagan (B-P) Lagrange Multiplier (LM) Test for Random Effects

B-P LM test examines if individual (or time) specific variance components are zero. The LM statistic follows the chi-squared distribution with one degree of freedom. The null hypothesis in the LM test is that variances across individuals are zero. If the null hypothesis is rejected, it can be concluded that there is a significant random effect in the panel data, and that the random effect model is able to deal with heterogeneity better than does the pooled OLS.

The following are the result of B-P LM test of each industry:

1. ISIC 31 (Food Products)

TP

```
tfpo[psid,t] = Xb + u[psid] + e[psid,t]

Estimated results:
             |      Var     sd = sqrt(Var)
    ---------+-----------------------------
        tfpo |  .1992997        .44643
           e |  .1851318      .4302695
           u |         0             0

Test:   Var(u) = 0
                  chibar2(01) =     0.00
                Prob > chibar2 =   1.0000
```

Conclusion: accept the null hypothesis.

2. ISIC 32 (Textile)

TP

```
tfpo[psid,t] = Xb + u[psid] + e[psid,t]

Estimated results:
             |      Var     sd = sqrt(Var)
    ---------+-----------------------------
        tfpo |  .2593977       .509311
           e |  .2567631       .506718
           u |         0             0

Test:   Var(u) = 0
```

chibar2(01) = 0.00
Prob > chibar2 = 1.0000

Conclusion: accept the null hypothesis.

OTE

ote[psid,t] = Xb + u[psid] + e[psid,t]

Estimated results:

	Var	sd = sqrt(Var)
ote	1131.57	33.63881
e	1121.4	33.48731
u	0	0

Test: Var(u) = 0
chibar2(01) = 0.00
Prob > chibar2 = 1.0000

Conclusion: accept the null hypothesis.

OSME
osme[psid,t] = Xb + u[psid] + e[psid,t]

Estimated results:

	Var	sd = sqrt(Var)
osme	369.7794	19.22965
e	370.2127	19.24091
u	0	0

Test: Var(u) = 0
chibar2(01) = 0.00
Prob > chibar2 = 1.0000

Conclusion: accept the null hypothesis.

3. ISIC 35 (Chemical)

TP

tfpo[psid,t] = Xb + u[psid] + e[psid,t]

Estimated results:

	Var	sd = sqrt(Var)
tfpo	.4873163	.6980804
e	.4870535	.6978922
u	0	0

```
Test:   Var(u) = 0
             chibar2(01) =    0.00
          Prob > chibar2 =   1.0000
```

Conclusion: accept the null hypothesis.

4. ISIC 38 (Metal Products)

TP

tfpo[psid,t] = Xb + u[psid] + e[psid,t]

```
Estimated results:
                 |       Var     sd = sqrt(Var)
        ---------+-----------------------------
            tfpo |   .0478029      .2186388
               e |   .0486014      .2204572
               u |          0             0

Test:   Var(u) = 0
             chibar2(01) =    0.00
          Prob > chibar2 =   1.0000
```

Conclusion: accept the null hypothesis.

OTE

ote[psid,t] = Xb + u[psid] + e[psid,t]

```
Estimated results:
                 |       Var     sd = sqrt(Var)
        ---------+-----------------------------
             ote |   .2985982      .5464414
               e |   .3029176      .5503795
               u |          0             0

Test:   Var(u) = 0
             chibar2(01) =    0.00
          Prob > chibar2 =   1.0000
```

Conclusion: accept the null hypothesis.

Appendix 7.3: The Results of F-test for Dummy Crisis Interaction Variables

	R squared Unrestricted	**R squared Restricted**	**F stat**	**F table**	**Conclusion**
ISIC 31					
TFP	0.0318	0.0246	9.187771	1.94	reject
TP	0.1125	0.0094	143.5268	1.94	reject
OTE	0.0078	0.0038	4.980851	1.94	reject
OSME	0.0261	0.0185	9.641442	1.94	reject
n=9899					
ISIC 32					
TFP	0.0029	0.0024	0.345627	1.94	accept
TP	0.0631	0.0038	43.62528	1.94	reject
OTE	0.0133	0.0031	7.125114	1.94	reject
OSME	0.0033	0.0028	0.345766	1.94	accept
n=5529					
ISIC 35					
TFP	0.0263	0.0229	1.992092	1.94	reject
TP	0.0303	0.013	10.17804	1.94	reject
OTE	0.0432	0.024	11.44816	1.94	reject
OSME	0.0273	0.0088	10.85047	1.94	reject
n=4579					
ISIC 38					
TFP	0.0518	0.0503	0.346446	1.94	accept
TP	0.0432	0.0186	5.630644	1.94	reject
OTE	0.0214	0.0201	0.290926	1.94	accept
OSME	0.0178	0.0154	0.535125	1.94	accept
n=1767					

Source: Author's calculation

Appendix 7.4: The Results of Test of Heteroskedasticity and Autocorrelation

Industry/Productivity	Heteroskedasticity		Autocorrelation		Conclusion	
	LR Chi2	Prob>chi2	F test	Prob>F	Heteros	Auto
ISIC 31 (Foods)						
TFP pre-crisis	35,060.95	0	1.03	0.31	Yes	No
TFP post-crisis	10,929.20	0	2.00	0.16	Yes	No
TP pre-crisis	883.17	0	58.00	0.00	Yes	Yes
TP post-crisis	1,147.67	0	3.22	0.07	Yes	No
OTE pre-crisis	-11,814.31	1	11.71	0.01	No	Yes
OTE post-crisis	-4,680.34	1	0.50	0.48	No	Yes
OSME pre-crisis	19,777.30	0	0.34	0.56	Yes	No
OSME post-crisis	6,360.83	0	1.86	0.17	Yes	No
ISIC 32 (Textile)						
TFP total	35,781.35	0	0.08	0.78	Yes	No
TP pre-crisis	294.26	0.4193	102.92	0.00	Yes	Yes
TP post-crisis	512.27	0	102.33	0.00	Yes	Yes
OTE pre-crisis	11,637.97	0	55.71	0.00	Yes	Yes
OTE post-crisis	12,192.08	0	2,495.84	0.00	Yes	Yes
OSME total	38,844.90	0	10.44	0.00	Yes	Yes
ISIC 35 (Chemicals)						
TFP pre-crisis	13,248.52	0	0.14	0.71	Yes	No
TFP post-crisis	3,011.58	0	3.69	0.06	Yes	No
TP pre-crisis	2,293.20	0	807.21	0.00	Yes	Yes
TP post-crisis	2,515.29	0	347.85	0.00	Yes	Yes
OTE pre-crisis	5,203.03	0	2.52	0.11	Yes	No
OTE post-crisis	-1,241.42	1	24.36	0.00	No	Yes
OSME pre-crisis	6,426.38	0	12.05	0.00	Yes	Yes
OSME post-crisis	1,646.44	0	46.49	0.00	Yes	Yes
ISIC 38 (Metal Products)						
TFP total	4,032.84	0	0.02	0.90	Yes	No
TP pre-crisis	0.00	1	42.22	0.00	No	Yes
TP post-crisis	0.27	1	381.39	0.00	No	Yes
OTE total	1,332.17	0	37.10	0.00	Yes	Yes
OSME total	4,591.80	0	2.82	0.10	Yes	No

Source: Author's calculation
Notes:
F stat alfa 0.05:
ISIC 31 = 3.84
ISIC 32 = 3.89
ISIC 35 = 3.89
ISIC 38 = 4

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