Doctoral Dissertation

Impact of Energy Efficiency Improvement on Productivity in Indonesia Manufacturing Sector

ERIK ARMUNDITO

Graduate School for International Development and Cooperation
Hiroshima University

September 2015

Impact of Energy Efficiency Improvement on Productivity in Indonesia Manufacturing Sector

D125446

ERIK ARMUNDITO

A Dissertation Submitted to
the Graduate School for International Development and Cooperation
of Hiroshima University in Partial Fulfillment
of the Requirement for the Degree of
Doctor of Philosophy

September 2015

We hereby recommend that the dissertation by Mr. ERIK ARMUNDITO entitled "Impact of Energy Efficiency Improvement on Productivity in Indonesia Manufacturing Sector" be accepted in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY.

Committee on Final Examination:

KANEKO, Shinji, Professor
Chairperson

市橋 勝

ICHIHASHI, Masaru, Professor

FUJIWARA, Akimasa, Professor

GOTO, Daisaku, Associate Professor

KAWANISHI, Masato
Senior Advisor, JICA

Date: July 25, 2015

Approved:

FUJIWARA Akimasa, Professor
Dean

Date: September 4, 2015

Graduate School for International Development and Cooperation
Hiroshima University

ABSTRACT

As a growing and developing country in Asia with a relatively large but young demographic structure, Indonesia will not only meet domestic policy challenges but also begin to draw international attention after China and India in seeking a future development pathway that is less fossil energy resource dependent. Manufacturing sector is one of the most important sectors in Indonesia due to its large potential for creating job opportunities and its contribution to development. When the roles of manufacturing sector are expected to continuously increase, some considerable obstruction should be confronted, in particular the increasing pollutions and the increasing domestic price of oil commodities. Although economic instruments implemented within climate change mitigation policies such as a carbon tax have not yet been implemented in Indonesia, the recent rising price of domestic oil commodities can be seen as quasi-carbon regulation instrument because it has similar consequences. This study provides useful information for policy makers to discuss the impact of the climate change mitigation and energy related policies on manufacturing sector. Environmental productivity and efficiency improvement are the main issues to be discussed in this study to formulate constructive policy designs to enhance manufacturing sector's performance in the future.

Annual Indonesia's manufacturing survey datasets are employed for the analysis in this study. Because the existence of data quality problems and the missing of key variables, therefore, the cleaned and balanced panel datasets are constructed for only four periods: 1990-1995, 1998-2000, 2003-2006, and 2008-2010. Substantial economic and political events are adopted to describe the contextual background of the present analysis. For these four periods the study provides empirical results from the baseline analysis for productivity measurements, estimation of average carbon abatement cost, and the impact of energy price on environmental productivity change and average abatement cost. To measure the environmental productivity change and average carbon abatement cost, the disposability of CO_2 emissions as undesirable outputs are not free activities is firstly assumed to respond the different impact of carbon regulation on manufacturing sector.

From the baseline analysis for productivity measurements it is observed that the TFP with CO2 emissions over time has grown faster than the TFP without CO2 emissions for the period 1, the period 2, and the period 4. The faster growth of the TPF with CO2 emissions over suggested that when accounting for changes in pollutions as undesirable outputs the average productivity growth is higher than the growth ignoring pollutions. The findings provide a clear message to policy makers that environmental damages should be considered in economic and manufacturing developments.

Further, average carbon abatement cost is estimated. When CO_2 emissions as undesirable outputs are weakly disposable, the average carbon abatement cost has increased as the price of oil commodities increased, particularly in the period 3 and 4. The fluctuation of these average carbon abatement cost is consistent with the trend of value added and carbon intensity because the measurement of carbon abatement cost is based on forgone profit and the amount of CO2 emissions, even though on average environmental efficiency show improvement.

Moreover, the relationship between energy factors and environmental productivity is analyzed to confirm that the increase in energy costs directly influence manufacturing productivity. The impact of energy factors on average carbon abatement cost is also examined to investigate the relationship of the increase in energy costs and CO_2 emissions reduction. The change of environmental component in productivity

measurement is associated with the adjusted energy prices. In addition, energy dependency negatively and significantly influenced average abatement cost for the periods 1 and 3. When energy is still subsidized during periods 1 and 2, the fuel price is significant and has a negative impact on average carbon abatement cost. Whereas energy subsidy started to be removed in the period 3, the fuel price is statistically significant and started to show a positive relationship to the averaged carbon abatement cost. Electricity price has a significantly negative relationship to the marginal abatement cost when energy subsidy is removed.

Finally, several constructive policy recommendations can be proposed to the policy makers as follow: CO_2 emissions as undesirable outputs can be considered in measuring manufacturing sector's productivity growth; carbon tax as one of economic instruments to control CO_2 emissions can be imposed on manufacturing sector in Indonesia based on the empirical results of this study that most of manufacturing sector show positive TFP environment growth after the increase of domestic oil price; technological improvement, in particular the cleaner technology, has to become a major concern for the manufacturing firms' long-term strategic planning after the changes in prices of oil commodities; the manufacturing sector performance has to continuously be improved; hence, its roles in contributing to Indonesia's GDP and providing more job opportunities can be maintained; to improve environmental productivity as the one of the manufacturing sector performance's indicators, energy efficiency has to be appropriately implemented.

ACKNOWLEDGEMENTS

Alhamdullilahirobbil alamin. I thank to the Almighty God, Allah SWT, who has given me very valuable time for living and studying in Hiroshima University for 3.5 years.

First of all, I would like to express my deeply gratitude to Professor Shinji KANEKO for his greatest supervisions. We have had intensive discussions throughout the three and a half years of working on this research. With the constructive guidance, comments, and suggestions received from the Professor, the dissertation has been significantly improved. My thankful expressed to Professor Masaru ICHIHASHI for his comments and suggestion during my examinations. Thanks to Associate Professor Daisaku GOTO for his comments and suggestions during my examinations and through the lab seminars. Sincere appreciation is also accorded to Professor Akimasa FUJIWARA and Masato KAWANISHI for their valuable comments and suggestions during my examinations.

My sincere gratitude expressed to JICA for granting me the great long term training scholarship. I would never affordable to study at Hiroshima University without kind of support from this program. Thanks to Fuji Xerox Co., Ltd., and the Setsutaro Kobayashi Memorial Fund for kindly provide a research grants-aids for the completion of my study.

I would like to thank to all IDEC staffs and faculty members for helping me in various official procedures during my academic life. Thanks to my lab mates for your comments and suggestions through lab seminars, reaction reports, and your support in various ways. Thank to Indonesian students at IDEC and in Hiroshima prefecture for your support, friendship and togetherness.

My gratitude expressed to Mrs. Endah Murniningtyas, Deputy Minister of Natural Resources and Environment in BAPPENAS and Mrs. Wahyuningsih Darajati, Director of Environmental Affairs in BAPPENAS for granting me an opportunity to study at Hiroshima University, Japan.

I would like to take this opportunity to deeply express my beloved wife and my beloved children for always stay beside me, keep me warm, raise me up, and keep encouraging me passing through hard times, especially during my study at IDEC, Hiroshima University, Japan. To my beloved big families, millions thanks for your encouragements.

Lastly, there are many others who have helped and supported me in various ways during my working on dissertation. Though it is not feasible to list out everyone’s name here, I absolutely appreciate to all of you.

ERIK ARMUNDITO

September 2015

CONTENS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1: INTRODUCTION

1.1. Indonesia's manufacturing sector

The abundance of fossil energy resources as well as a large population has been the foundation of development in Indonesia. However, since 2004, Indonesia has become a net oil importing country if we consider the trade balance of both crude oil and petroleum commodities. In addition, as of 2013, Indonesia ranked as the 11th largest CO_2 emitting country after Canada (Global Carbon Project 2014). As a growing and developing country in Asia with a relatively large but young demographic structure, Indonesia will not only confront domestic policy challenges but will also begin to draw international attention after China and India in seeking a future development pathway that is less fossil energy resource dependent and that creates more job opportunities.

Although these challenges should be addressed by various sectors as declared by Indonesia's master plan of 2011, the manufacturing sector is one of the most important sectors due to its large potential for creating job opportunities. At the same time, there is concern regarding the increasing demand for energy generated by the economic development policy through further industrialization and development of the manufacturing sector. Currently, total final energy consumption (TFEC) in the manufacturing sector represents 27.4% of the TFEC of Indonesia in 2011, and this share has been growing steadily over the last two decades (IEA 2013).

As the international oil price has increased since 2000 and has remained high compared to prices in the 1990s, the government of Indonesia as a net oil importing country started to gradually remove subsidies for energy commodities starting in 2005. Consequently, the domestic price of oil commodities in Indonesia has been rising since this time, which has caused a significant financial burden for the manufacturing industry. Although economic instruments implemented within climate change mitigation policies such as a carbon tax have not yet been implemented in Indonesia, the recent rising price of domestic oil commodities can be seen as quasi-carbon regulation instrument because it has similar consequences.

1.2. Annual manufacturing survey data

It should be noted that although historical data for manufacturing firms in Indonesia are available from the datasets of annual manufacturing surveys conducted by the Indonesian Statistics Agency (BPS) for medium and large-sized firms that employ at least 20 workers, the datasets contains inaccurate, incomplete, and erroneous data. Therefore, despite the availability of large sets of data, to the best of our knowledge, empirical studies of Indonesian manufacturing firms are limited.

To overcome this constraint, first a cleaned panel dataset are developed from the annual survey data of medium and large-sized firms in the manufacturing sector of Indonesia between 1990 and 2010, which is used for the present analysis. Because the system of firm identity codes was changed between 2000 and 2001, it is impossible to construct continuous annual firm datasets between two periods, namely 1990-2000 and

2001-2010. In addition, we found that some of key variables such as capital stock and energy consumption, which are necessary for the present analysis, are completely missing in the survey data for 1996, 1997, 2001, 2002 and 2007. Therefore, the cleaned and balanced panel datasets are constructed for only four periods: 1990-1995, 1998-2000, 2003-2006, and 2008-2010. For these four periods, the study provides empirical results from the baseline analysis for productivity measurements, environmental efficiency measurements, and the impacts of energy price on environmental productivity changes and carbon abatement cost.

1.3. Contextual background

The state-led industrial policy strategy began in the 1970s in Indonesia during the Suharto regime, driven by a large windfall in government oil revenue from 1973-1980 through the development of state-owned firms. The government strictly protected the state-owned firms and other domestic producers from international competition by providing tariff and non-tariff barriers, raw material subsidies, and credit subsidies in addition to maintaining undervalued exchange rates (Goeltom 1995; Pangestu 1996). Whereas the share of the manufacturing sector to GDP increased, empirical studies generally agreed that there was no gain and potentially negative total factor productivity (TFP) growth in the manufacturing sector in Indonesia during the period between 1975 and 1985 (Timmer 1999; Aswicahyono and Hill 2002; Vial 2006). In 1986, the devaluation of the exchange rate of the rupiah against the US dollar triggered a shift in foreign direct investment (FDI) from the Asian newly industrialized economies to Indonesia, which promoted a labor-intensive manufacturing base in industries such as textiles, shoes, wood products, and processed food. As a result of an increasingly open economic policy, the share of manufacturing products has significantly expanded in terms of foreign exports since the middle of the 1980s. Furthermore, with the development of the machinery industry driven by FDI, the export of machinery products has also increased since the late 1980s and early 1990s. The shift to an FDI-led import substitution policy of industrialization has resulted in an increase in TFP for the manufacturing sector of Indonesia.

Table 1.1 summarizes the results of the selected literature measuring the TFP growth of the Indonesian manufacturing sector using firm-level data for the period between 1970 and 2000. Although specific periods and numbers are not exactly the same and comparable, general shifts in TFP growth before and after the middle of the 1980s are commonly and consistently reported. Moreover, TFP growth seems to have continued until 1997, at which point the Asian economic crisis hit the Indonesian economy. Suharto's relinquishing presidential office in 1998 evidences the seriousness of the adverse effects from the Asian financial crisis on the Indonesian economy, and this crisis also caused significant turbulence and confusion in measurements of TFP growth.

As mentioned earlier, the datasets used in this analysis have several breaks, and the period before and after the Asian financial crisis is one of these breaks. Table 1.2 provides a summary of the key variables in the four analyzed periods to describe the contextual background of the present analysis.

Period 1 from 1990 to 1995, which is the longest among the four analyzed periods in the paper, exhibited the highest average GDP growth rate at 7.9%, and the growth rate of the manufacturing sector during this period was also the highest. Consequently, the share of the manufacturing sector to GDP increased from 21.6% to 24.5%, and the share in total merchandise exports also increased from 35.5% to 50.6%. Furthermore, the share of high-technology exports to manufactured exports expanded substantially from 1.6% to 7.3%. In contrast, the growth rate of total final energy consumption (TFEC) for Indonesia and the growth rate of the manufacturing sector grew less quickly than that for production, resulting in an elasticity of TFEC to GDP of 0.57 and 0.75, respectively. Although net crude oil exports and the share of fuel exports to merchandise exports have been declining during the period, trade surpluses of more than 30 million TOE of crude oil were maintained. Overall, the last phase of the Suharto regime can be summarized as a time when the productivity and energy efficiency of the manufacturing sector was improved through an export-led industrialization policy.

Table 1.1: TFP growth measurements using firm-level data for the Indonesian manufacturing sector

Authors	Methods	Periods	Annual TFP growth
1. Timmer (1999)	Growth accounting method	1975-1981	1.10%
		1982-1985	0.10%
		1986-1990	7.90%
		1991-1995	2.10%
		1975-1995	2.80%
2. Aswicahyono and Hill (2002)	Growth accounting method	1976-1980	1.10%
		1981-1983	-4.90%
		1984-1988	5.50%
		1989-1993	6.00%
		1975-1993	2.70%
3. Vial (2006)	Cobb-Douglas production function	1976-1980	1.50%
		1981-1983	-0.10%
		1984-1988	5.10%
		1989-1993	8.00%
		1976-1996	3.50%
4. Ikhsan-Modjo (2006)	Stochastic production frontier	1988-1992	2.70%
		1993-1996	2.90%
		1997-2000	-0.60%
		1988-2000	1.60%

Table 1.2: Summary of key variables for four analytical periods

Variables	Unit	Source	Period 1 (6 years)		Period 2 (3 years)		Period 3 (4 years)		Period 4 (3 years)	
			1990	1995	1998	2000	2003	2006	2008	2010
Per capita GDP	USD at 2005 price	a	840.2	1,129.1	1,057.1	1,086.1	1,180.5	1,324.5	1,451.6	1,570.2
GDP growth rate	%	a	7.9%		2.8%		5.4%		5.4%	
Growth rate of value added in manufacturing sector	%	a	10.6%		4.9%		5.2%		3.5%	
Share of manufacturing sector to GDP	%	a	21.6%	24.5%	26.0%	27.1%	27.3%	27.2%	26.1%	25.2%
Share of manufactures exports to merchandise exports	%	a	35.5%	50.6%	45.0%	57.1%	52.1%	44.7%	38.8%	37.5%
Share of high-technology exports to manufactured exports	%	a	1.6%	7.3%	10.4%	16.4%	14.8%	13.5%	10.9%	9.8%
Total final energy consumption (TFEC)	1,000 TOE	b	79,817	99,513	107,332	120,323	128,043	139,427	139,686	156,113
Growth rate of TFEC	%	b	4.5%		5.9%		2.9%		5.7%	
Elasticity of total TFEC to GDP	-	a/b	0.57		2.07		0.53		1.05	
Energy intensity (TFEC/GDP)	TOE/USD at 2005 price	a/b	531.8	454.1	500.2	530.2	497.2	462.3	410.8	413.1
TFEC in manufacturing sector	1,000 TOE	b	17,805	26,087	26,914	30,333	33,548	43,820	39,971	45,264
Growth rate of TFEC in manufacturing sector	%	b	7.9%		6.2%		9.3%		6.4%	
Elasticity of TFEC to GDP in manufacturing sector	-	a/b	0.75		1.25		1.80		1.85	
Energy intensity of manufacturing sector	TOE/USD at 2005 price	a/b	548.8	486.3	482.3	493.5	476.5	534.8	449.6	475.6
Net export of crude oil	1,000 TOE	b	32,328	30,744	27,349	17,390	7,043	(2,860)	1,350	(2,171)
Net export of oil products	1,000 TOE	b	8,054	2,675	1,529	(4,181)	(6,896)	(11,598)	(15,860)	(20,722)
Share of fuel exports to merchandise exports	%	a	44.0%	25.4%	19.1%	25.4%	25.8%	27.2%	29.1%	29.7%

Note: a) World Development Indicators 2014, b) IEA Energy Balance Tables for Non-OECD Countries, 2013
GDP gross domestic product, *USD* United State dollar, *TFEC* total final energy consumption, *TOE* ton of oil equivalent.

Period 2 from 1998 to 2000 is characterized as an immediate post economic crisis period and marks the beginning of democratic reforms after the Suharto regime. Per capita GDP in constant US dollars at 2005 prices moved to an even lower range compared to 1995, and the average GDP growth rate was only 2.8% during the period. However, the manufacturing sector performed relatively better despite the negative effects of the financial crisis. The share of the manufacturing sector to GDP slightly expanded from 26.0% to 27.1% and that of exports to merchandise increased from 45.0% to 57.1%. At the same time, the share of high-technology exports to manufactured exports also continued to increase from 10.4% to 16.4%. However, energy consumption in Indonesia sharply increased during this time, and the elasticity of TFEC to GDP was 2.07, whereas the elasticity of the manufacturing sector was 1.25. Net crude oil exports started to decline from 27.3 to 17.4 million TOE, and the net export of oil products turned negative during this period.

Period 3 between 2003 and 2006 covers a politically significant transitional moment when President Yudoyono became the first president of the country elected by a direct presidential election in 2004. Immediately after electing a new president, the Sumatra-Andaman earthquake and tsunami hit the country. The period first experienced a transition from positive to negative net oil exports considering both crude oil and oil commodities. Coincidentally, unprecedented and continuously soaring international oil prices finally forced the government of Indonesia to begin removing subsidies for oil commodities twice in one year in March and October 2005, doubling the prices for most oil commodities in the domestic market. Under these conditions, the manufacturing sector grew annually by 5.2% on average, which was slightly lower than GDP growth. Meanwhile, the share of manufactured exports to merchandise exports dropped from 52.1% to 44.7%, and the share of high-technology exports to manufactured exports also shrank from 14.8% to 13.5%. The energy intensity of the country as measured by the ratio of TFEC to GDP greatly improved, while the energy intensity of the manufacturing sector worsened. It is expected that manufacturing firms faced a significant increase in energy costs.

Period 4 from 2008 to 2010 was in the middle of the ten-year presidency of Yudoyono and of the global financial crisis triggered by the subprime mortgage crisis and the bankruptcy of Lehman Brothers in 2008. The adverse shock caused in Indonesia by the global financial crisis was relatively small, and the average GDP growth rate in Period 4 was maintained, staying as high as that of Period 3. However, the growth rate of the manufacturing sector slowed and the shares of the manufacturing sector to GDP, manufactured products to merchandise exports, and high-technology products to manufactured products all shrank. At the same time, dependency on imported oil commodities increased remarkably, whereas the average growth rate of TFEC in the manufacturing sector was 6.4%, which is much higher than production growth, resulting in an elasticity of 1.85. Amid such circumstances, the overall energy intensity of manufacturing firms did not improve. Further subsidy removal was implemented in 2008, and it is likely that the additional burden put a strain on manufacturing firms.

1.4. Research question and objectives

This research seeks to answer the following question: What is the impact of CO_2 emissions reduction on manufacturing sector productivity changes when carbon regulations are imposed? How should financial burden be arisen by manufacturing sector for its abatement activities? Does the domestic price of oil commodities directly affect environmental productivity change and average carbon abatement cost in manufacturing sector?

To respond to above questions, the overall objective of this study is to analyze the performance of Indonesia's manufacturing sector when energy and climate change related issues are taken into account. First of all, the changes in the TFP of manufacturing firms in Indonesia over time from 1990 to 2010 with and without considering CO_2 emissions as the undesirable outputs are estimated as a baseline analysis. Economic incentive instruments of carbon regulations are assumed to be imposed so as the undesirable outputs are weakly disposable. The comparison of the TFP with and without considering CO_2 emissions across different sectors of the manufacturing industry enables to identify firm reactions to changes in the prices of oil commodities. Further, this study estimate average carbon abatement costs as forgone profit of manufacturing firms as the impact of CO_2 emissions reduction and the increase of oil commodities prices. The relative efficiencies of manufacturing sector during the four periods are also reported. Finally, the impact of energy factors on environmental productivity change and average carbon abatement cost are analyzed to investigate the determinant of environmental productivity change and average carbon abatement cost before and after the increase price of oil commodities.

1.5. Definitions and terminology in this study

The definitions and terminology used in this study are described as follow:

a. Productivity is an average measure of the efficiency of production and can be expressed as the ratio of output to inputs used in the production process, e.g. labor productivity. In this research productivity growth over time is measured using two different approaches; Malmquist productivity index to measure productivity without considering CO_2 emissions as undesirable outputs and Malmquist-Luenberger productivity index to measure productivity with considering CO_2 emissions. The two approaches measure productivity of a firm relative to a production frontier and can be considered as a proxy of Total Factor Productivity (TFP) measurement with multiple inputs and outputs. Further, TFP measures the production obtained with respect to all factors of production; i.e. labor, capital and intermediate inputs, and might be reflected as technological improvement.
b. Environmental productivity is the measurement of the contribution of environmental component on productivity. This research defines environmental productivity as the ratio of the TFP with considering CO_2 emissions to the TFP without considering CO_2 emissions or TFP environment. The higher value of environmental productivity implies the positive achievement of proactive environmental measures.
c. Energy efficiency is described as the ability of a firm to utilize energy as an input to produce more manufacturing outputs, or to produce the same amount of outputs

for less energy input. In this research energy efficiency is considered as one of the measures to respond the increase of energy price.

d. Carbon abatement cost is the opportunity cost borne by a firm in reducing an amount of CO_2 emission proportional to the increase in outputs. This research defines carbon abatement cost as the difference in value added increasing between unregulated and regulated disposability scenarios using production frontier approach. Carbon abatement cost is also described as forgone profit of a firm for abatement activities. Moreover, average carbon abatement cost is defined as the cost to reduce per ton CO_2 emissions of a firm for each sector.

1.6. Significant of the study

This research discussed the environmental productivity and efficiency improvement of the Indonesia's manufacturing sector as the climate change mitigation and energy related policies become the major factors that strongly influence. In addition, the financial burden arisen when manufacturing sector decreases CO_2 emissions as undesirable outputs is examined. This study applies the cleaned and balanced datasets the annual manufacturing surveys conducted by the Indonesian Statistics Agency.

In general, this study presents the first case to empirically examine the productivity change with and without considering CO_2 emissions of manufacturing sector in Indonesia for firm-level data over sectors and time. It is the first study to measure environmental productivity over time as well. Furthermore, carbon abatement cost is estimated to measure opportunity cost of manufacturing firm in reducing CO_2 emissions.

1.7. Structure of the dissertation

The dissertation consists of six chapters as present in Figure 1. Chapter one is Introduction. This chapter briefly introduces the roles of manufacturing sector in Indonesia and the impact of the increase price of oil commodities. Then, the chapter discussed the annual manufacturing survey data as the basis for determining contextual background. Further, the research questions and objectives followed by the significant of the study, and the structure are set. Chapter two reports the development of a cleaned panel dataset as the annual manufacturing survey data consists of several data quality problems. Chapter three examines the productivity change over time with and without considering CO_2 emissions. Chapter four estimating average carbon abatement cost of manufacturing sector. Chapter five examines the impacts of energy price on environmental productivity change and abatement cost, and chapter six concludes the main findings from the study and aims to extracts some policy recommendation based on the main findings.

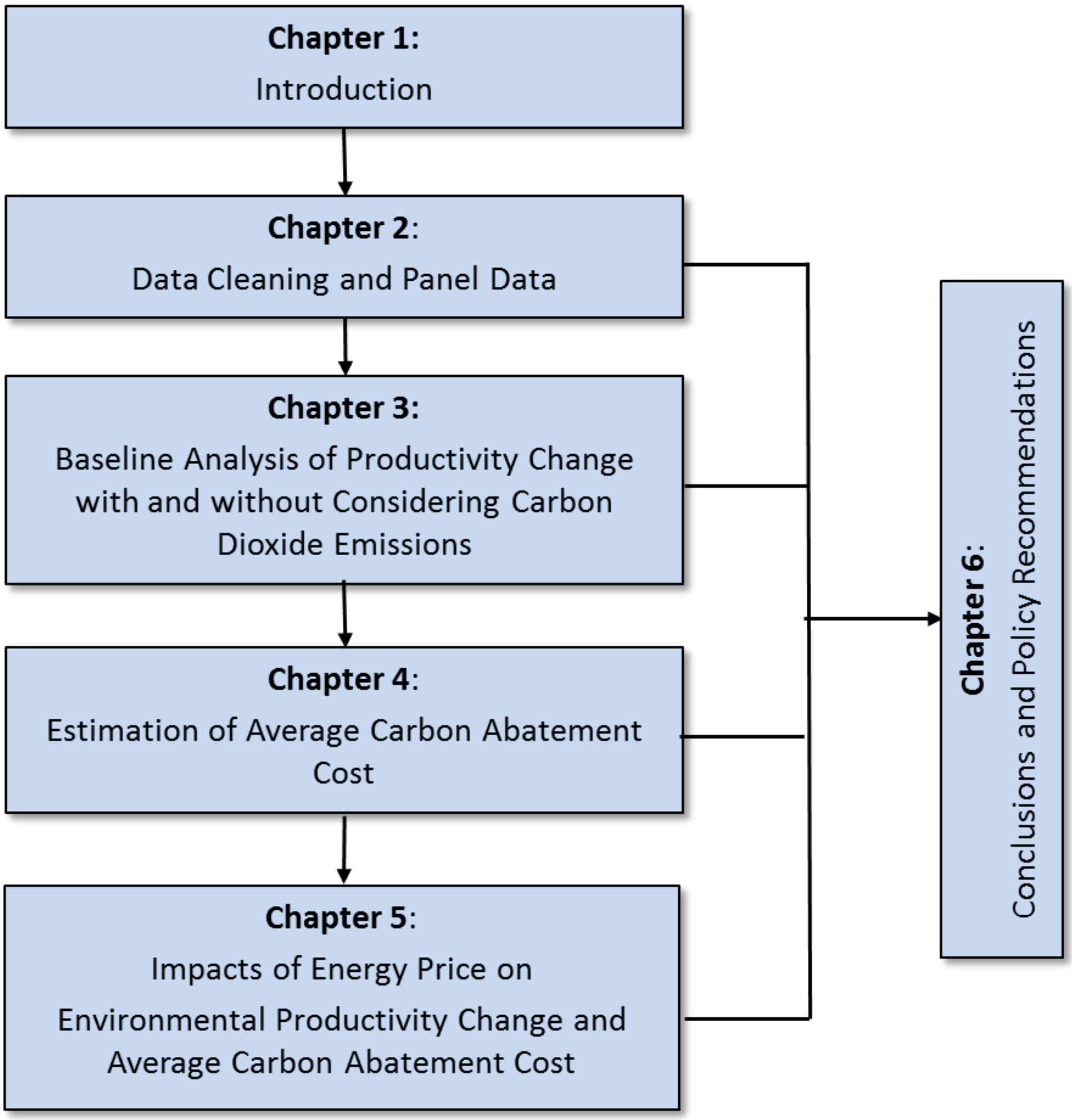

Figure 1.1: Structure of dissertation

CHAPTER 2: DATA CLEANING AND PANEL DATA

2.1. Introduction

Data is the basis for all scientific researches and used by academics, businessmen or practitioners. Collecting a good quality data plays a vital role in supplying objective information for the identifying problems, improving analytical understanding of the problems, and hence obtaining appropriate solutions. The presence of incorrect or inconsistent data can significantly negate the potential benefits of information-driven approaches. Making decision on the basis of poor quality data is risky and may lead to disastrous results, as the situation may be distorted and therefore all subsequent analyses and decision making will remain an improper effort.

Data quality problems, including missing values, the existence of duplicates, misspellings, data inconsistencies and wrong data formats, commonly arise in different application contexts and require appropriate treatment so as the data and information becomes reliable. Data cleaning deals with data problems once they have occurred. Error-prevention strategies can reduce many data quality problems but cannot eliminate them. Data cleaning is defined as a three-stage process, involving repeated cycles of screening, diagnosing, and editing of suspected data abnormalities (Van den Broeck, 2005).

A data cleaning approach should satisfy several requirements. First of all, it should detect and remove all major errors and inconsistencies from individual data sources and when integrating multiple sources. Furthermore, data cleaning should not be performed in isolation but together with schema-related data transformations based on comprehensive metadata. Mapping functions for data cleaning and other data transformations should be specified in a declarative way and be reusable for other data sources as well as for query processing (Rahm, 2000).

A detailed data analysis is required to detect data errors and inconsistencies to be removed. In addition to a manual inspection of the data samples, analysis programs should be used to gain metadata about the data properties and detect data quality problems. After single-sources errors have been removed, the cleaned data should also replace dirty data in the original sources to give legacy applications for the data and to avoid redoing the cleaning work for future data extraction (Rahm, 2000).

The need for data cleaning is centered on improving the quality of data to make them ‘fit for use’ by users through reducing data errors and improving documentation and presentation. Data errors are common and to be expected (Chapman, 2005). However, on the other hand, it is important to consider that data collection and observations are often affected by unusual events or disturbances that create spurious effects and results extraordinary patterns. These unusual values or outliers have adverse effects on understanding the properties of data collected.

Aggarwal (2013) emphasized the definition of an outlier in an available date set. An outlier is described as a particular data point which is significantly different from the other data. It also referred to as deviants, discordant, abnormalities, or anomalies in the statistics literature and data processing. In general purpose, the data is formed by one or more creation processes, which might represent activity in the system or observations collected. The generating of outliers occurs when the creating process performs in an uncommon way. Hence, an outlier often encompasses valuable information about abnormal characteristics of the systems and objects, which impacts the data creation processes. Identification of outliers is very important in many fields because it can contain information that may lead to an intervention of a process and prevent failures or abnormal operating conditions. Thus, there is also a need for effective and efficient methods for outlier detection.

Having the availability of various data cleaning approaches to obtain reliable data set, Maletic and Marcus (2000) and also Basu and Meckesheimer (2007) suggested that each of the proposed method has its strengths and weaknesses. Some of which are promising and could be successfully applied to the real-world data and the others need improvements.

The BPS conducts a manufacturing survey encompass all manufacturing firms with twenty or more employees on an annual basis for all of the 33 provinces throughout Indonesia. The datasets provides comprehensive firm level data covering over 22,000 firms. The survey is intended to obtain consistent and accurate manufacturing data for the improvement of national development planning. Because the data are collected from a survey, data quality problems also occur. Data treatment and management are required to acquire reliable data set that can be used for any purposes by removing outliers, eliminating missing value, and fixing duplications.

The objectives of this chapter are aimed to clean and balance the raw data of manufacturing survey, from 1990 to 2010, for the purpose of further analysis. Because the datasets is in a longitudinal format, data cleaning will result a complete and comprehensive panel data set consisting of the same firms within periods.

2.2. The Characteristics of Indonesian Manufacturing Survey Data

The BPS's annual manufacturing survey is an annual survey of medium-size and large-size firms that employ at least 20 workers in the 33 provinces throughout Indonesia. Since BPS has its branch offices in the 33 provinces, the survey is conducted simultaneously for all firms at the same period. The data obtained from the survey is expected to have the same characteristics and performance in the particular time.

Indonesian manufacturing sector was the engine of growth in the 1980s and for much of the 1990s, caused of a series of trade reforms following the end of the oil boom. In 1991, the sector's contribution to gross domestic product (GDP) exceeded the contribution of agriculture sector. Much of the expansion was concentrated in low-skill, labor-intensive, export-oriented industries, and it contributed greatly to a decline in poverty by providing expanded job opportunities. Hence, when the roles of the manufacturing sector to economic development increase, the demand for statistical data in the manufacturing sector also increases.

The information attained from the survey, as illustrated in the survey form, firstly informed about identity, address, firm status, and location, which described about the firm identity. Then it covered the information as follow:

- *Part I: General Information*, consisting of main product, percentage of capital owned, and number of workers;
- *Part II: Expenses*, consisting of wages of workers, fuel and lubricants, number of generator used, electricity purchased and sold, other expenses, and raw materials;
- *Part III: Production*, consisting of goods produced and percentage of actual production to production capacity;
- *Part IV: Other Income Received*, consisting of manufacturing services received, profit from sale of unprocessed goods, from non-manufacturing services, and from sale of scrap waste;
- *Part V: Fixed Capital*, consisting of estimated value of fixed capital (land, building, machinery and equipment, vehicle, and other), major repair, input costs, output value, and value added.

The numbers of firms obtained from the survey are varying from year to year. These differences are based on the performance and sustainability of the firm operation, that mostly affected by an economic condition at local, national, and international level. Table 2.1 presents the number of firms from 1990 to 2010. The number of firms was 16,536 in 1990, gradually increased to reach the highest number of 29,466 firms in 2006, then steadily decreased to 22,492 firms in 2010.

Table 2.1: Number of manufacturing firms from 1990 to 2010

Year	Number of Firms	Year	Number of Firms	Year	Number of Firms
1990	16,536	1997	22,997	2004	20,654
1991	16,494	1998	21,423	2005	20,684
1992	17,648	1999	22,070	2006	29,466
1993	18,163	2000	22,174	2007	27,994
1994	19,017	2001	21,392	2008	25,694
1995	21,551	2002	21,138	2009	24,466
1996	22,385	2003	20,322	2010	22,492

The data set consists of 66 and 23 classifications of manufacturing sector, based on the 3-digit and 2-digit ISIC (International Standard Industrial Classification) Revision 3 respectively. The 3-digit 66 classifications are begun with the code of 151 to 372 while the 2-digit 23 classifications are begun with the code of 15 to 37. For the purpose of empirical analysis, this paper will only consider 2-digit classification data. Table 2.2 describes the 2-digit code and classification of manufacturing sub-sectors data.

Based on manufacturing sector classification, the number of furniture and manufacturing sector has grown significantly from 1990 to 2000. Annually, around 110 new firms of this sub-sector were established. Followed by food product and beverages and other non-metallic mineral product sectors, annually around 91 and 53 new firms were established, respectively. For more detailed description about the number of firms established for each sub sector during 1990 to 2000 is presented in Appendix I. The number of firm of food product and beverages sector considerably increased around 71 firms annually for the second period, 2001 to 2010. Followed by textiles and furniture sectors, these firms annually increased around 31 and 20 new firms, respectively. Appendix II presents the detailed number of firms from 2001 to 2010.

Table 2.2: Classification of 2-digit manufacturing sub-sectors

Code	Classifications	Code	Classifications	Code	Classifications
15	Food product and beverages	23	Coal, refined petroleum product and nuclear fuel	31	Electrical machinery and apparatus n.e.c.
16	Tobacco	24	Chemicals and chemical product	32	Radio, television and communication equipment
17	Textiles	25	Rubber and plastics product	33	Medical, precision, optical instruments, and watch
18	Wearing apparel	26	Others non-metallic mineral product	34	Motor vehicle, trailers and semi-trailers
19	Tanning and dressing of leather	27	Basic metals	35	Other transport equipment
20	Wood and product of wood and plaiting	28	Fabricated metal product and equipment	36	Furniture and manufacturing n.e.c.
21	Paper and paper product	29	Machinery and equipment n.e.c.	37	Recycling
22	Publishing, printing and reproduction	30	Office, accounting, and computing machinery		

2.3. Methodology

2.3.1. Variables construction

The data for the period of 1990 to 2000 consists of 11-digits identification number, and the data for the period of 2001 to 2010 has 9-digits identification number. Since the methods of data collection are slightly different for the two different periods, two panel data will be developed.

The datasets consists of medium and large size firms. This grouping is based on the number of workers for each firm, regardless the size of capital or output. BPS defined a medium size firm is a firms that has 20 to 100 workers, while a large firm is described as a firm that has more than 100 workers. Table 2.3 describes the number of firm and its percentage for medium and large size firms from 1990 to 2000.

The BPS's raw data has much information about manufacturing firms, starting from the number of labor to the total value of output. Only selected information is used and will be considered as variables for analysis purposes. The important step in data cleaning is determining significant variables, such as main and intensity variables, to minimize additional efforts, because the data set consist more than 22,000 firms. The main variables selected are described in the following manner:

- *Capital* (k), measured as the estimated value of total fixed assets (land, building, machinery and equipment, vehicle, and other).
- *Labor wage* (l), measured as the total salary and other incentives of all workers, including production workers and other workers.

- *Raw material* (m), measured as the total materials used to produce a unit of output, obtained from domestic and also imported from other countries.

- *Value added* (v), measured as the total value generated from the transformation of raw materials to final product or finished goods or the difference between total sales revenue and total cost of components, materials, and services.

- *Output* (q), measured as the total values generated from the process of manufacturing activity in the form of goods produced, sold electricity power, industrial services, trading profits, the stock added, semi-finished goods, and other revenue within a year.

- *Energy consumption* (e), measured as the total energy use to operate manufacturing firm within a year in Tons of Oil Equivalent (TOE), including fuel and electricity used;

- *CO_2 emissions,* (CO_2), measured as the common type of gas emitted from the burning of fossil fuels used in manufacturing firms in tons CO_2 equivalent, calculated from fuel combustions used in manufacturing sector based on Intergovernmental Panel on Climate Change (IPCC) guidelines (IPCC 2006, 2006).

Table 2.3: The number of medium and large size firms

Year	All firms number	Medium firms		Large firms	
		Number	percentage	Number	percentage
1990	16,536	12,006	72.6	4,530	27.4
1991	16,494	11,485	69.6	5,009	30.4
1992	17,648	12,147	68.8	5,501	31.2
1993	18,163	12,344	68.0	5,819	32.0
1994	19,017	13,545	71.2	5,472	28.8
1995	21,551	15,110	70.1	6,441	29.9
1996	22,386	15,855	70.8	6,531	29.2
1997	22,997	16,415	71.4	6,582	28.6
1998	21,423	15,056	70.3	6,367	29.7
1999	22,070	15,497	70.2	6,573	29.8
2000	22,174	15,467	69.8	6,707	30.2
2001	21,392	14,734	68.9	6,658	31.1
2002	21,138	14,476	68.5	6,662	31.5
2003	20,323	13,813	68.0	6,510	32.0
2004	20,656	14,117	68.3	6,539	31.7
2005	20,684	14,199	68.6	6,485	31.4
2006	29,465	22,157	75.2	7,308	24.8
2007	27,997	20,921	74.7	7,076	25.3
2008	25,694	18,938	73.7	6,756	26.3
2009	24,466	17,797	72.7	6,669	27.3
2010	22,492	15,976	71.0	6,516	29.0
Total	454,766	322,055		132,711	

While the intensity variables are defined and described as follow:

- *Energy intensity* (e_q), is the amount energy used to produce a single unit of manufacturing output, measured as the ratio of total energy used to total output.
- *Labor productivity* (q_l), is the total value of output generated per worker, measured as the ratio of total output to total labor wage.
- *Raw material per output* (m_q), is the material used to produce a single unit of output, measured as the total materials used to total output.
- *Value added per output* (v_q), is the total valued added generate per output, measured as the ratio of total value added to total output.
- *Output per capital* (q_k), is the total value of output generated per total value of capital, measured as the ratio of total output to total capital.

The information related to monetary unit such as capital, labor wage, raw material, value added, and output are originally in thousands of Indonesian Rupiah (IDR). To avoid price changes over time, GDP (Gross Domestic Product) deflators are applied to convert these series of data set at constant prices based on the year 2000. Appendix III shows the GDP deflators of Indonesia from 1990-2000. Also, to convert the currency from Indonesian Rupiah to US dollar, currency rate from the year of 2000 is applied which was IDR 9,593 equal to USD 1.

2.3.2. Data Cleaning

After variables are constructed and defined, data cleaning is carried out base on the variables data. Several subsequent steps have to be done including removing missing and zero values, identifying outliers, removing outliers, and smoothing data trend. The result of data cleaning is a data set without data quality problems.

2.3.2.1. Removing Missing and Zero Values

A number of variables of the observations contained missing and zero values. Missing and zero values are a part of data quality problems that commonly appear during a data collection. The first step in cleaning data is to remove these values. However, it should be noted that zero value of a variable can be a real condition that provides important information of an observation.

The main variables that contain monetary values such as capital, labor wage, raw material, value added, and output should not have a zero value. The zero values have to be removed, because it is unreasonable for a capital variable or an output variable has a value of zero, which implies that there is no production process of a manufacturing firm. The missing values of these main variables have to be removed as well, because there is no precise information can be gained from a missing value, whether it is actually a zero value or it is a non-zero value.

The missing values have to be removed from fuel and electricity consumption data, because this data will be used to determine the main variable of energy consumption. If the unavailability of fuel and electricity consumption data occurs in a certain year, then all observations in the certain year will be removed. In this case, zero values of fuel or electricity consumption data will not be removed, as several firms use only particular energy sources.

2.3.2.2. Identifying Outliers

A method for cleaning data involves two major aspects. The first aspect is identifying which observations in a data set are outliers and the second aspect is addressing the issue of what have to do with the observation that have been identified as an outlier. It is important to consider that an outlier may have two interpretations, it can either be noise or it can be an indication of an anomaly for a specific reason.

In identifying outliers, several approaches can be applied based on the assumptions to model the outliers and properties of the underlying modeling approaches. The approaches that commonly used to identify outliers are model-based approach, proximity-based approach, and angle-based approach. Each of these approaches can be further elaborated into detailed approaches. For instance, the model-based approaches can be described as statistical model approach, depth-based approach, and deviation-based approach. Since the data is collected by annual survey and consists of a large number of observations, a statistical model approach is more appropriate to be applied.

2.3.2.3. Statistical Model Approach

Statistical model approaches can identity outliers of a large number of data set. The basic ideas of this approach are given a certain kind of statistical distribution, estimating the parameters assuming that all data points have been generated by such a statistical distribution (mean, median, or mode), and thus outliers are the points that have a low probability to be generated by the overall distribution. While the basic assumptions of the approach are normal data objects keep up with a distribution and occur in a high probability area of this model, and outliers deviate strongly from this distribution.

Kernel density estimation is employed to obtain a clear description of the original distribution of the raw data. Kernel density estimation is a non-parametric way to estimate the probability density function of a random variable, and also is a fundamental data smoothing problem where inferences about the population are made, based on a finite data sample. Figure 1 shows a sample of raw data distribution for capital variable from 1990 to 2000, and Figure 2 depicts a sample of raw data distribution for energy intensity variable from 1990 to 2000. Almost all of the variables for both periods showed a Zipf distribution, instead of a normal distribution, similar to the Figure 2.1 and Figure 2.2. A Zipf distribution can be interpreted that most of the raw data contain unrealistic values. If missing data or one extreme value contained in the data set it will strongly affected the development of a frontier in the data envelop analysis and directional distance function approaches that will be described in the next chapter.

Mean, median, and mode as central tendencies of statistical distribution of each sub-sector's intensity variables during each period are used and applied to define the range of intended data set. Multiplying by three certain values, which are 500, 1000, and 1500, the points of intended data set boundary can be identified. The employment of these three values is a trial and error effort because there is no initial information about the number of outliers of raw data. Figure 2.3 illustrates the application of central tendencies multiplied by 500 for labor productivity variable (q_l) of food and beverage sub-sector during 1990-2000. The points of mean, median, and mode can be defined in the kernel density distribution graph. Also, the points of central tendencies multiplied by a certain value of 500 are able to be identified.

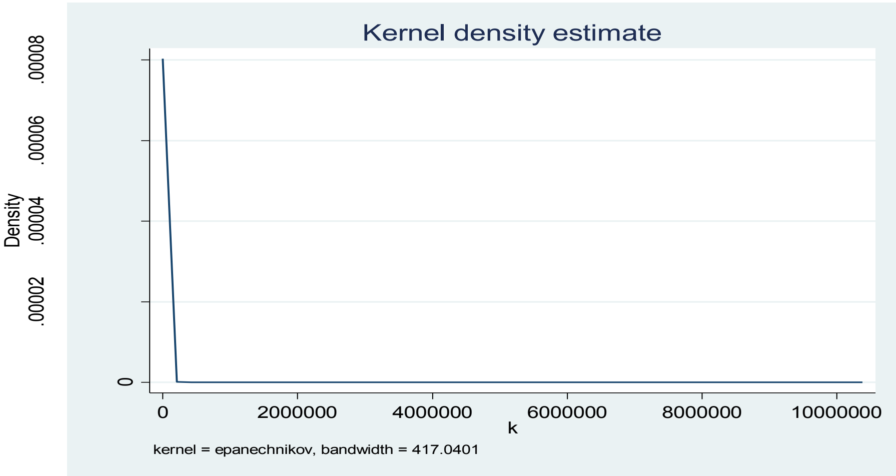

Figure 2.1: Raw data distribution for capital variable from 1990 to 2000

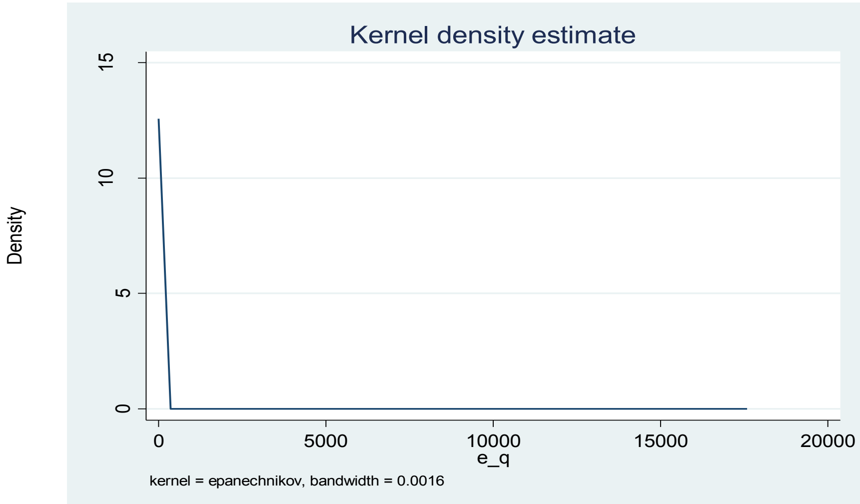

Figure 2.2: Raw data distribution for energy intensity variable from 1990 to 2000

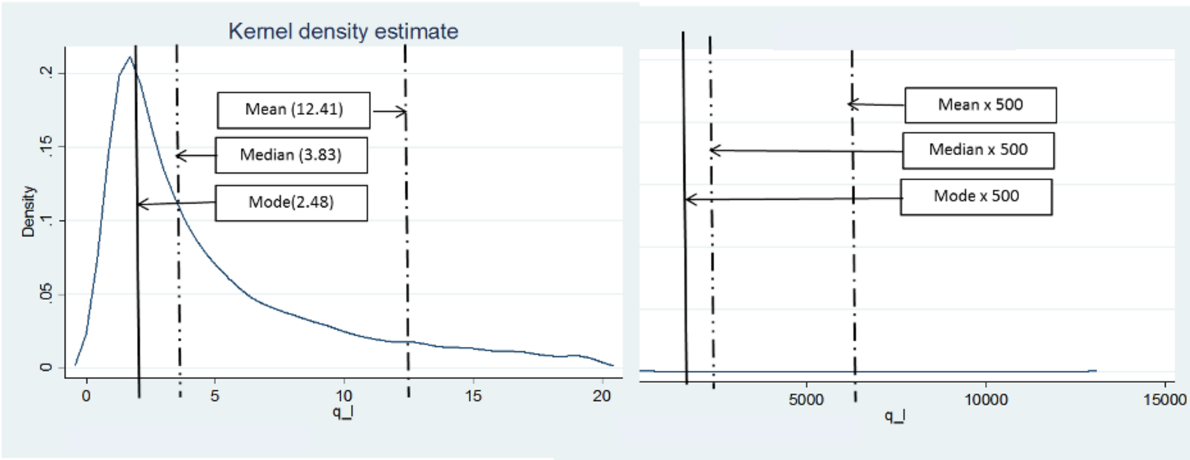

Figure 2.3: Identification of the boundary points of labor productivity variable, from 1990 to 2000

The identification of the boundary points in Figure 2.3 aims to obtain the right boundary points of intended data set. To identify the left boundary points, similar step is carried out using reverse variable of labor productivity, which is labor per output (l_q). Figure 2.4 shows the identification of the boundary points of labor per output variable from 1990-2000.

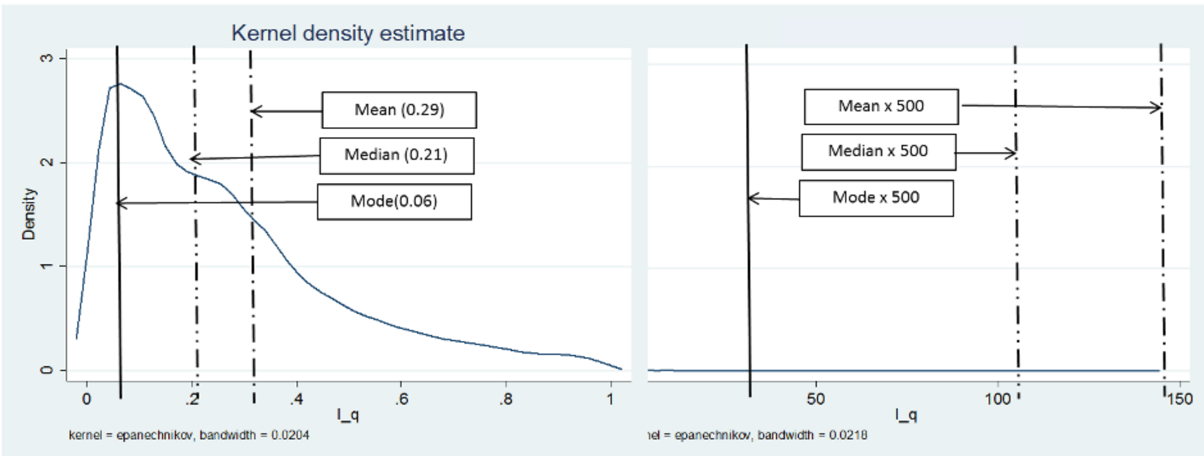

Figure 2.4: Identification of the boundary points of labor per output variable from 1990 to 2000

The outliers can be recognized from these two identification measures. They are defined as the observation beyond the range of intended data set. Amongst the three points in the left and the right boundaries, the using of mode showed that the distribution graph becomes stricter. The stricter distribution graph implies that more outliers can be removed. And finally, the more outliers can be removed is assumed that the data set is cleaner. Additionally, amongst the three certain values, the using of 500 demonstrates that the distribution graph becomes stricter. However, it must be note that the more stringent parameters applied for data cleaning, the less number of observation obtained. Consequently, the cleaned data can not represent the whole manufacturing sector, because several sub-sectors will also be removed. To this reason, certain values smaller than 500 are not applied. The similar measure using mode and the value of 500 are also applied for all intensity variables of all sub-sectors during both periods, from 1990 to 2000 and from 2001 to 2010.

2.3.2.4. Coefficient of Variant Approach

In additional to increase robustness of the cleaned data resulted from the statistical model, a coefficient of variant (CV) approach is implemented. Coefficient of variant is defined as the ratio of the standard deviation to the mean, and it is a useful statistic for comparing the degree of variation from one data series to another. CV can also describe the level of the data trend fluctuation.

A single value of CV of each sub-sector's intensity variables during each period is used to determine a boundary of which observations have to be removed. The value of 1 is selected by considering that for a zift or exponential distribution, the standard deviation is equal to its mean. The observations of cleaned data which have a CV value of its intensity variable more than 1 will be removed with the objective that the cleaned data trend is smoother.

2.3.3. Data Balancing

To develop a panel data, a firm identification number or a firm id is used as a base to synchronize and filter the data set within a period. A firm id is the first character which has to be examined whether it complies with the standard identification number, and will ease in identifying and distinguishing which one describes location, sector classification, and particular firm. They are 11-digit identification number for data from 1990 to 2000 and 9-digit identification number for data from 2001 to 2010. If a firm id does not comply with the standard identification number then the data have to be deleted. This firm id examination is also aimed to identify whether the firms are included in the category of manufacturing sector or other sectors.

Through a balancing process, the data set is stratified by year and compiled with the same firm id. It is expected that there are some firms with the same firm id exist throughout a period. Firms which do not have the same firm id throughout a period will be removed. By having the same firms throughout the year, the data set have been arranged in a longitudinal format. A balanced data with a longitudinal format is also known as a panel data.

Data cleaning and data balancing will result a data set consisted of some firms that survive in the list. The number of firms for each sub-sector varies based on the number of outliers removed. A further analysis can be appropriately carried out if a sector comprises of more than 15 firms. Otherwise, the result might not represent the whole manufacturing sector.

2.4. Results and Discussions

Applying a raw data from a manufacturing survey for an analysis will obtain unreliable results, because the raw data commonly has data quality problems. Data cleaning is the first and the most important step in any data processing. It aims to have access to reliable data to avoid false and misdirected conclusions. After cleaning the data, a data set will be consistent with other similar data set in the system. The raw data inconsistencies and outliers detected or removed may have been originally caused by human errors, by wrong format, or by corruption in transmission or storage.

Started with removing missing and zero values and outliers identification, two approaches to clean a raw data are applied to obtain reliable cleaned data set. Subsequently, balancing the cleaned data is the following step to be carried out to develop panel data. The results of data cleaning and data balancing are compiled in Table 2.4. The column A in Table 2.4 shows the number of observation from the BPS's survey data each year from 1990-2010. The total number of observation during 1990 to 2010 is 454,766. The column B is the result of removing zero values for monetary unit of certain variables. In this column the numbers of firms in 1996 and in 1997 are zero, because in these years the data of capital are zero. It is unreasonable for the firms containing zero capital values. Hence the observations in those years are removed. The total number of observation after removing zero values is 253,610 or 55.8 percent of the total number of raw data. The column C exhibits the result of removing missing value for fuel and electricity consumption. There are missing values for the consumption of coal and kerosene in the years 2001 and 2002. The unavailability of coal and kerosene data will have a significant impact in determining CO_2 emission, because coal and kerosene are the main fuels which have a high carbon contents. Without coal and kerosene data, CO_2 emission estimation cannot represent the actual emission of manufacturing sector. Previously in the column B, the number of observations decreased sharply in 2007 as the removing zero values measure had eliminated 77 percent of observations. To prevent the biasness in developing panel data in the future, the observations in 2007 are removed. The total number of observation after removing missing values is 222,062 or 49 percent of the total number of raw data. The column D is the result of data cleaning using statistical model and coefficient of variant approaches. In these measures outliers are identified and removed. Several observations are also removed to reduce the fluctuation of data trend. The result of these approaches will generate the remaining amount of 91,311 observations or 20 percent of the total number of raw data. The column E, is the result of data cleaning and data balancing of manufacturing sector data. The firms that do not continuously exist during the certain period will be removed. The final amount of observation is 19,772 or 4.3 percent of the total number of raw data, which consist of 1,556 firms each year for the first period and of 824 firms each year for the second period. Because all observations are removed in the year 1996, 1997, 2001, 2003, and 2007, the developed panel data that can be applied for the purpose analysis are; the period 1 from 1990 to 1995, the period 2 from 1998 to 2000, the period 3 from 2003 to 2006, and the period 4 from 2008 to 2010.

Table 2.4: The number of observations from data cleaning and panel data

Year	A	B	C	D	E
1990	16,536	13,140	13,140	5,429	1,556
1991	16,494	12,926	12,926	6,202	1,556
1992	17,648	14,439	14,439	6,608	1,556
1993	18,163	14,902	14,902	6,764	1,556
1994	19,017	15,488	15,488	7,121	1,556
1995	21,551	17,157	17,157	7,233	1,556
1996	22,386	0	0	0	0
1997	22,997	0	0	0	0
1998	21,423	14,850	14,850	6,312	1,556
1999	22,070	12,845	12,845	6,276	1,556
2000	22,174	13,237	13,237	5,918	1,556
2001	21,392	12,029	0	0	0
2002	21,138	13,059	0	0	0
2003	20,323	13,231	13,231	4,755	824
2004	20,656	13,562	13,562	5,206	824
2005	20,684	13,101	13,101	4,805	824
2006	29,465	11,468	11,468	3,262	824
2007	27,997	6,460	0	0	0
2008	25,694	13,458	13,458	4,961	824
2009	24,466	14,473	14,473	5,543	824
2010	22,492	13,785	13,785	4,916	824
TOTAL	454,766	253,610	222,062	91,311	19,772

Note:
A: raw data
B: results of removing zero values for monetary unit of certain variables
C: results of removing missing values for fuel and electricity consumption
D: results of data cleaning
E: results of data balancing

The number of firms that exist along the period based on the sectors classification is presented in Table 2.5. In particular, for several sectors such as coal, refined petroleum product and nuclear fuel; office, accounting, and computing machinery; and recycling, the number of observations are zero which implies that no firms can continuously present from 1990 to 2010. For further analysis these particular sectors are removed from cleaned dataset. As well as for the sectors that comprise of less than 15 firms each year, namely radio, television, and communication equipment and medical, precision, optical, and watch sectors are also removed. As the result of data cleaning and balancing, after removing some sectors, only 18 of 23 sectors remain exist.

In general, the average percentage of cleaned datasets of all 18 sectors is notably low, ranged from 2.9% to 6.5%. Among the remaining 18 sectors that can appropriately be applied for further analysis, the number of cleaned dataset of publishing, printing, and reproduction sector shows the highest percentage level (6.5%) consists of 832 observations. Food products and beverages sector presents the second highest percentage level (6%) even though the number of cleaned dataset is the largest (5,946 observations). The shrinking numbers of observations from 19,041 to 544 and from 12,160 to 356 are experienced by tobacco as well as tanning and dressing of leather sectors respectively and allow these sectors as the lowest percentage level of cleaned dataset (2.9%). However, since the number of firms of each sector is more than 15 annually, this study considers that the empirical results from the analysis using these datasets are able to represent the whole Indonesia's manufacturing sector.

Table 2.5: The number of observations of raw data and cleaned data for each sector

No	**Sub-sector**	**Raw data**	**Cleaned data**	
		Obs.	**Obs.**	**(%)**
1	Food product and beverages	99,924	5,946	6.0
2	Tobacco	19,041	544	2.9
3	Textiles	44,980	1350	3.0
4	Wearing apparel	44,569	1335	3.0
5	Tanning and dressing of leather	12,160	356	2.9
6	Wood and product of wood and plaiting	32,459	1,004	3.1
7	Paper and paper product	7,926	299	3.8
8	Publishing, printing and reproduction	12,802	832	6.5
9	Coal, refined petroleum product and nuclear fuel	973	0	0
10	Chemicals and chemical product	21,325	1,257	5.9
11	Rubber and plastics product	30,429	1,453	4.8
12	Others non-metallic mineral product	36,090	1,968	5.5
13	Basic metals	4821	152	3.2
14	Fabricated metal product and equipment	17,624	756	4.3
15	Machinery and equipment n.e.c.	8,358	311	3.7
16	Office, accounting, and computing machinery	166	0	0
17	Electrical machinery and apparatus n.e.c.	5,784	224	3.9
18	Radio, television and communication equipment	2,815	9	0.3
19	Medical, precision, optical instruments, and watch	1,299	118	9.1
20	Motor vehicle, trailers and semi-trailers	5,389	193	3.6
21	Other transport equipment	6,612	231	3.5
22	Furniture and manufacturing n.e.c.	38,157	1,561	4.1
23	Recycling	1,063	0	0
	TOTAL	454,766	19,772	4.3

The result of data cleaning and data balancing has to be verified to attain a consistent and reliable data set. One of the appropriate ways to verify the result is to be compared with available references, particularly those that applying the same treatment and process to Indonesian manufacturing data. However, a reference describing the result of data cleaning using Indonesia manufacturing data is rarely found. A considerable reference in this regard is Manning *et.al* (2012), as shown in Figure 2.5, that presents the relationship between wage and labor productivity of Indonesian manufacturing sector during 2006 to 2009 and comparing the estimation to other countries. The Ln (W) in Y-axis is log of average wage calculated as the ratio of wages and salaries paid by employees (converted to current US$) to number of employees. Ln (VA/L) in the X-axis is log labor productivity calculated as the ratio of value added (deflated by constant US dollar from the year 2000) to number of employees.

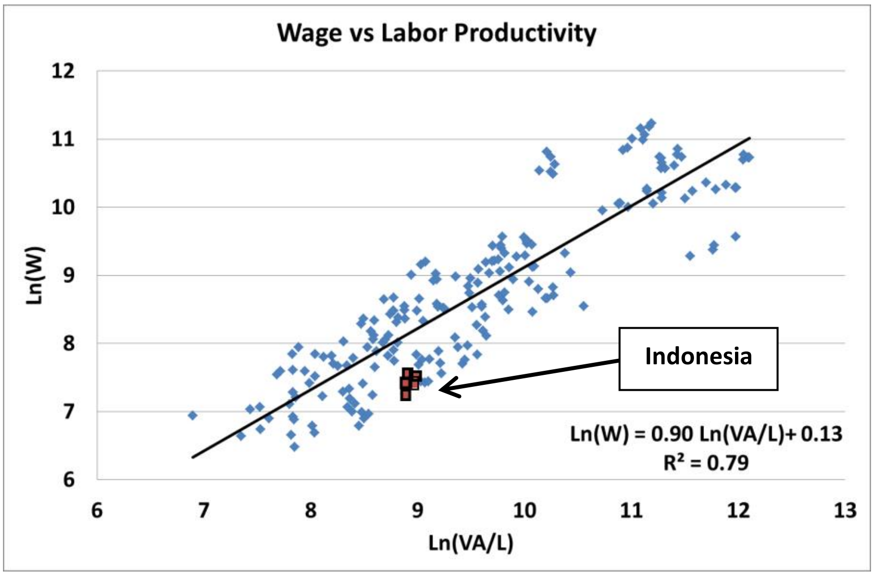

Figure 2.5: Wage and Labor Productivity of Manufacturing Sector across Countries, 2006-2009
Sources: INDSTAT, Manning *et.al* (2012), and author's modification.

Figure 2.6 presents wage and labor productivity of Indonesian manufacturing sector from data cleaning result only for the years of 2006, 2008, and 2009, because the observations in 2007 are removed. Ln (W) is also log of average wage calculated as the ratio of wages and salaries paid to employees to number of employees, whereas Ln (VA/L) is also log of labor productivity calculated as the ratio of value added to number of employees. Applying similar scales to the Figure 2.5, the position of Indonesian manufacturing sector for the years of 2006 2006, 2008, and 2009 can be appropriately identified in Figure 6, which is comparable to the reference. In both figures, Indonesian manufacturing sector is located below the trend line at the coordinates of Ln (W) = 7.5 and of Ln (VA/L) = 8.9.

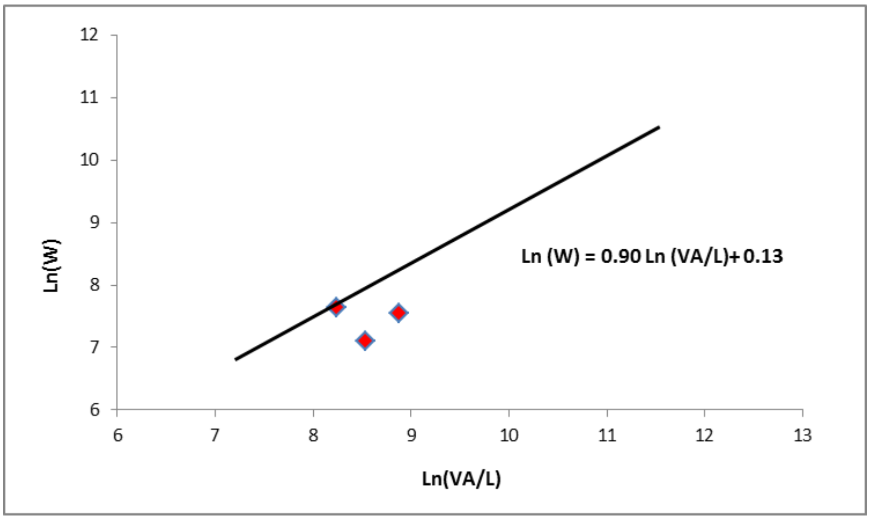

Figure 2.6. Wage and Labor Productivity of Indonesian Manufacturing Sector for Cleaned Data (2006, 2008, and 2009)
Sources: author's calculation.

To obtain a clearer description about data cleaning results the scales of the figure are expanded, where *x*-axis and *y*-axis are both started from zero, as showed in Figure 2.7. The new figure compares wage and labor productivity of Indonesian manufacturing sector for the raw and cleaned data. In this comparison, the positions of Indonesia manufacturing sector from the raw data during 2006 to 2009 are far from the trend line, which is located at the coordinates of Ln (W) = 1 and of Ln (VA/L) = 9.5. It can be assumed that data cleaning and data balancing improve the quality of data set, primarily for the data obtained from a survey. The verification of the result of data cleaning and data balancing can be carried out in various ways by comparing with the existing references. However, considering the difficulties in obtaining qualified references, Figure 2.6 is the best information available to this research.

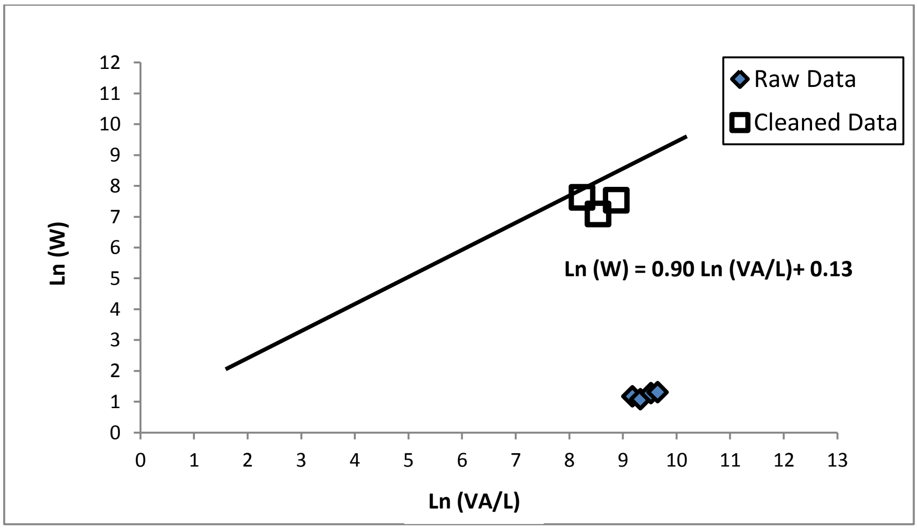

Figure 2.7: Wage and Labor Productivity of Indonesian Manufacturing Sector for Raw Data (2006-2009) and Cleaned Data (2006,2008,2009)
Sources: author calculation.

2.5. Conclusions

This chapter attempts to develop cleaned and balanced datasets of the annual Indonesia manufacturing survey from 1990 to 2010 for analysis purposes. The historical data for manufacturing firms in Indonesia are available from the datasets of annual manufacturing survey conducted by the Indonesian Statistics Agency for medium and large-sized firms that employ at least 20 workers. The datasets contains inaccurate, incomplete, and erroneous data. In addition, because almost all of the variables showed a Zipf distribution, which can be interpreted that most of the raw data comprised unrealistic values. If missing data or one extreme value contained in the data set it will strongly affected the development of a frontier in the data envelop analysis and directional distance function approaches that will be described in the further analysis. The three major findings are summarized below:

a. To overcome the data quality problems, data cleaning and data balancing are conducted. Several subsequent steps including statistical model and coefficient of variant approaches are applied to identify outliers which will be removed because they are considered as unrealistic data. However, it must be noted that the more stringent parameters applied for data cleaning, the less number of observations obtained. Consequently, the stringent cleaned datasets can not represent the whole manufacturing sector.
b. Four periods of manufacturing cleaned and balanced panel datasets are obtained; the period 1 is from 1990 to 1995, the period 2 is from 1998 to 2000, the period 3 is from 2003 to 2006, and the period 4 is from 2008 to 2010. The number of firms in the period 1 and the period 2 are 1,556 each year and the number of firms in the period 3 and the period 4 are 824 each year.
c. Furthermore, to verify the cleaned and balanced panel datasets, compared with the existing references is the significant effort to obtain the same descriptions of a particular variable. Unfortunately the references that also describe the condition of the manufacturing sector in Indonesia are rarely found.

CHAPTER 3: BASELINE ANALYSIS OF PRODUCTIVITY CHANGE WITH AND WITHOUT CONSIDERING CARBON DIOXIDE EMISSIONS

3.1. Introduction

A number of studies have attempted to analyze changes in productivity dealing with multiple outputs including both desirable and undesirable outputs. Data Envelopments Analysis (DEA) is one of the commonly employed approaches measuring productive efficiency, known as non-parametric frontier approach (Coelli 1995). The DEA develops a non-parametric envelopment frontier encompassing all sample data as observed points lie on or below the frontier. The points on the production frontier are considered as the efficient decision-making units (DMUs) and the points below the production frontier are regarded as inefficient DMUs. The efficiency of each observation is measured by calculating the distance between the observed level of production and the production frontier as solutions of a linear programming problem. However, the DEA method does not evaluate the shift in the frontier over time instead the DEA only estimates the performance of DMUs in reference to the best practice frontier in a given year. Malmquist productivity index is then introduced by adjusting the DEA application for multiyear observations alternately between t and t+1 to account for this shift in the frontier and allows measuring changes in productive efficiency over time. The index measuring change in productive efficiency is then regarded as TFP growth, which can be further decomposed into efficiency change (catch-up) and technical progress (frontier-shift).

Several ideas and methods have been proposed to incorporate undesirable outputs into the DEA approaches, while assuming asymmetrical treatments of disposability between desirable outputs and undesirable outputs when production possibilities are defined (Färe et al 1989). Among inputs, desirable outputs and undesirable outputs, efficiency improvement strategy for inefficient DMUs is assumed by holding one or two of them. For example, the input orientation refers to the strategy, where how much inputs can be reduced while holding both desirable and undesirable outputs unchanged is considered (i.e., Färe et al 1996). Some other suggests bads orientation strategy, where how much bads can be reduced while holding inputs and desirable outputs unchanged is considered (i.e., Tyteca 1997). Tyteca (1997) also considers the other strategy, where how much bads and inputs are reduced while holding desirable outputs unchanged. Following the earlier method of simultaneous change in desirable outputs and undesirable outputs following hyperbolic function where fixed inputs are assumed, Chung et al. (1997) proposed an application of directional distant function as well as a productivity index known as Malmquist-Luenberger productivity index. The directional distant function (DDF) defines the strategy where desirable outputs and undesirable outputs are simultaneously changed. While the efficiency measurement with DDF model in a single year is measured as the Luenberger productivity index, alternate application of the DDF models between t and t+1 for measuring Luenberger productivity index in a way that the Malmquist productivity index is constructed, can generate the Malmquist-Luenberger productivity index. Therefore, the Malmquist-Luenberger productivity index can be further decomposed into efficiency change (catch-up) and technical progress (frontier-shift).

Since Chung et al. (1997) has reported empirical results for the Swedish firms in paper and pulp industry with the directional distance function to develop the Malmquist-Luenberger productivity index, the Malmquist-Luenberger productivity index has been widely used in various studies in different levels from micro (firm-level data), industry (sector-level data), to macro (province, national, and regional-level data) for evaluating productivity changes considering undesirable outputs. Färe et al. (2001) employs the Malmquist-Luenberger productivity index to study the US manufacturing sector during the period of 1974-1986 and observed that average annual productivity growth was 3.6% when both desirable and undesirable outputs were considered, whereas it was 1.7% when undesirable outputs were ignored. Comparable finding was presented by Domazlicky and Weber (2004) that employed a similar approach to estimate productivity growth for six US chemical industries for the period of 1988-1993 and concluded that environmental protection measures did not reduce productivity growth. Several other studies, including He et al. (2013) and Piot-Lepetit and Le Moing (2007), have focused on micro-level issues, while Kaneko and Managi (2004), Kumar (2006), Oh (2010), Wu and Wang (2007), and Zhang et al. (2011) have focused on macro-level issues with state and regional level data. Furthermore, the Malmquist-Luenberger productivity index has also been applied to industrial-level issues by Boyd et al. (2002), Heng et al. (2012), and Krautzberger and Wetzel (2012).

TFP growth might increase or decrease when undesirable outputs are considered compared to the TFP measurement without considering undesirable outputs. Table 3.1 compiles several studies that analyze and examine TFP growth with use of the Malmquist-Luenberger productivity index, with various topics, variables, and time periods. The results are discussed with environmental regulation as the key determinant of difference of productivity measurements between with and without undesirable outputs. Chung *et al.* (1997), Kumar (2006), and He *et al.* (2013) confirmed that TFP growths are higher when undesirable outputs are considered under stringent environmental regulations. However, these findings contrasted with Zhang *et al.* (2011) who analyzed the TFP growth in the China's thirty provincial regions, implying that environmental regulations are not very stringent or not strictly enforced.

Further indexing of TFP is proposed by Färe *et al* (1996) for elucidating the net contribution of environmental factors to the productivity growth. Following this concept, Managi and Jena (2008) estimates the ratio of the TFP considering CO_2 emissions to the TFP without considering CO_2 emissions as an environmental productivity measurement, which is referred to as the TFP environment. The increase in TFP environment is considered as the positive achievement of proactive environmental measures.

This chapter reports empirical evidence of changes in the TFP of manufacturing firms in Indonesia over time from 1990 to 2010 with and without considering CO_2 emissions. The comparison of the TFP with and without considering CO_2 emissions across different sectors of the manufacturing industry enables us to identify firm reactions to changes in the prices of oil commodities.

Table 3.1: Selected studies using the Malmquist-Luenberger productivity index to analyze TFP growth

Authors	Topics	Unit of analysis	Period	TFP growth: Without undesirable output	TFP growth: With undesirable output
1. Chung *et al.* (1997)	Swedish pulp and paper industry: - Inputs: labor, wood fiber, energy, capital - Desirable outputs: pulp - Undesirable outputs: BOD, COD, and SS	Firm	1986-1990	-0.3%	3.9%
2.Färe *et al.* (2001)	US State manufacturing air pollution emission; - Inputs: employees, capital - Desirable output: Gross State Product - Undesirable outputs: SOx, CO	Industry	1974-1986	16.9%	36.3%
3.Kumar (2006)	41 developed and developing countries; - Inputs: labor, capital, energy consumption - Desirable output: GDP - Undesirable output: CO_2	Country	1971-1992	-0.002%	0.02%
4.Zhang *et al.* (2011)	China's thirty provincial regions; - Inputs: labor, capital - Desirable output: GDP - Undesirable output: SO_2	Province	1989-2008	4.84%	2.46%
5.He *et al.* (2013)	China’s iron and steel industry: - Inputs: net fixed assets, employees, energy - Desirable output: value added - Undesirable output: waste water, waste gas, solid waste	Firm	2006-2008	19.2%	19.8%

Note:
BOD biochemical oxygen demand, *COD* chemical oxygen demand, *SS* suspended solids, *SOx* sulphur oxide.

3.2. Methodology

The Malmquist-Luenberger productivity index is applied to estimate the productivity change over time with considering CO_2 emissions in manufacturing firms. Because no definite climate change mitigation policies such as carbon regulations have been imposed in Indonesia, an assumption that considering the disposability of CO_2 emissions as undesirable outputs is not a free activity must be made. The productivity without considering CO_2 emissions is also calculated using the Malmquist productivity index. The comparison of the productivity change over time with and without considering CO_2 emissions will define the TFP environment. The sequential steps in developing the approaches are described in this section.

3.2.1. Modeling technology outputs

Let us consider a production process that use a vector of input $x \in \Re_{+}^{N}$, to produce a vector of desirable output and a vector of undesirable output, which are denoted as $y \in \Re_{+}^{M}$ and $b \in \Re_{+}^{I}$, respectively. The relationship between input and output is represented by the technology of its output set:

$$P(x) = \{(y, b): x \text{ can produce } (y, b)\}, x \in \Re_{+}^{N}. \quad (1)$$

The output set is assumed to have the following properties:

a. The first assumption is null-jointness, which implies that a positive amount of desirable output cannot be produced without producing an undesirable output:

$$(y, b) \in P(x) \text{ and } b = 0, \text{ then } y = 0 \quad (2)$$

b. The second assumption is referred to as the weak disposability of desirable and undesirable outputs:

$$(y, b) \in P(x) \text{ and } 0 \leq \theta \leq 1, \text{ then } \theta(y, b) \in P(x) \quad (3)$$

This assumption indicates that it is not possible to reduce undesirable output without reducing desirable output. When firms face an environmental regulation, the disposal of undesirable outputs may not be free.

c. The third assumption is known as the strong disposability of desirable output:

$$(y, b) \in P(x) \text{ and } y' \leq y, \text{ then } (y', b) \in P(x). \quad (4)$$

This assumption suggests that it is possible to reduce desirable outputs without reducing undesirable outputs.

To satisfy the above conditions, following Färe *et al.* (1994) a data enveloping analysis (DEA) model can be formulated. It is assumed that for each time period $t = 1, \ldots, T$, there are $k = 1, \ldots, K$ observations for inputs and outputs $(x^{k,t}, y^{k,t}, b^{k,t})$. By employing DEA and these data, an output set can be constructed that satisfies the above three properties:

$$P^{t}(x^{t}) = \{ (y^{t}, b^{t}): \ \sum_{k=1}^{K} z_{k}^{t} x_{kn}^{t} \leq x_{n}^{t} \qquad n = 1, \ldots, N \quad (5)$$

$$\sum_{k=1}^{K} z_k^t y_{km}^t \geq y_m^t \qquad m = 1, \ldots, M$$

$$\sum_{k=1}^{K} z_k^t b_{ki}^t = b_i^t \qquad i = 1, \ldots, I$$

$$z_k^t \geq 0 \qquad k = 1, \ldots, K \quad \}$$

where z_k^t are non-negative weights assigned to each observation in constructing the production possibility frontier, implies that the production technology exhibits constant returns on scale. Moreover, to integrate the null-jointness of outputs, the following requirements are imposed on the DEA model:

$$\sum_{k=1}^{K} b_{ki}^t > 0 \qquad i = 1, \ldots, I \tag{6}$$

$$\sum_{i=1}^{I} b_{ki}^t > 0 \qquad k = 1, \ldots, K \tag{7}$$

These requirements imply that every undesirable output is produced by some firm *k* and that every firm *k* produces at least one undesirable output.

The distance functions for each observation in the Malmquist index are calculated as the solutions to a linear programming problem. For example, for k',

$$(D_0^t\,(x^{tk'}, y^{tk'}, b^{tk'};\, y^{tk'}))^{-1} = \max\theta, \tag{8}$$

$$\text{s.t. } \sum_{k=1}^{K} z_k^t x_{k'n}^t \leq x_{k'n}^t \qquad n = 1, \ldots, N$$

$$\sum_{k=1}^{K} z_k^t y_{k'm}^t \geq \theta y_{k'm}^t \qquad m = 1, \ldots, M$$

$$\sum_{k=1}^{K} z_k^t b_{k'i}^t = \theta b_{k'i}^t \qquad i = 1, \ldots, I$$

$$z_k^t \geq 0 \qquad k = 1, \ldots, K$$

3.2.2. Directional distance function

The directional distance function allows a firm to increase the production of desirable outputs and simultaneously decrease the production of undesirable outputs with a given of inputs, formally defined as

$$\vec{D}_0\,(x, y, b; 0,\ g_y, -g_b) = \sup\{\beta: (y + \beta g, b - \beta g) \in P(x - 0)\}. \tag{9}$$

where *g* is the vector of directions in which both outputs can be scaled. Following Chung *et al.* (1997), the direction applied is $g = (0, g_y, -g_b)$, implies that desirable outputs are increased, undesirable outputs are decreased, and inputs does not change. Figure 3.1 illustrates the difference between the output distance function and the directional distance function. Suppose that *Oy₃RSTb* is output set, $P^S(x)$, under unregulated technology and does not satisfy the null-jointness assumption while *OERSTb* is output set, $P^W(x)$, under regulated technology and satisfies null-jointness assumption. The direction vector is defined as *g = (0, y, - b)*. The output distance function scales point A to point R on the boundary based on an output vector, indicates that desirable outputs increase from y_1 to y_3. In contrast, the directional distance function scales point A to point A' on the boundary in the direction of increasing desirable outputs from y_1 to y_2 and decreasing undesirable outputs from b_2 to b_1. At point A', the output vector is $(y + \beta^* g_y, b - \beta^* g_b)$, where $\beta^* = \vec{D}_0(x, y, b\,;\, 0, g_y - g_b)$, with $\beta^* g_y$ being added to the desirable outputs and $\beta^* g_b$ being subtracted from the undesirable outputs.

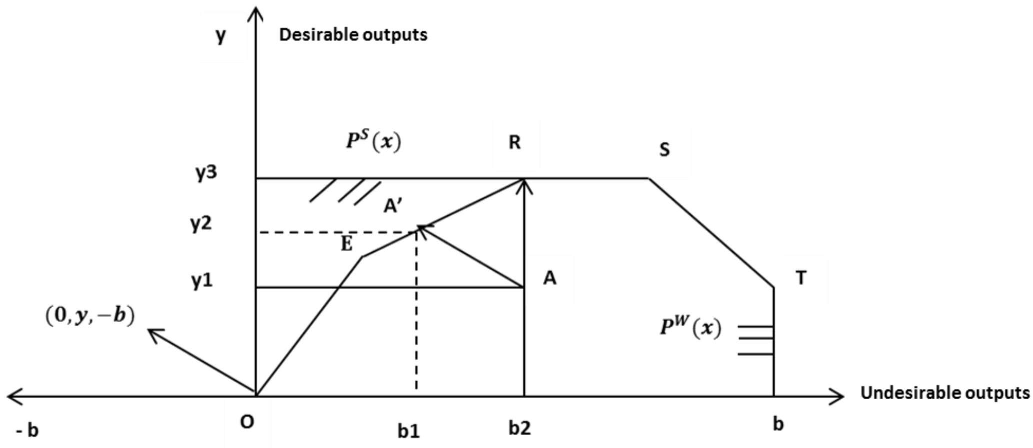

Figure 3.1: Output distance function and directional distance function

3.2.3. The Malmquist-Luenberger productivity index

To define the Malmquist-Luenberger productivity index, directional distance functions are used with the direction of a vector as *g = (0, y, -b)* and the technology of periods *t* and *t+1* as the reference technologies. Following Chung *et al.* (1997), the index between the period *t* and *t+1* is expressed as:

$$ML_t^{t+1} = (ML^t \times ML^{t+1})^{1/2} \tag{10}$$

Where ML^t and ML^{t+1} are the Malmquist-Luenberger productivity indices with the technology of the periods t and t+1 as the reference technologies, respectively. Both indices can be described as the following:

$$ML^t = \frac{\left[1 + \vec{D}_0^t\left(x^t, y^t, b^t; y^t, -b^t\right)\right]}{\left[1 + \vec{D}_0^t\left(x^{t+1}, y^{t+1}, b^{t+1}; y^{t+1}, -b^{t+1}\right)\right]} \tag{11}$$

$$ML^{t+1} = \frac{\left[1 + \vec{D}_0^{t+1}\left(x^t, y^t, b^t; y^t, -b^t\right)\right]}{\left[1 + \vec{D}_0^{t+1}\left(x^{t+1}, y^{t+1}, b^{t+1}; y^{t+1}, -b^{t+1}\right)\right]} \tag{12}$$

The Malmquist-Luenberger productivity index can be decomposed into an index of efficiency change (MLEFFCH) and an index of technological progress (MLTECH)

$$ML_t^{t+1} = MLEFFCH_t^{t+1} \times MLTECH_t^{t+1} \quad (13)$$

where

$$MLEFFCH_t^{t+1} = \frac{[1+\vec{D}_0^t(x^t, y^t, b^t; y^t, -b^t)]}{[1+\vec{D}_0^{t+1}(x^{t+1}, y^{t+1}, b^{t+1}; y^{t+1}, -b^{t+1})]} \quad (14)$$

and

$$MLTECH_t^{t+1} = \left\{\frac{[1+\vec{D}_0^{t+1}(x^t, y^t, b^t; y^t, -b^t)][1+\vec{D}_0^{t+1}(x^{t+1}, y^{t+1}, b^{t+1}; y^{t+1}, -b^{t+1})]}{[1+\vec{D}_0^t(x^t, y^t, b^t; y^t, -b^t)][1+\vec{D}_0^t(x^{t+1}, y^{t+1}, b^{t+1}; y^{t+1}, -b^{t+1})]}\right\}^{1/2} \quad (15)$$

The values that are greater than one for ML_t^{t+1}, EFFCH_t^{t+1} and TECH_t^{t+1}indicate the improvements in productivity, efficiency, and technology, respectively, while the values less than one indicate that productivity, efficiency, and technology are in decline. More specifically, the improvement of EFFCH_t^{t+1} from Eq. (14) implies that the firm is closer to the frontier in the period t+1 than it was in the period t as measured in terms of a proportional increase in the desirable outputs and a decrease in the undesirable outputs. The improvement of TECH_t^{t+1} from Eq. (15) suggests that a firm shift of the frontier in this direction that produces more desirable outputs and fewer undesirable outputs.

Linear programming (LP) is used to compute directional distance functions. Four LPs have to be solved for each observation. Two LPs use the observations and technologies for the period t or t+1, and two LPs use mixed period technologies calculated from the period t with the observations of t+1 and from the period t+1 with the observations of t. The directional distance function for observation k in the period t using period t technology can be solved using Eq. (16). For observation k in the period t+1 using period t+1 technology, the time superscript t in Eq. (16) for both sides have to be changed to t+1.

$$\vec{D}_0^t\,(x^t, y^t, b^t; y^t, -b^t) = \max \beta, \quad (16)$$

8s.t. $\sum_{k=1}^{K} z_k^t x_{kn}^t \leq x_{k'n}^t \qquad n = 1, \ldots, N \qquad$ (i)

$\sum_{k=1}^{K} z_k^t y_{km}^t \geq (1+\beta)\, y_{k'm}^t \qquad m = 1, \ldots, M \qquad$ (ii)

$\sum_{k=1}^{K} z_k^t b_{ki}^t = (1-\beta)\, b_{k'i}^t \qquad i = 1, \ldots, I \qquad$ (iii)

$z_k^t \geq 0 \qquad k = 1, \ldots, K \qquad$ (iv)

Similarly, for mixed periods, the directional distance function for observation k in the period t using period t+1 technology can be solved using Eq. (17). For observation k in the period t+1 using period t technology, the time superscripts on the left-hand side of the constraints in Eq. (18) are t+1 and vice versa: the time superscripts on the right-hand side of the constraints are t.

$$\vec{D}_0^t\,(x^{k't+1},\, y^{k't+1},\, b^{k't+1};\, y^{k't+1}, -\, b^{k't+1}) = \max \beta, \tag{17}$$

s.t. $\sum_{k=1}^{K} z_k^t x_{kn}^t \leq x_{k'n}^{t+1}$ $\quad n = 1, \ldots, N$ (i)

$\sum_{k=1}^{K} z_k^t y_{km}^t \geq (1+\beta)\, y_{k'm}^{t+1},$ $\quad m = 1, \ldots, M$ (ii)

$\sum_{k=1}^{K} z_k^t b_{ki}^t = (1-\beta) b_{k'i}^{t+1},$ $\quad i = 1, \ldots, I$ (iii)

$z_k^t \geq 0$ $\quad k = 1, \ldots, K$ (iv)

The Malmquist productivity index is constructed in a similar way to the Malmquist-Luenberger productivity index. The Malmquist productivity index also can be decomposed into two components: the first component is MEFFCH, measures the efficiency change between the two periods and the second component is MTECH, measures the technical change between the two periods.

$$M_t^{t+1} = MEFFCH_t^{t+1} \times MTECH_t^{t+1} \tag{18}$$

where

$$MEFFCH_t^{t+1} = \frac{\left[D_0^t(x^t, y^t, b^t;\, y^t)\right]}{\left[D_0^{t+1}(x^{t+1}, y^{t+1}, b^{t+1};\, y^{t+1})\right]} \tag{19}$$

and

$$MTECH_t^{t+1} = \left\{\frac{\left[D_0^{t+1}(x^t, y^t, b^t; y^t)\right]\left[D_0^{t+1}(x^{t+1}, y^{t+1}, b^{t+1};\, y^{t+1})\right]}{\left[D_0^t(x^t, y^t, b^t;\, y^t)\right]\left[D_0^t(x^{t+1}, y^{t+1}, b^{t+1}; y^{t+1})\right]}\right\}^{1/2} \tag{20}$$

3.3. Data

The annual survey data are classified into 23 different sectors based on ISIC (International Standard Industrial Classification) Revision 3. For the present analysis, Armundito and Kaneko (2014) have developed a cleaned panel dataset to address data quality problems. First removing zero and missing values of particular variables and then applying several consecutive steps including statistical modeling, coefficient of variant approaches, and data balancing, a large number of observations have been removed.

The datasets used for the analysis in this chapter are obtained in the chapter 2. Armundito and Kaneko (2014) have developed a cleaned panel dataset to address data quality problems resulting the four periods of cleaned and balanced panel datasets are obtained: 1990-1995, 1998-2000, 2003-2006, and 2008-2010. The number of observations compared to the initial raw data has shrunk to approximately 4% in the final result. Considering the number of firms for each sector, only sectors that consist of more than 15 firms are selected for further analysis. Therefore, only 18 out of the 23 sectors are employed for the analysis. To avoid price changes over time, GDP deflators are applied to convert these series of datasets into constant prices based on the year 2000. Additionally, to convert the currency from Indonesia's rupiah to the US dollar, the currency rate for the year 2000 is applied.

Data on quantities of inputs, desirable outputs and undesirable outputs are required to estimate productivity change over time using the Malmquist productivity index and the Malmquist-Luenberger productivity index. All firms are assumed to share the same production processes, characterized by the production of one desirable output and one undesirable output. Value added to manufacturing production and CO_2 emissions are considered to be the proxies for desirable (y) and undesirable (b) outputs, whereas capital ($x1$), labor wages ($x2$), and raw materials ($x3$) are considered as inputs. The value added v is measured as the difference between the total sales revenue of a firm and the total cost of components, materials, and services in millions of US dollars. Capital k is measured by the replacement value of fixed assets in thousands of US dollars. Labor wage l is measured as the total salary and other incentives for all workers, including production workers and other workers, in thousands of US dollars. Raw material m is measured as the total materials used to produce a unit of output in thousands of US dollars. Finally, both direct and indirect CO_2 emissions CO_2 are measured as the most common type of gas emitted from the burning of fossil fuels used in manufacturing firms in tons CO_2 equivalent. Direct and indirect CO_2 emissions are calculated from fuel combustion in the manufacturing sector based on the Intergovernmental Panel on Climate Change (IPCC) guidelines (Eggleston et al. 2006). Further, Indonesia's currency rate has devalued since 1998 and a high inflation rate occurred in 1998, resulting in a monetary value for some variables in periods 3 and 4 that are smaller than the monetary value in periods 1 and 2. The descriptive statistics of the variables used for this chapter is shown in Table 3.2.

To enable understanding in what situations environmental productivity as TFP environment can be applied, Table 3.3 presents the terms and conditions of environmental productivity trend as energy price either increase or decrease. When environmental productivity increase, the situation that can be described is the increase rate of productivity growth occurred simultaneously with the increased level of pollution abatement. As the energy price increase and environmental productivity also increase, firms successfully improve productivity and manage the impact of energy price through fuel switching, energy saving, and investment for new technologies. Thereafter, as the energy price is constant and environmental productivity increase, firms successfully improve productivity and do not need to manage the impact of energy price through fuel change. Conversely, when environmental productivity decreases, it can be interpreted that firm simultaneously experience in the decreasing rates of productivity growth with the decreasing levels of pollution abatement. As the energy price increase and environmental productivity decrease, firms fail to improve productivity and manage the impact of energy price. It might be related to the high energy intensity, no investment for new technologies, and firms might pay the cost of energy price increase. Similarly, as the energy price is constant and environmental productivity also decrease, firms fail to improve productivity and do not need to manage the impact of energy price through fuel change.

Table 3.2: Descriptive statistics of the variables used for the chapter 3

Variable code	Description	Unit	Mean	Standard Deviation
Period of 1990-1995				
k	Capital	Thousands of US dollar	450.80	1691.45
l	Labor wage	Thousands of US dollar	263.94	873.13
m	Raw Material	Thousands of US dollar	607.63	2774.68
v	Value added	Thousands of US dollar	317.11	1370.26
CO_2	CO_2 emissions	Tons CO_2 equivalent	584.88	2113.26
No. of observations 9336				
Period of 1998-2000				
k	Capital	Thousands of US dollar	352.88	1530.00
l	Labor wage	Thousands of US dollar	86.35	404.82
m	Raw Material	Thousands of US dollar	596.34	3302.94
v	Value added	Thousands of US dollar	381.29	3211.77
CO_2	CO_2 emissions	Tons CO_2 equivalent	666.49	2229.87
No. of observations 4668				
Period of 2003-2006				
k	Capital	Thousands of US dollar	127.14	408.26
l	Labor wage	Thousands of US dollar	86.27	216.78
m	Raw Material	Thousands of US dollar	236.26	1489.42
v	Value added	Thousands of US dollar	119.65	583.46
CO_2	CO_2 emissions	Tons CO_2 equivalent	282.02	1434.19
No. of observations 3296				
Period of 2008-2010				
k	Capital	Thousands of US dollar	120.00	441.86
l	Labor wage	Thousands of US dollar	84.76	253.55
m	Raw Material	Thousands of US dollar	298.67	1924.40
v	Value added	Thousands of US dollar	119.50	385.95
CO_2	CO_2 emissions	Tons CO_2 equivalent	243.63	1054.26
No. of observations 2472				

Table 3.3: Terms and conditions of environmental productivity analysis

Environmental Productivity		Energy price increase		Energy price constant	
Increase/ decrease?	Situation	Condition	Measures	Condition	Measures
Increase	Increased rates of productivity growth occurred simultaneously with increased levels of pollution abatement	Firm successfully improve productivity and manage the impact of energy price	Fuel switching, energy saving, invest for new technology	Firm successfully improve productivity and does not need to manage the impact of energy price	Efficiency and technology improvement
Decrease	Simultaneously experienced decreased rates of productivity growth with decreased levels of pollution abatement	Firm fails to improve productivity and manage the impact of energy price	Energy intensity is high, no investment for new technology, pay the cost	Firm fails to improve productivity and does not need to manage the impact of energy price	Efficiency and technology do not improve

3.4. Results and Discussions

Under two assumptions of disposability of undesirable outputs the Malmquist productivity index is applied to estimate the TFP without CO_2 emissions over time and the Malmquist-Luenberger productivity index is employed to measure the TFP with CO_2 emissions over time. A summary of the estimation results based on the average annual basis for the period 1 from 1990 to 1995 is presented in Table 3.4. Of the measurements without CO_2 emissions, the average productivity index score is 1.0014, implies that the annual TFP without CO_2 emissions over time for the manufacturing sector increase by 0.14% over the entire period. This annual TFP score is obtained as the weight mean of all sector's TFP score as the number of firms is different of each sector. On average, this growth is due to the increase in efficiency change by 0.97% and the decrease in technological progress by 0.01%. Based on the sector-by-sector analysis, considerable variation across sectors is observed. The sector that exhibits the highest productivity growth is motor vehicle, trailers and semi-trailers (1.64%), and the sector with the lowest growth is fabricated metal product and equipment (-0.07%). Furthermore, for the measurement with CO_2 emissions the weighted mean of TFP score is 1.0198, indicates that the annual TFP with CO_2 emissions over time for the manufacturing sector increases by 1.98% over the entire period. This increasing growth is considerably higher than the growth of TFP without CO_2 emissions. This average TFP with CO_2 emissions over time is due to an increase in efficiency change (7.69%) and technological progress (5.87%). The sector that shows the highest productivity growth is others non-metallic mineral product (11.1%) and the sector with the lowest growth is chemicals and chemical product (-2.7%). At the same time, the average TFP environment score for the period 1 is 1.0184, suggested that environmental productivity increases by 1.84% annually.

Table 3.4: Average annual changes in productivity growth and its components for the period 1

Sector	*TFP growth without CO_2 emissions*			*TFP growth with CO_2 emissions*			*TFP Env.*
	M	*EFFCH*	*TECH*	*ML*	*EFFCH*	*TECH*	
Food products and beverages	1.0041	0.9990	1.0080	1.0303	1.1903	1.5534	1.0261
Tobacco	1.0102	1.0431	0.9722	1.0199	1.1650	0.9346	1.0096
Textiles	1.0073	1.0259	0.9902	1.0052	1.1220	1.0507	0.9980
Wearing apparel	0.9985	0.9886	1.0115	1.0174	1.0305	1.0115	1.0189
Tanning and dressing of leather	0.9907	1.0465	0.9520	0.9402	1.1152	0.8797	0.9491
Wood and products of wood and plaiting	1.0027	1.0118	0.9915	0.9783	1.0507	0.9713	0.9757
Paper and paper products	1.0094	1.0205	0.9947	0.9915	1.0964	0.9463	0.9823
Publishing, printing and reproduction	0.9943	0.9931	1.0020	1.0154	1.1494	0.9776	1.0212
Chemicals and chemical products	1.0053	0.9982	1.0106	0.9730	0.9372	1.1142	0.9679
Rubber and plastics products	1.0050	0.9999	1.0099	0.9797	1.0146	1.0938	0.9748
Others non-metallic mineral products	0.9916	1.0070	0.9871	1.1110	1.1159	1.0953	1.1205
Basic metals	1.0318	1.0346	0.9980	1.0165	1.0182	1.0433	0.9852
Fabricated metal products and equipment	0.9903	1.0041	1.0031	0.9924	1.0795	1.0858	1.0021
Machinery and equipment	1.0017	1.0360	0.9739	1.0327	1.2134	0.9832	1.0310
Electrical machinery and apparatus.	1.0070	0.9630	1.0548	1.0065	0.9444	1.1185	0.9995
Motor vehicle, trailers and semi-trailers	1.0164	1.0005	1.0195	1.0105	0.9965	1.0517	0.9943
Other transport equipment	1.0101	1.0124	1.0113	1.0619	1.1018	1.1400	1.0513
Furniture and manufacturing	0.9923	0.9898	1.0074	0.9971	1.0436	1.0061	1.0049
Weighted Mean	1.0014	1.0097	0.9999	1.0198	1.0769	1.0587	1.0184

The productivity measurement for the period 2 from 1998 to 2000 is presented in Table 3.5. The average of the weight mean productivity index score is 0.9933, indicates that the annual TFP without CO_2 emissions over time for the manufacturing sector dropped by 0.67% over the entire period. The growth is triggered by the increase in efficiency change (1.58%) and the decrease in technological progress (1.94%). Based on the sector-by-sector analysis, the sector that shows the highest productivity growth is textiles (0.49%), and the sector with the lowest productivity growth is paper and paper product (-3.04%). Whereas for the measurement with CO_2 emissions, the weighted mean of TFP score is 1.0652, implies that the annual TFP with CO_2 emissions over time increases by 6.52% over the entire period. This increasing growth is also significantly higher than the growth of TFP without CO_2 emissions. This remarkable growth is caused by the increase in efficiency (8.06%) and technological progress (5.68%). The sector that demonstrates the best performance is rubber and plastics product with the productivity growth of 20.47%, and the sector with the worst performance is paper and paper product with the decrease of productivity by 2.22%. Meanwhile, the TFP environment score for the period 2 is 1.0724, suggests that environmental productivity increases by 7.24% annually.

Table 3.5: Average annual changes in productivity growth and its components for the period 2

Sector	*TFP growth without CO_2 emissions*			*TFP growth with CO_2 emissions*			*TFP Env.*
	M	*EFFCH*	*TECH*	*ML*	*EFFCH*	*TECH*	
Food products and beverages	0.9933	1.0163	0.9774	1.0603	1.2147	0.8838	1.0674
Tobacco	0.9979	1.0054	0.9923	1.0129	1.0670	0.9754	1.0150
Textiles	1.0049	1.0105	0.9965	1.0448	1.1088	0.9967	1.0397
Wearing apparel	0.9985	1.0236	0.9797	1.1001	1.2215	0.9992	1.1017
Tanning and dressing of leather	1.0002	0.9941	1.0108	1.0559	0.9083	1.4272	1.0557
Wood and products of wood and plaiting	0.9953	0.9746	1.0243	0.9778	0.7279	1.5209	0.9824
Paper and paper products	0.9696	0.9944	0.9825	0.9286	0.8073	1.2034	0.9577
Publishing, printing and reproduction	0.9754	1.0192	0.9641	0.9674	0.9221	1.0727	0.9918
Chemicals and chemical products	0.9947	1.0293	0.9703	1.1403	1.0646	1.0855	1.1464
Rubber and plastics products	0.9941	1.0109	0.9875	1.2047	1.1510	1.0871	1.2118
Others non-metallic mineral products	0.9952	1.0039	0.9933	1.1013	1.1688	0.9872	1.1066
Basic metals	0.9939	1.0757	0.9339	1.0869	1.4516	0.8474	1.0936
Fabricated metal products and equipment	0.9825	1.1075	0.8949	1.0471	1.5578	0.7498	1.0657
Machinery and equipment	0.9774	1.0396	0.9440	0.9954	1.1737	0.9150	1.0184
Electrical machinery and apparatus.	0.9795	0.9774	1.0043	1.0224	0.9711	1.0791	1.0439
Motor vehicle, trailers and semi-trailers	0.9903	0.9726	1.0199	1.0516	0.9376	1.1286	1.0619
Other transport equipment	1.0010	1.0067	0.9972	1.0212	0.9297	1.1017	1.0202
Furniture and manufacturing	0.9978	1.0220	0.9784	1.0091	1.0678	0.9622	1.0113
Weighted Mean	0.9933	1.0158	0.9806	1.0652	1.0806	1.0568	1.0724

The productivity measurement for the period 3 from 2003-2006 is presented in Table 3.6 as the average TFP without CO_2 emissions score is 1.0050. The average TFP score indicate that the annual TFP without CO_2 emissions over time increases by 0.50% over the entire period. The increase of efficiency change (0.49%) and technological progress (1.55%) are the sources of this TFP growth. Tobacco is the sector that shows the highest productivity growth (4.45%) whereas textiles sector is the sector that exhibits the lowest productivity growth (1.71%). At the same time, the weighted mean score of TFP with CO_2 emissions is 1.0036, implies that the annual TFP with CO_2 emissions over time increased by 0.36% over the entire period. The increase in efficiency change (7.18%) and technological progress (7.57%) are the engine of this TPF growth. The sector that shows the highest productivity growth is wood and product of wood and plaiting (11.37%) and the sector with the lowest growth is chemicals and chemical product (-19.67%). On average, the TFP environment score for the period 3 is 0.9986, suggested that environmental productivity decrease by 0.14% annually.

Table 3.6: Average annual changes in productivity growth and its components for the period 3

Sector	***TFP growth without CO_2 emissions***			***TFP growth with CO_2 emissions***			***TFP Env.***
	M	***EFFCH***	***TECH***	***ML***	***EFFCH***	***TECH***	
Food products and beverages	0.9991	0.9724	1.0286	1.0100	0.9201	1.1757	1.0109
Tobacco	1.0445	1.0883	0.9698	1.1102	1.7478	0.8695	1.0629
Textiles	0.9829	0.9917	0.9940	0.9698	0.9885	1.0951	0.9867
Wearing apparel	0.9956	1.0288	0.9701	1.0064	1.3685	0.9862	1.0109
Tanning and dressing of leather	1.0438	1.0262	1.0169	1.0460	1.0516	1.0048	1.0021
Wood and products of wood and plaiting	1.0098	0.9497	1.0813	1.1137	1.0586	1.2980	1.1029
Paper and paper products	1.0042	1.0073	0.9967	1.0074	1.0321	0.9822	1.0032
Publishing, printing and reproduction	1.0042	1.0073	0.9967	1.0074	1.0321	0.9822	1.0032
Chemicals and chemical products	0.9906	0.9726	1.0226	0.8033	0.7201	1.2626	0.8109
Rubber and plastics products	1.0140	1.0428	0.9764	0.9827	1.4561	0.6780	0.9691
Others non-metallic mineral products	1.0001	0.9653	1.0385	0.9714	0.8091	1.2040	0.9712
Basic metals	1.0370	0.9432	1.1123	1.0719	0.9100	1.2206	1.0336
Fabricated metal products and equipment	1.0345	0.9963	1.0450	0.9685	0.8542	1.2306	0.9362
Machinery and equipment	1.0229	0.9871	1.0360	1.0435	0.9220	1.1443	1.0201
Electrical machinery and apparatus.	1.0443	1.0774	0.9854	1.0548	1.2721	0.9612	1.0100
Motor vehicle, trailers and semi-trailers	1.0280	1.0108	1.0176	1.0367	1.0575	1.0440	1.0084
Other transport equipment	1.0055	1.0374	0.9726	1.0418	1.0333	1.0084	1.0361
Furniture and manufacturing	1.0003	0.9836	1.0185	1.0160	1.0583	1.2153	1.0157
Weighted Mean	1.0050	1.0049	1.0155	1.0036	1.0718	1.0757	0.9986

The productivity measurement for the period 4 from 2008-2010 is shown in Table 3.7. The average of the weight mean productivity index score is 1.0311, implies that the annual TFP without CO_2 emissions over time increases by 3.11% over the entire period. The growth is due to the increase in efficiency change by 0.33% and in technological progress by 3.65%. The sector with the highest productivity growth is electricityal machinery and apparatus. (6.72%), and the sector with the lowest growth is tanning and dressing of leather (0.06%). Furthermore, the measurement of TFP with CO_2 emissions results that the weighted mean of TFP score is 1.0523, suggests that the annual TFP with CO_2 emissions over time increases by 5.23% over the entire period. The growth is generated by the increase in efficiency change (1.77%) and technological progress (11.83%). The sector that shows the highest productivity growth is basic metals (14.73%) and the sector that presents the lowest productivity growth is tobacco (0.89%). The TFP environment score for the period 4is 1.0206, implies that environmental productivity increases by 2.06% annually.

Table 3.7: Average annual changes in productivity growth and its components for the period 4

Sector	*TFP growth without CO_2 emissions*			*TFP growth with CO_2 emissions*			*TFP Env.*
	M	*EFFCH*	*TECH*	*ML*	*EFFCH*	*TECH*	
Food products and beverages	1.0167	0.9672	1.0524	1.0450	1.0338	1.1743	1.0279
Tobacco	1.0178	0.9742	1.0454	0.9911	0.9483	1.1034	0.9738
Textiles	1.0209	0.9432	1.0853	1.0482	0.8590	1.2842	1.0267
Wearing apparel	1.0257	1.0027	1.0283	1.0506	1.0228	1.0659	1.0243
Tanning and dressing of leather	1.0006	0.9825	1.0198	1.0433	1.0420	1.0203	1.0426
Wood and products of wood and plaiting	1.0106	1.0217	0.9903	1.0437	1.2793	0.8615	1.0327
Paper and paper products	1.0302	0.9352	1.1086	1.1013	0.9327	1.2866	1.0690
Publishing, printing and reproduction	1.0368	0.9064	1.1480	1.1205	0.8171	1.4283	1.0807
Chemicals and chemical products	1.0622	1.0002	1.0675	1.0875	0.9524	1.1803	1.0238
Rubber and plastics products	1.0408	1.0099	1.0370	1.0543	1.0127	1.0979	1.0130
Others non-metallic mineral products	1.0345	1.0613	0.9794	1.0499	1.1142	0.9681	1.0148
Basic metals	1.0333	1.0542	0.9798	1.1473	1.0788	1.0463	1.1103
Fabricated metal products and equipment	1.0277	0.9560	1.0801	1.0571	0.7765	1.4569	1.0286
Machinery and equipment	1.0378	1.0756	0.9841	1.0484	1.1844	1.0512	1.0102
Electrical machinery and apparatus.	1.0672	1.0750	0.9991	1.0582	1.0682	1.0525	0.9916
Motor vehicle, trailers and semi-trailers	1.0475	1.0374	1.0121	1.0634	1.0838	1.0027	1.0152
Other transport equipment	1.0349	1.0461	0.9904	1.0565	1.1154	0.9563	1.0209
Furniture and manufacturing	1.0583	1.0111	1.0492	1.0627	0.9977	1.0929	1.0042
Weighted Mean	1.0311	1.0033	1.0365	1.0523	1.0177	1.1183	1.0206

The comparisons between the entire periods enable to evaluate the impact of policy implemented or economic circumstances as contextual background of this analysis on manufacturing performance. The export-led industrialization policy implemented in the period 1 resulted in the highest level of the GDP growth rate and the growth rate of manufacturing sector, and also positively influence on the growth of the TFP with CO_2 emissions. In this period the growth of the TFP with CO_2 emissions over time was tenfold than the growth of the TFP without CO_2 emissions. The TFP environment over time in the period 1 also shows positive moderate growth.

Considered as immediate post economic crisis period and the beginning of democratic reforms during the period 2, the growth of the TFP with CO_2 emissions over time was the highest. At the same period, the decline of average GDP growth and the growth rate of manufacturing sector from the previous period has resulted the negative growth of TFP without CO_2 emissions. Meanwhile, the TFP environment over time in the period 2 also exhibited the highest growth, even surpassing the TPF with CO_2 emissions over time. The remarkable achievement of environmental measure in this period is consistent with the notable increase of the manufactures exports' share to merchandise export and the share of high-technology exports to manufactured exports.

Period 3 is regarded as a period of politically significant transitional moments, and the government of Indonesia began to remove subsidies for oil commodities. During the period 3, the growth of TFP with CO_2 emissions over time dropped sharply compared with the previous period. Several sectors, particularly for the high energy-intensive sectors, are negatively affected by the increase in prices of oil commodities. The TPF with CO_2 emissions over time of the high energy-intensive sectors: food and beverages; textiles and its related industry; chemicals and chemical product; rubber and plastics product; others non-metallic mineral product sectors present considerable decline in this period. Only basics metal sector that shows insignificant decrease. The effort in reducing CO_2 emissions seems to have further pressures due to the increase in prices of oil commodities. A similarly worsened performance was also experienced by the TFP environment over time as the growth dramatically declined to reach a negative level. In contrast, TFP without CO_2 emissions over time indicated positive growth. Almost all of the sectors show a notable increase of this TPF, except for textiles and wearing apparel sectors. Despite the increase in energy costs, the growth rate in the manufacturing sector increased from the previous period. The possible conditions and measures taken by manufacturing sectors in this period are energy intensity is high, no investment for new clean technology, or firms pay the increase of energy cost.

Furthermore in the period 4 when the global financial crisis took place, the growth of all TPF over time demonstrated remarkable increase compared with the period 3. Compared to the previous three periods, the growth of TFP without CO_2 emissions over time was the highest in this period even though the level of growth was still lower than the TFP without CO_2 emissions over time. At the same time, the TFP environment over time has also grown at the level as equal as to that in the period 1. The possible conditions and measures taken by manufacturing sectors in this period are fuel switching, energy saving, invest for new technology. The economic and political policies implemented by the government during this period were able to address the adverse effects of the global financial crisis in Indonesia, particularly in the manufacturing sector. Overall, it is observed that the TFP with CO_2 emissions over time has grown faster than the TFP without CO_2 emissions for the period 1, the period 2, and the period 4. The faster growth of the TPF with CO_2 emissions over time is consistent with Domazlicky and Weber (2004), Färe *et al.* (2001), and Kumar (2006) that suggested when accounting for changes in pollutions as undesirable outputs the average productivity growth is higher than the growth ignoring pollutions. The TFP with CO_2 emissions over time is lower than the TFP without CO_2 emissions was observed in the period 3. However, in general, the manufacturing sector showed the best performance in the period 4, characterized by the positive growth level for all TFPs, including the positive growth level of its component; efficiency change and technological progress. Efficiency change is the source of productivity growth in the period 1 and the period 2 whereas technical progress is the basis of productivity growth in the period 3 and the period 4. The higher productivity growth with CO_2 emissions provides a clear suggestion to policy makers that environmental damages can be considered in economic and manufacturing developments.

Further, considering the potential impact of carbon tax implementation on manufacturing sector in Indonesia, several sectors are indicated has been prepared for the implementation. Table 3.8 shows several sectors that ready for carbon regulations based on the positive growth of TFP environment in the period 3 and period 4 after the increasing price of oil commodities. In particular, eleven outstanding sectors have been noted to be the best performing sectors which show the positive response to the changes in prices of oil commodities by maintaining the positive growth of TFP environment. Even though in general the increase price of oil commodities have greatly affected the high energy-intensive sectors, however, food products and beverages, paper and paper products, and basic metals demonstrate that the impact has been well managed.

Table 3.8: Sectors that have been ready for carbon tax implementation

No	Sector	TFP Environment	
		Period 3	Period 4
1	Food products and beverages	1.0109	1.0279
2	Wearing apparel	1.0109	1.0243
3	Tanning and dressing of leather	1.0021	1.0426
4	Wood and products of wood and plaiting	1.1029	1.0327
5	Paper and paper products	1.0032	1.069
6	Publishing, printing and reproduction	1.0032	1.0807
7	Basic metals	1.0336	1.1103
8	Machinery and equipment	1.0201	1.0102
9	Motor vehicle, trailers and semi-trailers	1.0084	1.0152
10	Other transport equipment	1.0361	1.0209
11	Furniture and manufacturing	1.0157	1.0042

3.5. Conclusion

The paper provides a baseline analysis of TFP growth over time with and without considering CO_2 emissions from 1990 to 2000. Regarding the current data problems and the missing of key variables data, the cleaned and balanced panel datasets are constructed only for four periods: 1990-1995, 1998-2000, 2003-2006, and 2008-2010. The employing of the four periods of the cleaned and balanced panel datasets enable to evaluate the impact of policy implemented or economic circumstance during each period. An assumption that undesirable outputs are weakly disposable is taken because Indonesia has not implemented carbon regulations. The Malmquist productivity index is employed to estimate the TFP without CO_2 emissions over time and the Malmquist-Luenberger productivity index is applied to estimate the TFP with CO_2 emissions over time. The influent of energy factors on environmental productivity changes over time is also investigated.

The main findings of this paper can be summarized as follows. First, on average, the TFP with CO_2 emissions over time has grown faster than the TFP without CO_2 emissions particularly for the period 1, the period 2, and the period 4. Second, efficiency change is the source of productivity growth in the period 1 and the period 2 whereas technical progress is the basis of productivity growth in the period 3 and the period 4. Third, the increase price of oil commodities might affect environmental productivity, in particular for the high energy-intensive sectors. Fourth, eleven sectors are identified to be ready for the implementation of carbon tax based on the positive growth of TFP environment in the period 3 and period 4 after the increasing price of oil commodities.

Several constructive policy designs can be derived from these findings. The results suggest that CO_2 emissions as undesirable outputs can be considered in measuring manufacturing sector's productivity growth as a response to the climate change mitigation policy. At the same time, technological improvement is expected to be a major concern for the manufacturing firms' long-term strategic planning after the changes in prices of oil commodities.

CHAPTER 4: ESTIMATION OF AVERAGE CARBON ABATEMENT COST

4.1. Introduction

Many processes and products consume significant quantities of fossil fuel due to the wide variety of raw materials and treatment options available, which lead to a great variety of end products. Manufacturing sector has energy requirements throughout all stages of the production process. Thus, energy consumption becomes a central part in many key stages of the process. However, manufacturing sector plays an important role to Indonesian development, which is still considered as the engine of economic growth. The share of manufacturing sector value added for national gross domestic product is expected to increase to reach a remarkable target at the point of 40% in the future. To achieve this significant growth, manufacturing sector has to improve its performance by increasing productivity and efficiency. While improving its performance, reducing its CO_2 emissions as a part of global measure to cope with climate change mitigations policy is another significant challenge for manufacturing sector.

The objective of this chapter is to analyze the relative efficiency of manufacturing sector and estimate financial burden of manufacturing sector in reducing CO_2 emissions. We obtain efficiency indices that serve to measure the impact on firm performance in two different scenarios related to efficiency improvement aimed to reduce the production of CO_2 emissions. The impact of clean technological improvement or energy saving may be reflected by marginal abatement cost as forgone profit of a manufacturing firm. The analysis is focused on the comparison of marginal abatement cost between four different periods.

This chapter also applied an assumption, as Mandal and Madheswaran (2010) suggested, that it can ideally consider of several environmentally hazardous elements, generated by manufacturing sector, as a vector of different kinds of solid, liquid and air pollutions with CO_2 being the most important element of it. Therefore, under the ceteris paribus condition, the increase of CO_2 emissions must increase in environmental degradation. In absence of any information about the other relevant component, as it can be easily understood, ceteris paribus is not an invalid assumption in this regard. So, in our opinion, reducing CO_2 emission could be termed as environmental efficiency.

4.2. Methodological Approach

4.2.1. Directional distance function

A production process that use a vector of input $x = (x_1, \dots, x_N) \in \Re^N_+$, to produce a vector of desirable output $y = (y_1, \dots, y_M) \in \Re^M_+$ and a vector of undesirable output $b = (b_1, \dots, b_I) \in \Re^I_+$, need to be considered. All technologically feasible relationships between input and output are described by the technology of its output set

$$P(x) = \{(y, b): x \text{ can produce } (y, b)\} \qquad (1)$$

Because two different outputs are employed in the technology then the output set is assumed to have the following properties:

a. The first assumption is referred to as the weak disposability of desirable and undesirable outputs:
$(y, b) \in P(x)$ and $0 \leq \theta \leq 1$, then $\theta(y, b) \in P(x)$ (2)

   This assumption indicates that it is not possible to reduce undesirable output without reducing desirable output. When firms face an environmental regulation, the disposal of undesirable outputs may not be free.

b. The second assumption is known as the strong disposability of desirable output:
$(y, b) \in P(x)$ and $y' \leq y$, then $(y', b) \in P(x)$. (3)

   This assumption suggests that it is possible to reduce desirable outputs without reducing undesirable outputs.

c. The third assumption is null-jointness, which implies that a positive amount of desirable output cannot be produced without producing an undesirable output:
$(y, b) \in P(x)$ and $b = 0$, then $y = 0$ (4)

Directional distance function allows a firm to increase the production of desirable outputs and simultaneously decrease the production of undesirable outputs with a given of inputs, and defined as

$$\vec{D}_0\,(x, y, b;\, 0,\, g_y, -g_b) = \max\,\{\,\beta: (y + \beta g_y,\, b - \beta g_b) \in P(x - 0)\}. \qquad (5)$$

where g is the vector of directions in which both outputs can be scaled. Following Chung *et al.* (1997), the direction applied is $g = (g_y, -g_b)$, implies that desirable outputs are increased undesirable outputs are decreased, and inputs does not change. β is a measurement of inefficiency.

The environmental directional distant function for the production process k in reference to the sample of N production processes, where the undesirable outputs are not regulated, the strong disposability is then assumed. The unregulated undesirable outputs can be freely disposed and be specified as follows:

$$\vec{D}_k^S\,(x_k, y_k, b_k;\; 0, y_k, -b) = \max \beta_k \qquad (6)$$

s.t. $\sum_{k=1}^{K} z_k x_{kn} \leq x_{k'n}$ $\quad n = 1, \ldots, N$ (i)

$\sum_{k=1}^{K} z_k y_{km} \geq (1 + \beta_k)\, y_{k'm}$ $\quad m = 1, \ldots, M$ (ii)

$\sum_{k=1}^{K} z_k b_{ki} \geq (1 - \beta_k) b_{k'i}$ $\quad i = 1, \ldots, I$ (iii)

$z_k \geq 0$ $\quad k = 1, \ldots, K$ (iv)

The directions of inequality constrains in Eq. 6 are mainly determined by inputs or outputs. The first inequality indicate that each input h of the production process k should be equal to or more than the linear combination of the inputs h of the reference assumption production process on the frontier. The second inequality illustrates that for each desirable output m of the k, with the additional extension of β_k of the observed desirable outputs of k should be equal to or less than the linear combination of the outputs m on the reference frontier. However, even at the attainable expansion of desirable outputs where β_k is maximized, the desirable outputs of k can be less than the reference assumption production process on the frontier. In contrast, for each undesirable output j of the k contracted with β_k of the observed undesirable outputs of k should be equal to the linear combination of the undesirable outputs j of the reference frontier observations in the third inequality. When the firm tries to increase the desirable outputs with the increase of β_k, it is restricted to decrease the undesirable outputs with this equality condition. In the fourth constrain, z_k^t signifies a vector of positive intensity variables and constant returns to scale is assumed, although other assumptions on the scale properties of the technology can be also possible.

For the case where the desirable outputs are regulated by imposing environmental regulations, the weak disposability is assumed. The regulated undesirable outputs cannot be freely disposed for which the null-jointness assumption exits. Fare et al. (1989) and Picazo-Tadeo et al. (2005) modified Eq. (6) to Eq. (7) as follows:

$$\vec{D}_k^W\,(x_k, y_k, b_k;\ 0, y_k, -\mathrm{b}) = \max \beta_k \tag{7}$$

s.t. $\sum_{k=1}^{K} z_k x_{kn} \leq x_{k'n}$ $\quad n = 1, \ldots, N$ (i)

$\sum_{k=1}^{K} z_k y_{km} \geq (1 + \beta_k)\, y_{k'm}$ $\quad m = 1, \ldots, M$ (ii)

$\sum_{k=1}^{K} z_k b_{ki} = (1 - \beta_k) b_{k'i}$ $\quad i = 1, \ldots, I$ (iii)

$\beta_k \geq 0$

$z_k \geq 0$ $\quad k = 1, \ldots, K$ (iv)

In Eq. (7) more contractions of undesirable outputs with larger β_k are allowed, implies that more expansion of the desirable outputs. The forth constraint in Eq. (7) is added from the equation (6), which restrict the assumption reference production process should take either zero or any positive value. As the null-jointness is no longer applied, the additional forth constrain is compulsory. Similar to the Eq. (6), z_k^t in Eq. (7) reflects a vector of positive intensity variables with constant returns to scale assumption.

Figure 1 illustrates the difference between Eq. (6) and Eq. (7) as the relationship between desirable outputs (y) and undesirable outputs (b), while remaining the given inputs (x) unchanged. Suppose that *Oy_3RSTb* is output set, $P^S(x)$, under unregulated technology and does not satisfy the null-jointness assumption while *OERSTb* is output set, $P^W(x)$, under regulated technology and satisfies null-jointness assumption. The direction vector is defined as $g = (0, y, -b)$. The unregulated technology scales point A to point R on the boundary based on an output vector, indicates that desirable outputs increase from y_1 to y_3. In contrast, the regulated technology scales point A to point A' on the boundary in the direction of increasing desirable outputs from y_1 to y_2 and undesirable outputs from b_2 to b_1. At point A', the output vector is

$(y+ \beta^* g_y, b - \beta^* g_b)$, where $\beta^* = \vec{D}_0 (x, y, b\ ;\ g_y - g_b)$, with $\beta^* g_y$ being added to the desirable output and $\beta^* g_b$ being subtracted from the undesirable output.

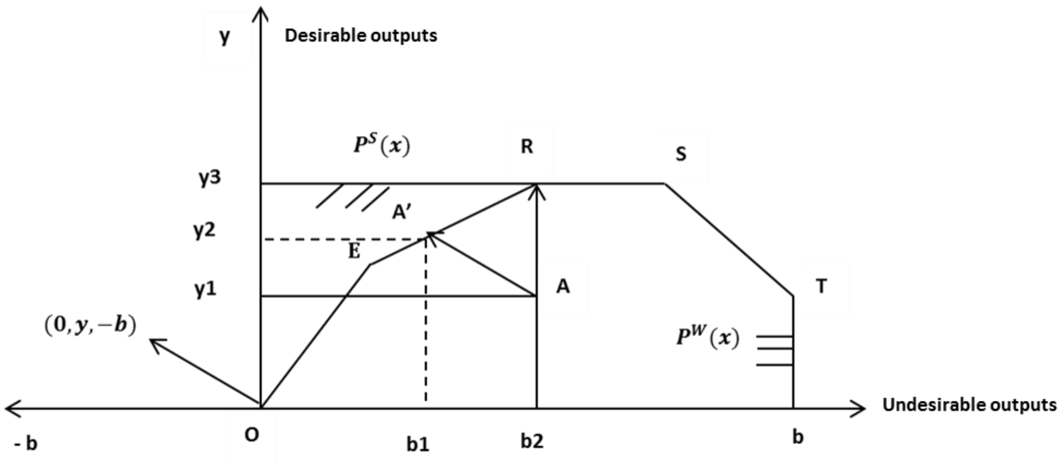

Figure 4.1: Regulated and unregulated assumptions of directional distance function

4.2.2. Carbon abatement cost

Following the arguments in the study by Hernandes-Sancho et al. (2000) and Picazo-Tadeo et al. (2005), the difference between attainable expansions of desirable outputs between Eq. (6) and Eq. (7) is regarded as regulatory impacts or opportunity costs to prevent free disposal of undesirable output. The opportunity costs as carbon abatement cost (CAC) is interpreted as all possible costs or foregone profit of a firm to reduce CO_2 emissions caused by the impact of environmental regulations.

Mathematically, CAC can be defined as:

$$\text{CAC} = \left(1 + \beta_k^S\right) y_{mk} - \left(1 + \beta_k^W\right) y_{mk} = \left(\beta_k^S - \beta_k^W\right) y_{mk} \qquad (8)$$

Further, average carbon abatement cost (ACAC) is defined as the ratio of total carbon abatement cost to the total unit of CO_2 emissions reduced, and formally expressed as:

$$\text{ACAC} = \text{total CAC / total unit of } CO_2 \text{ emissions reduced} \qquad (9)$$

4.3. Data

This chapter employed the cleaned and balanced datasets similar to the datasets used for the analysis in the chapter 3. The datasets obtained from the chapter 2 consist of four periods' datasets. The descriptive statistics of the variables used for this chapter is shown in Table 4.1.

Table 4.1: Descriptive statistics of the variables used for the chapter 4

Variable code	Description	Unit	Mean	Standard Deviation
Period of 1990-1995				
k	Capital	Thousands of US dollar	450.80	1691.45
l	Labor wage	Thousands of US dollar	263.94	873.13
m	Raw Material	Thousands of US dollar	607.63	2774.68
v	Value added	Thousands of US dollar	317.11	1370.26
CO_2	CO_2 emissions	Tons CO_2 equivalent	584.88	2113.26
No. of observations 9336				
Period of 1998-2000				
k	Capital	Thousands of US dollar	352.88	1530.00
l	Labor wage	Thousands of US dollar	86.35	404.82
m	Raw Material	Thousands of US dollar	596.34	3302.94
v	Value added	Thousands of US dollar	381.29	3211.77
CO_2	CO_2 emissions	Tons CO_2 equivalent	666.49	2229.87
No. of observations 4668				
Period of 2003-2006				
k	Capital	Thousands of US dollar	127.14	408.26
l	Labor wage	Thousands of US dollar	86.27	216.78
m	Raw Material	Thousands of US dollar	236.26	1489.42
v	Value added	Thousands of US dollar	119.65	583.46
CO_2	CO_2 emissions	Tons CO_2 equivalent	282.02	1434.19
No. of observations 3296				
Period of 2008-2010				
k	Capital	Thousands of US dollar	120.00	441.86
l	Labor wage	Thousands of US dollar	84.76	253.55
m	Raw Material	Thousands of US dollar	298.67	1924.40
v	Value added	Thousands of US dollar	119.50	385.95
CO_2	CO_2 emissions	Tons CO_2 equivalent	243.63	1054.26
No. of observations 2472				

Table 4.2 presents the terms and conditions of average carbon abatement cost trend as energy price either increase or decrease to recognize in what situations average carbon abatement cost can be applied. When average carbon abatement cost increase, the situation that can be described is firms simultaneously experience decreasing rates of desirable outputs production with increased levels of undesirable outputs production for regulated scenario. As the energy price increase and average carbon abatement cost also increase, firms fail to improve efficiency and manage the impact of energy price, resulted in reducing less CO_2 emissions. Next, as the energy price is constant and average carbon abatement cost increase, firms fail to improve efficiency and do not need to manage the impact of energy price, also resulted in reducing less CO_2 emissions. On the other hand, when average carbon abatement cost decrease, firms increase desirable outputs production simultaneously decrease undesirable outputs production for regulated scenario. As the energy price increase and average carbon abatement cost decrease, firm successfully improve efficiency and manage the impact of energy price for regulated scenario, resulted in reducing more CO_2 emissions. Similarly, as the energy price is constant and average carbon abatement cost decrease, firm successfully improve efficiency and does not need to manage the impact of energy price, also resulted in reducing more CO_2 emissions.

Table 4.2: Terms and conditions of average carbon abatement cost estimation

Average Carbon Abatement Cost		Energy price increase		Energy price constant	
Increase/ decrease?	Condition	Situation	Measures	Situation	Measures
Increase	Simultaneously experienced decreased rates of desirable outputs production with increased levels of undesirable outputs production for regulated scenario → an amount of profit sacrificed reduces less CO2 emission	Firm fails to improve efficiency and manage the impact of energy price → reduce less CO2 emissions	Energy intensity is high, carbon-intensive energy use, no investment for new technology, expansion of production, pay the cost	Firm fails to improve efficiency and does not need to manage the impact of energy price → reduce less CO2 emissions	Efficiency and technology do not improve
Decrease	Increased rates of desirable outputs production occurred simultaneously with decreased levels of undesirable outputs production for regulated scenario -→ an amount of profit sacrificed reduces more CO2 emissions	Firm successfully improve efficiency and manage the impact of energy price for regulated scenario → reduce more CO2 emissions	Change fuel, energy saving, invest for new technology	Firm successfully improve efficiency and does not need to manage the impact of energy price → reduce more CO2 emissions	Efficiency and technology improvement

4.4. Results and Discussions

First of all, the CO_2 intensity is defined as the ratio of CO_2 emissions per unit of value added to obtain a brief overview of the CO_2 intensity of Indonesia's manufacturing sector. Table 4.3 provides the average CO_2 intensity of Indonesia's manufacturing sector for all sectors and all periods. In the period 1 the average CO_2 intensity is 0.0020, implies that to generate US 1,000 dollar of value added, the manufacturing sector, on average, have to emit 0.002 tons of energy-related CO_2. The sector that exhibits the highest CO_2 intensity is others non-metallic mineral product (0.0047) and the sector with the lowest CO_2 intensity is tobacco (0.0004). Meanwhile in the period 2, the average CO_2 intensity is 0.0025, increase 25% from the period 1. The sector that shows the highest CO_2 intensity is rubber and plastics product (0.007) and the sector with the lowest CO_2 intensity is tobacco (0.0005). Further, when the price of oil commodities has increased in the period 3, the average CO_2 intensity rises 24% from the previous period to reach 0.0031. The sector that shows the highest CO_2 intensity is rubber and plastics product (0.007) and the sector with the lowest CO_2

intensity is tobacco (0.0005). Moreover, the average CO_2 intensity in the period 4 is 0.0025, decline 19% from the previous period. Rubber and plastics product is the sector that shows the highest CO_2 intensity (0.0061), whereas tobacco sector exhibits the lowest CO_2 intensity (0.0005).

Table 4.3: The Average CO_2 intensity of Indonesia's manufacturing sector for all periods (tons per thousand of US dollar)

No	Sector	Period			
		1	2	3	4
1	Food product and beverages	0.0030	0.0040	0.0043	0.0038
2	Tobacco	0.0004	0.0005	0.0005	0.0005
3	Textiles	0.0034	0.0043	0.0043	0.0040
4	Wearing apparel	0.0008	0.0015	0.0013	0.0012
5	Tanning and dressing of leather	0.0008	0.0007	0.0014	0.0009
6	Wood and product of wood and plaiting	0.0021	0.0026	0.0039	0.0029
7	Paper and paper product	0.0024	0.0015	0.0055	0.0031
8	Publishing, printing and reproduction	0.0014	0.0019	0.0018	0.0017
9	Chemicals and chemical product	0.0011	0.0009	0.0017	0.0013
10	Rubber and plastics product	0.0044	0.0070	0.0070	0.0061
11	Others non-metallic mineral product	0.0047	0.0051	0.0046	0.0048
12	Basic metals	0.0013	0.0035	0.0044	0.0031
13	Fabricated metal product and equipment	0.0017	0.0031	0.0033	0.0027
14	Machinery and equipment n.e.c.	0.0016	0.0019	0.0028	0.0021
15	Electrical machinery and apparatus n.e.c.	0.0008	0.0007	0.0013	0.0009
16	Motor vehicle, trailers and semi-trailers	0.0019	0.0027	0.0037	0.0028
17	Other transport equipment	0.0019	0.0014	0.0024	0.0019
18	Furniture and manufacturing n.e.c.	0.0015	0.0021	0.0026	0.0020
	Average	0.0020	0.0025	0.0031	0.0025

Under the two assumptions of the disposal of CO_2 emissions, the inefficiency scores are computed by solving linear programing in Eq. (6) and Eq. (7) for each sample observation. Manufacturing sector achieves the best performance in environmental efficiency when the production efficiencies under regulated assumption reach to the frontier. The Wilcoxon Rank-sum test has been conducted to verify whether efficiency scores, based on weak disposability assumption, are significantly different from those obtained from strong disposability assumption for each period. The null hypothesis is that efficiency scores obtained from the two assumptions have the same population of relative frequency distribution for each period. The value of two tailed 'p' statistic is 0.000 for each period, hence the null hypothesis can be rejected at 1% level, implying that efficiency scores based on weak disposability assumption is significantly difference from those of strong disposability

Table 4.4 shows the average inefficiency scores under unregulated and regulated assumptions for all periods. In the period 1, the average inefficiency scores are 0.5644 for the unregulated assumption and 0.4114 for the regulated assumption. Whereas in the period 2, the average inefficiency scores exhibits modest incline for the both assumptions. The incline average inefficiency scores implies that in the immediate post economic crisis period environmental efficiency decrease from 0.4115 to 0.4180. Further, when the government of Indonesia began to remove subsidies for oil commodities in the period 3, the average inefficiency scores shows significant decline for the both assumptions and environmental efficiency remarkably increase to 0.2802. Moreover, in the period 4, the average inefficiency scores slightly increase for the unregulated assumption but showed slight decrease for the regulated scenario.

Table 4.4: The average inefficiency scores under unregulated and regulated assumption for all periods

No	Sector	Unregulated assumption				Regulated assumption			
		Period				Period			
		1	2	3	4	1	2	3	4
1	Food product and beverages	0.8677	0.9020	0.7581	0.7737	0.7523	0.7811	0.6353	0.6457
2	Tobacco	0.2604	0.3646	0.5767	0.5291	0.1492	0.1628	0.3525	0.2889
3	Textiles	0.6156	0.5488	0.5288	0.4335	0.4555	0.4221	0.2661	0.3153
4	Wearing apparel	0.6627	0.7439	0.7028	0.5324	0.5008	0.5197	0.5669	0.3715
5	Tanning and dressing of leather	0.3866	0.6660	0.1299	0.1687	0.2372	0.4086	0.1147	0.1065
6	Wood and product of wood and plaiting	0.7316	0.7249	0.4702	0.4014	0.5417	0.5338	0.3159	0.2540
7	Paper and paper product	0.3812	0.5204	0.0993	0.2573	0.2235	0.3352	0.0272	0.1738
8	Publishing, printing and reproduction	0.7535	0.6833	0.4519	0.5610	0.6226	0.5488	0.3328	0.3977
9	Chemicals and chemical product	0.7872	0.7458	0.5703	0.5231	0.6239	0.5853	0.4044	0.3700
10	Rubber and plastics product	0.6336	0.6409	0.7295	0.6084	0.4975	0.5574	0.5897	0.4707
11	Others non-metallic mineral product	0.7269	0.6654	0.4872	0.4012	0.4967	0.4262	0.4095	0.3070
12	Basic metals	0.2625	0.2654	0.1036	0.2425	0.2094	0.1850	0.0035	0.0277
13	Fabricated metal product and equipment	0.6016	0.6863	0.4303	0.5224	0.4741	0.4517	0.1984	0.3683
14	Machinery and equipment n.e.c.	0.4881	0.5350	0.2910	0.2348	0.2232	0.3276	0.0985	0.1083
15	Electrical machinery and apparatus n.e.c.	0.4282	0.5193	0.1167	0.1989	0.3172	0.4143	0.0725	0.1683
16	Motor vehicle, trailers and semi-trailers	0.5261	0.3658	0.2541	0.2186	0.3183	0.1890	0.0648	0.1122
17	Other transport equipment	0.3787	0.3846	0.1330	0.0306	0.2426	0.2469	0.0690	0.0289
18	Furniture and manufacturing n.e.c.	0.6665	0.5966	0.7033	0.7722	0.5189	0.4283	0.5212	0.5977
	Average	0.5644	0.5866	0.4187	0.4117	0.4114	0.4180	0.2802	0.2840

Furthermore, to calculate ACAC as a foregone profit of a manufacturing firm to reduce CO_2 emissions, Eq. (8) and Eq. (9) are applied. Table 4.5 shows the ACAC of manufacturing sector for the period 1 in US dollar per ton CO_2. When the export-led industrialization policy was implemented in period 1, the ACAC of manufacturing sector is 430.99. It is observed that the ACAC has constantly decreased since the beginning of the period 1. However, the ACAC suddenly increased from the middle of the period 1. The sector that shows the highest ACAC is tobacco (3,408.38) and the sector that presents the lowest ACAC is rubber and plastics product (63.51).

The immediate post economic crisis period and the beginning of democratic reforms were considered for the period 2. Table 4.6 exhibits the ACAC of manufacturing sector for the period 2. During the period 2 the ACAC of manufacturing sector is 306.86, implies that the cost to abate one ton CO_2 emissions is 306.86 US dollar. The ACAC in the period 2 decreased 28.8% from the previous period. The sector with the highest ACAC is tobacco (2,596.82), and the sector with the lowest ACAC is rubber and plastics product (26.77).

Table 4.5: The ACAC of manufacturing sector for the period 1
(US dollar per ton CO_2)

No	Sector	Year						
		1990	1991	1992	1993	1994	1995	Average
1	Food product and beverages	65.97	55.70	54.89	69.50	68.67	41.01	70.96
2	Tobacco	3461.71	2241.08	1263.13	3013.53	3980.29	6490.52	3408.38
3	Textiles	57.20	184.58	110.02	104.11	308.07	140.28	150.71
4	Wearing apparel	642.25	733.18	691.03	472.72	594.43	404.72	589.72
5	Tanning and dressing of leather	800.10	443.18	499.62	1072.59	447.31	365.95	604.79
6	Wood and product of wood and plaiting	102.75	115.83	159.85	138.42	304.03	192.69	168.93
7	Paper and paper product	355.29	327.60	697.28	460.27	449.94	732.12	503.75
8	Publishing, printing and reproduction	474.65	544.01	190.13	348.00	253.92	220.02	338.46
9	Chemicals and chemical product	207.94	188.66	178.76	75.42	122.57	394.62	194.66
10	Rubber and plastics product	42.62	47.02	56.18	90.74	97.57	46.92	63.51
11	Others non-metallic mineral product	100.87	178.75	264.04	273.01	256.26	172.75	207.61
12	Basic metals	68.18	65.33	105.80	147.18	54.19	765.23	200.98
13	Fabricated metal product and equipment	215.50	48.42	42.73	353.69	384.90	140.07	197.55
14	Machinery and equipment n.e.c.	1001.67	811.75	720.42	1947.38	1221.45	1370.28	1178.82
15	Electrical machinery and apparatus n.e.c.	148.22	274.36	210.98	238.90	469.58	557.43	316.58
16	Motor vehicle, trailers and semi-trailers	795.61	711.51	539.00	512.44	1442.09	1735.98	956.11
17	Other transport equipment	211.97	292.50	460.62	582.84	377.91	584.18	418.34
18	Furniture and manufacturing n.e.c.	256.17	287.34	418.20	453.51	113.73	261.01	298.33
	Average	500.48	419.49	370.15	575.24	605.94	811.43	430.99

Table 4.6: The ACAC of manufacturing sector for the period 2
(US dollar per ton CO_2)

No	Sector	Year			
		1998	1999	2000	Average
1	Food product and beverages	39.20	43.92	40.30	41.14
2	Tobacco	2507.74	2202.05	3080.67	2596.82
3	Textiles	78.92	91.51	60.79	77.07
4	Wearing apparel	467.90	375.19	314.48	385.86
5	Tanning and dressing of leather	764.75	974.72	459.63	733.04
6	Wood and product of wood and plaiting	133.67	186.27	80.56	133.50
7	Paper and paper product	316.42	265.94	114.48	232.28
8	Publishing, printing and reproduction	116.36	130.95	182.67	143.33
9	Chemicals and chemical product	178.54	174.87	295.13	216.18
10	Rubber and plastics product	42.06	20.13	18.13	26.77
11	Others non-metallic mineral product	107.35	95.07	149.37	117.27
12	Basic metals	203.15	149.63	196.58	183.12
13	Fabricated metal product and equipment	170.25	176.24	271.92	206.14
14	Machinery and equipment n.e.c.	337.04	284.74	289.80	303.86
15	Electrical machinery and apparatus n.e.c.	234.72	451.33	194.01	293.35
16	Motor vehicle, trailers and semi-trailers	181.45	343.19	416.08	313.57
17	Other transport equipment	214.87	311.28	370.31	298.82
18	Furniture and manufacturing n.e.c.	309.17	226.94	89.58	208.56
	Average	355.75	361.33	368.03	306.86

Period 3 is regarded as the period of politically significant transitional moments, and the government of Indonesia began to remove subsidies for oil commodities. As the consequence of the removing subsidies the price of oil commodities increased. Table 4.7 presents the ACAC of manufacturing sector for the period 3. During the period 3 the ACAC of manufacturing sector is 419.72 which increased 36.77% from the period 2. The sector that shows the highest ACAC is tobacco (3,445.35) and the sector with the lowest ACAC is rubber and plastics product (84.53).

Table.4.7: The ACAC of manufacturing sector for the period 3
(US dollar per ton CO_2)

No	Sector	Year				
		2003	2004	2005	2006	Average
1	Food product and beverages	196.31	95.28	65.24	81.98	109.70
2	Tobacco	427.66	3195.55	5418.11	4740.09	3445.35
3	Textiles	1938.64	730.45	876.23	1207.42	1188.18
4	Wearing apparel	565.00	151.92	424.69	516.43	414.51
5	Tanning and dressing of leather	86.21	184.12	34.48	47.50	88.08
6	Wood and product of wood and plaiting	842.97	456.41	444.93	340.03	521.09
7	Paper and paper product	1158.62	0.00	3722.71	0.00	1220.33
8	Publishing, printing and reproduction	576.15	597.67	163.38	228.72	391.48
9	Chemicals and chemical product	352.02	404.40	382.01	320.78	364.80
10	Rubber and plastics product	159.63	79.95	28.36	70.20	84.53
11	Others non-metallic mineral product	77.58	133.69	51.42	112.23	93.73
12	Basic metals	96.08	88.93	49.46	1202.97	359.36
13	Fabricated metal product and equipment	247.52	192.41	225.16	414.95	270.01
14	Machinery and equipment n.e.c.	435.56	182.18	277.54	300.22	298.87
15	Electrical machinery and apparatus n.e.c.	842.14	1068.87	518.20	918.82	837.01
16	Motor vehicle, trailers and semi-trailers	787.08	274.68	99.71	584.47	436.48
17	Other transport equipment	522.22	743.79	747.19	1394.35	851.89
18	Furniture and manufacturing n.e.c.	1553.07	1224.29	1377.25	1964.25	1529.72
	Average	603.58	544.70	828.12	802.52	419.72

Furthermore in period 4, when the global financial crisis took place, the ACAC of manufacturing sector is 495.81 as presented in table 4.8. The ACAC in the period 4 incased 18.12% from the period 3. The sector that exhibits the highest ACAC is still tobacco (4,110.90) and the sector with the lowest ACAC is rubber and plastics product (129.07).

Table 4.8: The ACAC of manufacturing sector for the period 4
(US dollar per ton CO_2)

No	Sector	Year			
		2008	2009	2010	Average
1	Food product and beverages	81.75	153.87	180.46	138.69
2	Tobacco	3876.79	3192.05	5263.86	4110.90
3	Textiles	647.58	433.71	387.09	489.46
4	Wearing apparel	577.01	596.47	1088.98	754.16
5	Tanning and dressing of leather	1170.06	153.24	217.26	513.52
6	Wood and product of wood and plaiting	382.32	273.03	689.40	448.25
7	Paper and paper product	984.38	638.67	1411.09	1011.38
8	Publishing, printing and reproduction	682.78	559.46	342.70	528.31
9	Chemicals and chemical product	215.10	387.92	925.56	509.53
10	Rubber and plastics product	87.48	78.08	221.66	129.07
11	Others non-metallic mineral product	104.21	66.38	187.86	129.48
12	Basic metals	73.21	195.70	246.45	171.79
13	Fabricated metal product and equipment	382.32	691.06	1074.02	715.80
14	Machinery and equipment n.e.c.	521.41	371.60	1378.75	757.26
15	Electrical machinery and apparatus n.e.c.	758.29	960.40	2669.80	1462.83
16	Motor vehicle, trailers and semi-trailers	409.72	576.41	1153.42	713.18
17	Other transport equipment	556.21	409.67	3905.03	1623.64
18	Furniture and manufacturing n.e.c.	1086.33	1427.64	3184.49	1899.49
	Average	81.75	153.87	180.46	495.81

Overall, the environmental efficiency of manufacturing sector from 1990 to 2010 can be estimated by applying two different assumptions of CO_2 emissions disposal as the response to climate change mitigation policy. Among the four periods, the average carbon intensity showed the highest level in the period 3, which considerably increased from the previous period, however deceased in the next period. In addition, the average environmental efficiencies are reported notably increased in the period 3. Almost all sectors exhibit the improvement of environmental efficiency.

Moreover, the ACAC of manufacturing sector from 1990 to 2010 present moderate fluctuation due to the economic and political policies implemented by the government which strongly influenced the manufacturing sector performance. In the period 1 and the period 2, when the price of oil commodities were still subsidized by the government, the manufacturing sector on average has to give up 430.99 US dollar and 306.86 US dollar of its profit to abate one ton of CO_2 emissions, respectively. When the price of oil commodities increased in the period 3, on average the manufacturing sector will allocate 419.72 US dollar of its profit to reduce one ton of CO_2 emissions. Furthermore, 495.81 US dollar are required if the manufacturing sector aim to cut one ton of CO_2 emissions in the period 4. The increase of efficiency and ACAC might be associated with the conditions that firms increase the production of desirable outputs but reduce less CO_2 emissions, high energy intensity, no new technology investment, or the technology improvement does not have any significant impact on CO_2 emissions reduction. The fluctuation of these ACAC is consistent with the trend of value added and carbon intensity because the measurement of carbon abatement cost is based on forgone profit and the amount of CO_2 emissions, even though on average environmental efficiency show improvement.

Based on the sector-by-sector analysis, there is no empirical evidence that the high energy-intensive sectors have higher ACAC for all periods. The sector that has the lowest ACAC for all periods is rubber and plastics product. The conditions that may explain the lowest ACAC are that rubber and plastics product sector increases the production of desirable outputs and simultaneously reduces more CO_2 emissions. On the contrary, the sector that demonstrated the highest ACAC is tobacco. As the majority of cigarette industry in Indonesia still applies a hand-made production, technology improvement might be rarely required. Because most of CO_2 emissions are not generated from its main production processes, hence the cost to reduce CO_2 emissions in tobacco sector is expensive.

The measurement of ACAC provides an obvious description of which sectors that have a greater burden in reducing CO_2 emissions during its production process. The ACAC of each sector resulted in this study might be different from other literatures due to the method and approach applied. The type of technology used, the sort of energy consumed, or the efficiency measure taken could be the main cause of the amount CO_2 emissions. In the future, if the trend of declining carbon intensity can be maintained and value added can be improved, the ACAC can be continually decreased. However, fostering and constructive recommendations should be provided by policy makers for manufacturing sectors to reduce the ACAC. In addition, the increasing trend of the ACAC since the period 3 has to be a major concern for policy makers to take considerable and strategic measures to improve manufacturing sector performance to respond the climate change mitigation and energy related policies in the future, so as the share of manufacturing sector to Indonesia's GDP and more job opportunities can also be maintained.

4.5. Conclusions

This chapter highlights the usefulness of directional distance function to estimate and evaluate the ACAC as the impact of CO_2 emissions reduction on Indonesia manufacturing sector. An assumption that undesirable outputs are weakly disposable has to be made because Indonesia has not implemented carbon regulations. The proposed methodology is demonstrated with an empirical application to the Indonesia manufacturing sector panel datasets. The cleaned and balanced panel datasets are constructed only for four periods: 1990-1995, 1998-2000, 2003-2006, and 2008-2010. In particular, it is assumed that manufacturing firms aim to maximize their production (desirable output) and simultaneously reducing CO_2 emissions (undesirable output) without any changing in inputs.

The main findings of the paper can be summarized as follow. First, the average ACAC estimated for the period 1, 2, 3, and 4 are: 430.99, 306.86, 419.72, and 495.81 US dollar to reduce one ton of CO_2 emissions. The fluctuation of these ACAC is consistent with the trend of value added and carbon intensity because the measurement of carbon abatement cost is based on forgone profit and the amount of CO_2 emissions, even though on average environmental efficiency show improvement. Second, the environmental efficiency and ACAC have increased as the price of oil commodities increased, particularly in the period 3. Third, the sector that has the lowest ACAC for all periods is rubber and plastics product and the sector that demonstrated the highest ACAC is tobacco. No empirical evidence that the high energy-intensive sectors have higher ACAC for all periods.

The ACAC estimated in this chapter enables to identify the additional financial burden that should be provide by manufacturing sector to respond the climate change mitigation and energy related policies. Particular attentions should be given to the manufacturing sector that bear high abatement costs and provide strategic measures to improve manufacturing sector performance so as the share of manufacturing sector to Indonesia's GDP and more job opportunities can be maintained.

CHAPTER 5: IMPACTS OF ENERGY PRICE ON ENVIRONMENTAL PRODUCTIVITY CHANGE AND AVERAGE CARBON ABATEMENT COST

5.1. Introduction

As economic growth and manufacturing sector are highly dependent on energy, the increase of oil price has affected on the economic growth of many emerging economies. The studies that investigated the impact of oil price changes on economic activities has significantly grown since Hamilton (1988) suggested a negative relationship between oil price changes and economic activities. This finding is also supported by Hooker (2002) who argued that oil price changes significantly caused to the US inflation and productivity and Hamilton (2009) who analyzed the impact of oil price changes on the US macroeconomic components during 2007-2008. In particular, Aye *et al.* (2014) analyzed the effect of oil price changes on the manufacturing production in South Africa. The analysis results suggested that oil price changes significantly and negatively impacts on South Africa's manufacturing production and manufacturing production gave asymmetric responses to the increasing and decreasing oil price changes. Unexpected increase in oil price directly triggers to the production cost increase and hence leads to the declining of productivity. If the high oil cost persists, energy shift or energy saving might be required for the long term productivity growth.

The increase price of oil commodities might have affected environmental productivity. Because energy consumption is not directly used as input in the analysis of productivity change, the direct impact of the increase price of oil commodities cannot be identified. The relationship between TFP environment change over time and changes of energy factors is analyzed to investigate the determinant of environmental productivity. The increase of oil price could have an impact on carbon abatement cost as well since the CO_2 emissions in this study are calculated based on the fossil fuel consumptions. This impact is also significant to be analyzed to examine the CO_2 emissions reduction efforts during the period of this study. The objective of this chapter is to estimate the energy factors when the price of oil commodities increase that directly influence environmental productivity and average carbon abatement cost for the Indonesia manufacturing sector. The average carbon abatement cost employed in this analysis is the cost of abate one ton of CO_2 emissions.

5.2. Methodology

5.2.1. Empirical models

The approach applied to analyze the influent of energy factors on environmental productivity over time and average carbon abatement cost in Indonesia's manufacturing sector is to conduct simple regression analysis using panel datasets.

Formally the mathematical model to examine environmental productivity can be defined as:

$$\mathrm{Y}_{\mathrm{i}(\mathrm{t},\mathrm{t}+1)} = \mathrm{f}(\mathrm{X}_{\mathrm{i},\mathrm{t}}) = \beta + \sum \beta_i X_{it} + \mu_{\mathrm{it}} \quad (1)$$

Where $\mathrm{Y}_{\mathrm{i}(\mathrm{t},\mathrm{t}+1)}$ is environmental productivity change over time of i^{th} firm at t to $t+1$ periods and X_{it} is the determinant (the explanatory variables) of i^{th} firm at t period, β's are parameters to be estimated, and μ is the error term.

Whereas the mathematical model to examine average carbon abatement cost is described as:

$$\mathrm{ACAC}_{\mathrm{i},\mathrm{t}} = \mathrm{f}(\mathrm{X}_{\mathrm{i},\mathrm{t}}) = \beta + \sum \beta_i X_{it} + \mu_{\mathrm{it}} \quad (2)$$

Where $\mathrm{ACAC}_{\mathrm{i},\mathrm{t}}$ is average carbon abatement cost of i^{th} firm at t periods and X_{it} is the determinant (the explanatory variables) of i^{th} firm at t period, β's are parameters to be estimated, and μ is the error term.

The explanatory variables for Eq. (1) and Eq. (2) are the average domestic fuel price (*Fuelprice)*, the average electricity price (*Elecprice)*, and energy dependency (*Energydep*). The energy dependency is defined as the ratio of the total energy expenditures to the total intermediate input expenditures.

5.2.2. Data

The data applied for the analysis in this chapter are the cleaned and balanced datasets obtained from the chapter 2 which consist of four periods' dataset. In addition, the environmental productivity changes over time datasets are acquired from the productivity measurement of both TFP with and without CO_2 emissions for the firm-level data analysis in the Chapter 3, whereas the average carbon abatement cost datasets are obtained from the carbon abatement cost calculation for the firm-level data analysis in the Chapter 4. The average domestic fuel price (*Fuelprice)* and the average electricity price (*Elecprice)* are converted from the original Indonesia's rupiah to the real price in US dollar. Table 5.1 presents the descriptive statistics of the variables used in this chapter.

Table 5.2 shows the expected signs of variables to examine environmental productivity: energy dependency is expected to have negative impact on environmental productivity as the greater use of energy in manufacturing sector resulted the efforts to reduce CO_2 emissions will be more severe; fuel price is predicted to have positive impact on manufacturing productivity as the fuel price increase, firm will be more energy efficient; and electricity price is projected to have positive impact on environmental productivity as the electricity price increase, firm will be more energy efficient. Whereas Table 5.3 depicts the expected signs of variables to examine environmental productivity: energy dependency is predicted to have negative impact on average carbon abatement cost as the greater use of energy in manufacturing sector resulted the efforts to reduce CO_2 emissions will be easier; fuel price is projected to have negative impact on average carbon abatement cost as the fuel price increase, firm will be more energy efficient and resulted CO_2 emissions will increase; and electricity price is expected to have negative impact on average carbon abatement cost as the electricity price increase, firm will be more energy efficient.

Table 5.1: Descriptive statistics of the variables used for all periods

Variable code	Description	Unit	Mean	Standard Deviation
Period of 1990-1995				
Y	Environmental productivity change over time	%	1.15	2.72
ACAC	Marginal Abatement Cost	US dollar / Tons CO_2 emissions	240.04	876.55
energydep	Energy dependency	%	2	0.02
fuelprice	Fuel price	US dollar/ Tons of Oil Eq.	40.88	16.17
elecprice	Electricity price	US dollar/ Tons of Oil Eq.	152.99	82.46
No. of observations 9336				
Period of 1998-2000				
Y	Environmental productivity change over time	%	1.10	1.10
ACAC	Marginal Abatement Cost	US dollar / Tons CO_2 emissions	164.19	654.14
energydep	Energy dependency	%	5	0.06
fuelprice	Fuel price	US dollar/ Tons of Oil Eq.	67.47	25.99
elecprice	Electricity price	US dollar/ Tons of Oil Eq.	194.83	97.90
No. of observations 4668				
Period of 2003-2006				
Y	Environmental productivity change over time	%	1.154	1.04
ACAC	Marginal Abatement Cost	US dollar / Tons CO_2 emissions	526.69	2062.83
energydep	Energy dependency	%	8	0.08
fuelprice	Fuel price	US dollar/ Tons of Oil Eq.	215.66	104.18
elecprice	Electricity price	US dollar/ Tons of Oil Eq.	696.57	431.92
No. of observations 3296				
Period of 2008-2010				
Y	Environmental productivity change over time	%	1.08	0.56
ACAC	Marginal Abatement Cost	US dollar / Tons CO_2 emissions	1668.41	10817.22
energydep	Energy dependency	%	13	0.12
fuelprice	Fuel price	US dollar/ Tons of Oil Eq.	518.55	186.15
elecprice	Electricity price	US dollar/ Tons of Oil Eq.	1007.62	660.44
No. of observations 2472				

Table 5.2: Expected signs of variables to examine environmental productivity

Variable	Unit	Expected sign	Remark
Energy dependency	%	(-)	The greater use of energy, the efforts to reduce CO2 emissions will be more severe→ Environmental productivity decrease
Fuel price	US dollar	(+)	When the fuel price increase, firm will be more energy efficient → CO2 emissions reduction will increase → Environmental productivity increase
Electricity price	US dollar	(+)	When the electricity price increase, firm will be more energy efficient → CO2 emissions reduction will increase → Environmental productivity increase

Table 5.3: Expected signs of variables to examine average carbon abatement cost

Variable	Unit	Expected sign	Remark
Energy dependency	%	(-)	The greater use of energy, the efforts to reduce CO2 emissions will be easier → average carbon abatement cost decrease
Fuel price	US dollar	(-)	When the fuel price increase, firm will be more energy efficient → CO2 emissions reduction will increase → average carbon abatement cost decrease
Electricity price	US dollar	(-)	When the electricity price increase, firm will be more energy efficient → CO2 emissions reduction will increase → average carbon abatement cost decrease

5.3. Results and Discussions

Because there is no empirical evidence confirming that the increase in energy costs might directly affect manufacturing productivity or average carbon abatement cost, the relationship between energy factors and environmental productivity and also between energy factors and average carbon abatement cost are analyzed. The estimation results to evaluate the influent of energy factors on environmental productivity changes over time in Indonesia's manufacturing sector are presented in Table 5.4. Fuel price is statistically significant during 2003-2006 and shows a negative relationship to the changes of environmental productivity. When energy is still subsidized during 1990-1994 and 1998-2000 periods, the energy dependency of manufacturing sector is relatively small. The fuel and electricity prices do not have significant role in enhancing environmental productivities. While the energy policies implemented after 2003 aims to remove subsidies of oil commodities caused the fuel and electricity prices increase. As the energy dependency also increase, the energy price started to negatively influence on environmental productivity improvements.

Table 5.4: Factors associated with changes in environmental productivity

Independent Variables	Periods			
	1990-1995	1998-2000	2003-2006	2008-2010
Energydep	3.6865	- 1.3378	1.1156	- 0.3859
Fuelprice	0.0024	- 0.0004	- 0.0005 **	- 0.0001
Elecprice	- 0.0015 **	0.0001	- 0.0000	- 0.0000 **
Constant	1.2080 ***	1.1654 ***	0.9887 ***	1.2812 ***
Number of Observations	7,795	3,118	2,451	1,634

*** indicates that a variable is significant at a 1% level of significance
** indicates that a variable is significant at a 5% level of significance
* indicates that a variable is significant at a 10% level of significance

The impact of energy factors on average abatement cost in Indonesia manufacturing sector is also examined to investigate the relationship between the increase in energy costs and CO_2 emissions reduction. The estimation results are presented in Table 5.5. Energy dependency negatively and significantly influenced average abatement cost for the periods 1 and 3. The relationship between energy dependency and average carbon abatement cost in the period 1 and 3 is as expected. The greater use of energy, the efforts to reduce CO_2 emissions will be easier; hence if more CO_2 emissions can be reduced the average carbon abatement cost will decrease. When energy is still subsidized during periods 1 and 2, the fuel price is significant and has a negative impact on average carbon abatement cost. The relationship between fuel price and average carbon abatement cost in the period 1 and 2 is also as expected However, during 2003-2006 when energy subsidy started to be removed, the fuel price is statistically significant and started to show a positive relationship to the averaged carbon abatement cost. This positive relationship might be associated with the conditions that manufacturing firms increase the production of desirable outputs but reduce less CO_2 emissions, high energy intensity, no new technology investment, or the technology improvement does not have any significant impact on CO_2 emissions reduction. Different influences are showed by electricity price, which has a significantly negative relationship to the marginal abatement cost when energy subsidy is removed in the period 3.

Table 5.5: Factors associated with marginal abatement cost

Independent Variables	Periods			
	1990-1995	1998-2000	2003-2006	2008-2010
Energydep	- 1481.66 ***	- 755.45	- 8025.39 ***	7.44e+13
Fuelprice	- 3.54 ***	- 4.58 ***	1.05 ***	- 5.98e+10
Elecprice	0.29	0.16	- 0.03 ***	1.86e+10
Constant	580.0 ***	613.05 ***	1395.19 ***	9.14e+12
Number of Observations	7,795	3,118	2,451	1,634

*** indicates that a variable is significant at a 1% level of significance
** indicates that a variable is significant at a 5% level of significance
* indicates that a variable is significant at a 10% level of significance

5.4. Conclusions

The relationship between energy factors and environmental productivity is analyzed to confirm that the increase in energy costs directly influence manufacturing productivity. The impact of energy factors on average abatement cost is also examined to investigate the relationship of the increase in energy costs and CO_2 emissions reduction. The four periods of cleaned and panel datasets from the Chapter 2 and the analysis results in the Chapters 3 and 4 are employed in this analysis.

The empirical results show that when the fuel and electricity prices increase and the energy dependency also increase in the period 3, the energy price started to negatively influence on environmental productivity improvements. Hence, the change of environmental component in productivity measurement, in term of the level of CO_2 emissions reduction, is associated with the adjusted energy prices. Furthermore, energy dependency negatively and significantly influenced average abatement cost for the periods 1 and 3. The greater use of energy, the efforts to reduce CO_2 emissions will be easier; hence if more CO_2 emissions can be reduced the average carbon abatement cost will decrease. The fuel price is significant and has a negative impact on average carbon abatement cost. When energy is still subsidized during periods 1 and 2, the fuel price is significant and has negatively affects average carbon abatement cost. The relationship between fuel price and average carbon abatement cost in the period 1 and 2 is also as expected. However, during 2003-2006 when energy subsidy started to be removed, the fuel price is statistically significant and started to show a positive relationship to the averaged carbon abatement cost. Electricity price has a significantly negative relationship to the marginal abatement cost when energy subsidy is removed.

The empirical results obtained in the Chapter 5 enable policy makers to observe the determinant of environmental productivity and carbon abatement related to the energy factors. Immediate strategic efforts can be provide to anticipate the negative impact of the rise in energy prices on manufacturing sector performance in the future. Furthermore, the particular sectors that will experience the worst impact should be the main concern of policy makers.

CHAPTER 6: CONCLUSION AND POLICY RECOMMENDATION

6.1. Conclusion

Manufacturing sector is one of the most important sectors due to its large potential for creating job opportunities and its contribution to Indonesia's development. When the roles of manufacturing sector are expected to continuously increase, some considerable challenges should be confronted, in particular the increasing pollutions and the increasing demand for energy. This study empirically measures the impact of the climate change mitigation and energy related policies on manufacturing sector. Environmental productivity and efficiency improvement are the main issues to be discussed in this study to formulate constructive policy designs to enhance manufacturing sector's performance in the future.

Annual manufacturing survey datasets are employed for the analysis in this study. Because the existence of data quality problems and the missing of key variables, therefore, the cleaned and balanced panel datasets are constructed for only four periods: 1990-1995, 1998-2000, 2003-2006, and 2008-2010. Substantial economic and political events are adopted to describe the contextual background of the present analysis. For these four periods the study provides empirical results from the baseline analysis for productivity measurements, estimation of average carbon abatement cost, and the impact of energy price on environmental productivity change and average abatement cost. To measure the environmental productivity change and average carbon abatement cost, the disposability of CO_2 emissions as undesirable outputs are not free activities is firstly assumed to respond the different impact of carbon regulation on manufacturing sector.

The findings from the chapter 3 reported that on average the TFP with CO_2 emissions over time has grown faster than the TFP without CO_2 emissions particularly for the period 1, the period 2, and the period 4. The higher productivity growth with CO_2 emissions provides a clear suggestion that environmental damages should be considered in economic and manufacturing developments. Further, the increase price of oil commodities might affect environmental productivity, in particular for the high energy-intensive sectors in the period 3. Because energy consumption is not considered as input in the analysis, hence no empirical evident showed that the price of oil commodities has a direct impact on manufacturing productivity. Eleven manufacturing sectors are identified to be ready for the implementation of carbon tax based on the positive growth of TFP environment in the period 3 and period 4 after the increasing price of oil commodities.

Results from chapter 4 show that when CO_2 emissions as undesirable outputs are weakly disposable, the average carbon abatement cost has increased as the price of oil commodities increased, particularly in the period 3 and 4. The fluctuation of these average carbon abatement cost is consistent with the trend of value added and carbon intensity because the measurement of carbon abatement cost is based on forgone profit and the amount of CO_2 emissions, even though on average environmental efficiency show improvement. During all periods, the sector that has the lowest average carbon abatement cost is rubber and plastics products and the sector that demonstrated the highest average carbon abatement cost is tobacco. No empirical evidence that the high energy-intensive sectors have a higher average carbon abatement cost.

Findings from chapter 5 verify that when energy dependency increases, the increase of energy price in the period 3 negatively influences the environmental productivity improvements. This finding is confirmed by the facts from table 1.2 which reports the energy intensity of the manufacturing sector worsened in the period 3 and manufacturing firms are expected to admit a significant increase in energy costs. Therefore, the environmental productivity also worsened in the period 3. Furthermore, energy dependency negatively and significantly influenced average abatement cost for the periods 1 and 3. The greater use of energy, the efforts to reduce CO_2 emissions will be easier; hence if more CO_2 emissions can be reduced the average carbon abatement cost will decrease. When energy is still subsidized during periods 1 and 2, the fuel price is significant and has a negative impact on average carbon abatement cost. Whereas energy subsidy started to be removed in the period 3, the fuel price is statistically significant and started to show a positive relationship to the averaged carbon abatement cost. Electricity price has a significantly negative relationship to the marginal abatement cost when energy subsidy is removed.

The recent rising price of domestic oil commodities can be seen as quasi-carbon regulation instrument as a basis to assume that CO_2 emissions are weakly disposable. The increase price of oil commodities negatively affected environmental productivity and increase energy intensity. Even though technical progress are the sources of productivity growth over time, when CO_2 emissions are considered, the impacts of the increase price of oil commodities are greater than technological improvement. Arguably, it can be interpreted that when energy efficient is not appropriately implemented in manufacturing sector resulting in the decrease of environmental productivity growth over time.

6.2. Policy recommendations

Based on the major conclusions above, several constructive policy recommendations can be proposed to the policy makers as follow:

a. CO_2 emissions as undesirable outputs can be considered in measuring manufacturing sector's productivity growth as a response to the potential impact of climate change mitigation and energy related policies. Moreover, the higher productivity growth with CO_2 emissions provides a clear message to policy makers that environmental damages should be considered in economic and manufacturing developments.
b. Carbon tax as one of economic instruments to control CO_2 emissions can be imposed on manufacturing sector in Indonesia based on the empirical results of this study that most of manufacturing sector show positive TFP environment growth after the increase of domestic oil price.
c. Technological improvement, in particular the cleaner technology, has to become a major concern for the manufacturing firms' long-term strategic planning after the changes in prices of oil commodities.

d. The manufacturing sector performance has to continuously be improved; hence, its roles in contributing to Indonesia's GDP and providing more job opportunities can be maintained.
e. To improve environmental productivity as the one of the manufacturing sector performance's indicators, energy efficiency has to be appropriately implemented.

The situations that make it possible to implement the policy recommendations are:

a. The stability of politics and economics conditions in Indonesia. In the short run, it is assumed that there are no circumstances that significantly affect politics and economics conditions in Indonesia, e.g. economic crisis, political reforms, or natural disasters.
b. Manufacturing sector is still one the most important sector in Indonesia due to its large share to GDP and large potential for creating job opportunities. If manufacturing sector is not the important sector, then productivity and efficiency are not the main concerns.

6.3. Limitations and suggestions for further study

In spite of the fact that there was no a piece of perfect study in the real world, this study was conducting under some limitations. First of all, this study employed primary data that obtained from annual manufacturing survey. The main methods employed for data cleaning are based on the best practice methods in removing outliers of the raw datasets. If different methods are applied may obtain different results of data cleaning. Second, the CO_2 emissions in this study are calculated based on the combustion of fossil fuels. This may not fully reflect the total amount of CO_2 emitted by manufacturing sector. Because the source of CO_2 emissions may come from other sources, e.g. from particular production process or non-fossil fuels combustions. Third, the measurement and calculation in this study using available methods which possibly consist of some weakness. Therefore, the results and conclusions might not reflect the actual condition of Indonesia's manufacturing sector nor meet the expectations.

Several improvements and more detailed analysis are suggested for the future study to obtain a comprehensive description of the Indonesia's manufacturing sector performance. The efforts are expected to enable to propose more constructive policy designs and recommendations for the policy makers.

References

Chapter 2: Data cleaning and panel data:

Aggarwal CC (2013) Outlier Analysis, Springer;

Basu S, and Meckesheimer M (2007) Automatic Outlier Detection for Time Series: An Application to Sensor Data, Knowledge and Information Systems, Volume 11 Issue 2, pp. 137 – 154;

BPS (2008) Large and Medium Industrial Statistics Indicators, Statistics of Indonesia Catalogue, No. 6102001;

Chapman AD (2005) Principle and Methods of Data Cleaning: Primary Species and Species-Occurrence Data, version 1.0. Report for the Global Biodiversity Information Facility, Copenhagen;

Guyon I, Matic N, and Vapnik V (1996) Discovering Informative Patterns and Data Cleaning, AAAI Technical Report WS-94-03;

Manning C, Aswicahyono H, Purnagunawan MR (2012) Labor Demand, Productivity, and Unit Labor Costs in Manufacturing, USAID-SAEDI project, DAI/Nathan Group;

Maletic JI, and Marcus A (2000) Data Cleansing: Beyond Integrity Checking, Proceedings of The Conference on Information Quality (IQ2000), Massachusetts Institute of Technology, October 20-22, pp. 200-209;

Rahm E, and Do HH (2000) Data cleaning: Problems and Current Approaches, IEEE Database Engineering Bulletin, Vol. 23, pp. 3-13;

UNStat (2014) United Nations Statistics Division, http://unstats.un.org;

Van den Broeck J, Cunningham SA, Eeckels R, and Herbst K (2005) Data cleaning: detecting, diagnosing, and editing data abnormalities. PLoS Medicine, 2(10), e267;

Varian HR (2010) Intermediate Microeconomics: A Modern Approach, 8th Edition, W. W. Norton & Company, New York – London;

Chapter 3: Baseline analysis of productivity change with and without considering carbon dioxide emissions:

Armundito E, Kaneko S (2014) Note on Data Cleaning and Panel Data Development of Indonesian Manufacturing Survey Data (IDEC DP2 Series No. 4-9). Hiroshima University, Graduate School for International Development and Cooperation (IDEC)

Aswicahyono H, Hill H (2002) “Perspiration” vs “Inspiration” in Asian Industrialisation: Indonesia Before the Crisis. J Dev Stud 38:138–163. doi: 10.1080/00220380412331322381

Bing W, Yanrui W, Pengfei Y (2008) Environmental Regulation and Total Factor Productivity Growth: An Empirical Study of the APEC Economies. Econ Res J 5:19–32.

Boyd GA, Tolley G, Pang J (2002)) Plant level productivity, efficiency, and environmental performance of the container glass industry. Environ Resour Econ 23:29–43.

Chung YH, Färe R, Grosskopf S (1997) Productivity and undesirable outputs: A directional distance function approach. J Environ Manage 51:229–240. doi: http://dx.doi.org/10.1006/jema.1997.0146

Coelli TJ (1995) Recent Developments in Frontier Modelling and Efficiency Measurement. Aust J Agric Resour Econ 39:219–245. doi: 10.1111/j.1467-8489.1995.tb00552.x

Domazlicky BR, Weber WL (2004) Does environmental protection lead to slower productivity growth in the chemical industry? Environ Resour Econ 28:301–324. doi: 10.1023/B:EARE.0000031056.93333.3a

Eggleston H, Buendia L, Miwa K, Ngara T, Tanabe K (2006) IPCC guidelines for national greenhouse gas inventories. Institute for Global Environmental Strategies, Hayama, Japan

Färe R, Grosskopf S, Lovell C (1994) Production frontiers. Cambridge University Press

Färe R, Grosskopf S, Lovell C a K, Pasurka C (1989) Multilateral productivity comparisons when some outputs are undesirable: a nonparametric approach. Rev Econ Stat 71:90–98. doi: 10.2307/1928055

Färe R, Grosskopf S, Pasurka C a. (2001) Accounting for air pollution emissions in measures of state manufacturing productivity growth. J Reg Sci 41:381–409. doi: 10.1111/0022-4146.00223

Färe R, Grosskopf S, Tyteca D (1996) An activity analysis model of the environmental performance of firms—application to fossil-fuel-fired electricity utilities. Ecol Econ 18:161–175. doi: 10.1016/0921-8009(96)00019-5

Global Carbon Project (2014) The Global Carbon Project. http://www.globalcarbonproject.org. Accessed 14 Apr 2015

Goeltom M (1995) Indonesia’s Financial Liberalization : an Empirical Analysis of 1981-88 Panel Data. ASEAN Economic Research Unit, Institute of Southeast Asian Studies, Singapore.

He F, Zhang Q, Lei J, Fu W, Xu X (2013) Energy efficiency and productivity change of China's iron and steel industry: Accounting for undesirable outputs. Energy Policy 54:204–213. doi: 10.1016/j.enpol.2012.11.020

Heng Y, Lim SH, Chi J (2012) Toxic air pollutants and trucking productivity in the US. Transp Res Part D Transp Environ 17:309–316. doi: 10.1016/j.trd.2012.01.001

IEA (2013) Energy Balances of non-OECD countries 2013. International Energy Agency, Paris

Ikhsan-Modjo M (2006) Total Factor Productivity in Indonesian Manufacturing: a Stochastic Frontier Approach. Monash University (ABERU Discussion Paper 28).

Kaneko S, Managi S (2004) Environmental productivity in China. Econ Bull 17:1–10.

Krautzberger L, Wetzel H (2012) Transport and CO2: Productivity Growth and Carbon Dioxide Emissions in the European Commercial Transport Industry. Environ Resour Econ 53:435–454. doi: 10.1007/s10640-012-9569-z

Kumar S (2006) Environmentally sensitive productivity growth: A global analysis using Malmquist-Luenberger index. Ecol Econ 56:280–293. doi: 10.1016/j.ecolecon.2005.02.004

Managi S, Jena PR (2008) Environmental productivity and Kuznets curve in India. Ecol Econ 65:432–440. doi: 10.1016/j.ecolecon.2007.07.011

Mandal S, Madheswaran S (2010) Environmental efficiency of the Indian cement industry: An interstate analysis. Energy Policy 38:1108–1118. doi: 10.1016/j.enpol.2009.10.063

Oh DH (2010) A global Malmquist-Luenberger productivity index. J Product Anal 34:183–197. doi: 10.1007/s11123-010-0178-y

Pangestu M (1996) Economic Reform, Deregulation, and Privatization: The Indonesian Experience. Centre for Strategic and International Studies, Jakarta

Piot-Lepetit I, Moing ML (2007) Productivity and environmental regulation: The effect of the nitrates directive in the French pig sector. Environ Resour Econ 38:433–446. doi: 10.1007/s10640-007-9086-7

Timmer MP (1999) Indonesia's Ascent on the Technology Ladder: Capital Stock and Total Factor Productivity in Indonesian Manufacturing, 1975–95. Bull Indones Econ Stud 35:75–97. doi: 10.1080/00074919912331337497

Tyteca D (1997) Linear programming models for the measurement of environmental performance of firms - Concepts and empirical results. J Product Anal 8:183–197.

Vial V (2006) New Estimates of Total Factor Productivity Growth in Indonesian Manufacturing. Bull Indones Econ Stud 42:357–369. doi: 10.1080/00074910601053227

Zhang C, Liu H, Bressers HT a, Buchanan KS (2011) Productivity growth and environmental regulations - accounting for undesirable outputs: Analysis of China's thirty provincial regions using the Malmquist-Luenberger index. Ecol Econ 70:2369–2379. doi: 10.1016/j.ecolecon.2011.07.019

Chapter 4: Environmental efficiency and carbon abatement cost:

Chambers R, Chung Y, Färe R (1996) Benefit and distance functions. Journal of economic theory. 70: 407-419;

Chambers R, Chung Y, Färe R (1998) Profit, directional distant function and Nerlovian efficiency. Journal of optimization theory and application. 98, 351-364;

Chung YH, Färe R, Grosskopf S (1997) Productivity and undesirable outputs: a directional distance function approach. Journal of environmental management, 51(3), 229-240.

Färe R, Grosskopf S, Lovell CAK, Pasurka C (1989) Multilateral productivity comparison when some outputs are undesirable: a non-parametric approach. The review of economic and statistics. 71, 90-98;

Färe R, Grosskopf S (2000) Theory and application of directional distance functions. Journal of productivity analysis. Volume 13, pp. 93–103;

Färe R, Grosskopf S, Pasurka C (2001) Accounting for Air Pollution Emissions in Measures of State Manufacturing Productivity Growth. Journal of Regional Science, Wiley Blackwell, vol. 41(3), pages 381-409.

Färe R, Grosskopf S, Noh DW, Weber W (2005) Characteristics of a pollution technology: theory and practice. Journal of economics. 126: 469-492:

Hernandez-Sancho F, Picazo-Tadeo AJ, Reig-Martinez E (2000) Efficiency and environmental regulation: an application to Spanish wooden goods and furnishings industry. Environmental and resource economics. 15: 365-378;

Mandal SK, Madheswara S (2010) Environmental efficiency of the Indian cement industry: An Interstate Analysis. Energy policy. Volume 38, pp. 1108-1118;

Picazo-Tadeo AJ, Reig-Martinez E, Hernandez-Sancho F (2005) Directional distance functions and environmental regulation. Resource and energy economics. Volume 27, Issue 2, pp. 131-142;

Priambodo A, Khumar S (2001) Energy use and carbon dioxide emission of Indonesian small and medium scale industries. Energy conversion and management. 42: 1335-1348;

Chapter 5: The impacts energy price on environmental productivity and carbon abatement cost:

Aye GC, Dadam V, Gupta R, Mamba B (2014) Oil price uncertainty and manufacturing production. Energy Econ 43:41–47. doi: 10.1016/j.eneco.2014.02.004

Hamilton JD (2009) Causes and Consequences of the Oil Shock of 2007-08. Cambridge, MA

Hamilton JD (1988) A Neoclassical Model of Unemployment and the Business Cycle. J Polit Econ 96:593. doi: 10.1086/261553

Hooker MA (2002) Are oil shocks inflationary?: Asymmetric and nonlinear specifications versus changes in regime. J Money Credit Bank 34:540–561.

Appendix I : Number of manufacturing firms based on 2-digit ISIC Revision 3 from 1990 to 2000

Code	Classification	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
15	Food product and beverages	3,655	3,516	3,790	3,943	4,078	4,521	4,670	4,769	4,573	4,666	4,661
16	Tobacco	961	943	902	880	748	815	874	839	785	807	821
17	Textiles	1,828	1,794	1,881	1,953	2,017	2,242	2,173	2,255	2,188	2,055	2,027
18	Wearing apparel	1,766	1,699	1,870	1,798	1,862	2,110	2,159	2,329	1,764	2,214	2,258
19	Tanning and dressing of leather	364	442	481	507	544	606	610	646	600	603	587
20	Wood and product of wood and plaiting	1,357	1,269	1,422	1,491	1,599	1,767	1,692	1,793	1,747	1,779	1,766
21	Paper and paper product	184	217	258	268	305	311	345	359	403	433	431
22	Publishing, printing and reproduction	566	538	548	555	577	645	704	732	535	533	540
23	Coal, refined petroleum product and nuclear fuel	5	9	13	13	12	25	39	37	58	66	57
24	Chemicals and chemical product	864	814	852	892	922	1,008	1,041	1,035	1,055	1,067	1,087
25	Rubber and plastics product	1,190	1,170	1,233	1,249	1,302	1,379	1,481	1,509	1,304	1,371	1,392
26	Others non-metallic mineral product	1,323	1,393	1,461	1,498	1,603	2,027	2,064	2,158	1,948	1,880	1,907
27	Basic metals	161	179	200	216	226	257	283	265	232	225	221
28	Fabricated metal product and equipment	566	584	617	646	722	870	888	969	833	880	892
29	Machinery and equipment n.e.c.	259	271	324	343	365	431	504	485	326	348	347
30	Office, accounting, and computing machinery	7	6	8	9	6	6	6	6	8	8	8
31	Electrical machinery and apparatus n.e.c.	197	216	250	269	319	367	459	393	245	257	259
32	Radio, television and communication equipment	6	9	12	17	19	21	19	22	227	234	227
33	Medical, precision, optical instruments, and watch	51	55	64	59	65	72	62	73	75	63	61
34	Motor vehicle, trailers and semi-trailers	196	204	220	235	241	259	279	279	232	244	246
35	Other transport equipment	242	245	271	279	296	320	322	340	304	320	312
36	Furniture and manufacturing n.e.c.	788	921	971	1,043	1,189	1,492	1,711	1,704	1,909	1,949	1,989
37	Recycling	0	0	0	0	0	0	0	0	72	68	78
	TOTAL	**16,536**	**16,494**	**17,648**	**18,163**	**19,017**	**21,551**	**22,385**	**22,997**	**21,423**	**22,070**	**22,174**

Appendix II: Number of manufacturing firms based on 2-digit ISIC Revision 3 from 2001 to 2010

Code	Classification	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
15	Food product and beverages	4,562	4,543	4,419	4,649	4,718	6,619	6,345	6,078	5,888	5,344
16	Tobacco	811	813	785	807	860	1,282	1,204	1,124	1,044	902
17	Textiles	1,978	1,955	1,916	1,954	1,973	2,968	2,883	2,599	2,454	2,322
18	Wearing apparel	2,055	1,947	1,841	1,860	1,911	3,159	2,952	2,497	2,351	2,177
19	Tanning and dressing of leather	560	540	502	492	475	792	738	688	665	641
20	Wood and product of wood and plaiting	1,739	1,693	1,488	1,437	1,358	1,841	1,704	1,487	1,311	1,159
21	Paper and paper product	345	342	343	357	365	489	469	429	416	401
22	Publishing, printing and reproduction	592	582	568	582	595	947	896	782	733	540
23	Coal, refined petroleum product and nuclear fuel	40	39	42	40	39	61	59	65	62	59
24	Chemicals and chemical product	1,027	1,014	994	1,005	1,007	1,179	1,135	1,075	1,050	1,006
25	Rubber and plastics product	1,493	1,503	1,464	1,491	1,473	1,826	1,760	1,667	1,624	1,550
26	Others non-metallic mineral product	1,657	1,621	1,529	1,513	1,536	2,075	1,952	1,813	1,725	1,613
27	Basic metals	239	237	231	230	226	304	290	273	274	267
28	Fabricated metal product and equipment	906	909	865	861	821	1031	985	902	880	849
29	Machinery and equipment n.e.c.	562	538	508	508	494	565	552	530	505	487
30	Office, accounting, and computing machinery	11	11	10	10	10	14	11	10	10	10
31	Electrical machinery and apparatus n.e.c.	239	243	243	242	238	273	260	247	239	230
32	Radio, television and communication equipment	85	127	138	147	141	193	188	184	178	172
33	Medical, precision, optical instruments, and watch	69	70	63	60	58	62	61	60	58	56
34	Motor vehicle, trailers and semi-trailers	249	280	276	272	270	319	305	296	289	282
35	Other transport equipment	296	306	297	297	285	345	339	317	307	290
36	Furniture and manufacturing n.e.c.	1,876	1,821	1,796	1,830	1,820	3,044	2,821	2,489	2,328	2,099
37	Recycling	1	4	4	10	11	78	85	82	75	36
	TOTAL	**21,392**	**21,138**	**20,322**	**20,654**	**20,684**	**29,466**	**27,994**	**25,694**	**24,466**	**22,492**

Appendix III: Indonesian GDP deflator

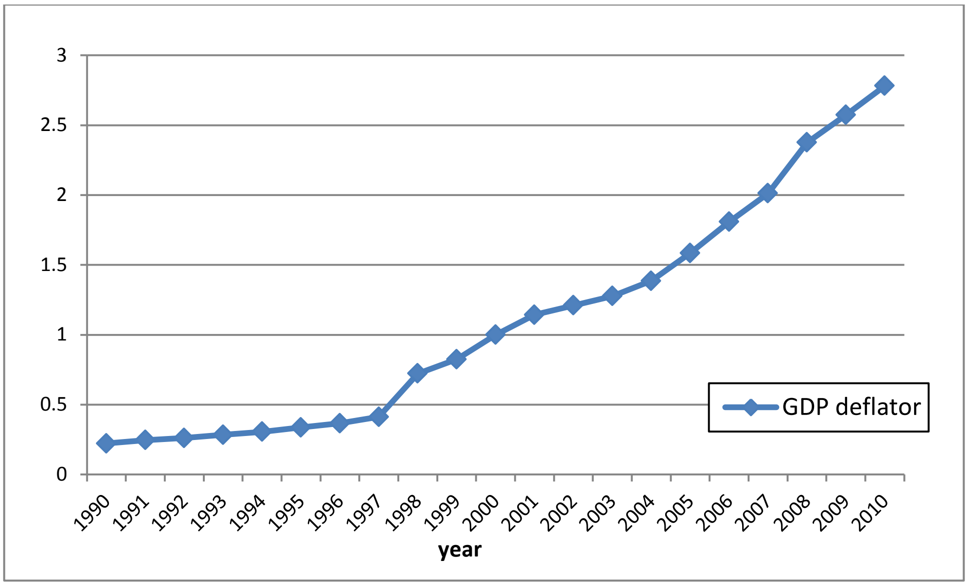

Figure III.1. Indonesian GDP deflator, 1990-2000