Energy Intensity in Indonesia: Four Empirical Studies with Policy Implications

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Abstract

Indonesia is a large energy user, with energy supply heavily based on fossil fuels and with a long history of subsidies to energy use. The Indonesian Government has set out to make the country more energy-efficient, in the process reducing energy use per unit of real GDP (energy intensity), while reducing the reliance on fossil fuels. To contribute to improved policy development, this study attempts to identify the determinants of the changes in energy intensity across industries and relative to other countries in Indonesia's region and analyse the factors that affect energy efficiency.

To support this process, this thesis sets out to analyse changing trends in energy intensity in Indonesia relative to its ASEAN neighbours, to improve understanding of changes in energy use and energy intensity in key industries within Indonesia, to document variations in energy intensity across Indonesia’s 34 provinces and to draw from these analyses some lessons about the future direction of energy policies in Indonesia. The analysis is based on final energy consumption rather than total final energy supply, and hence excludes energy used in the production of final energy. It draws mainly on data on real value-added and energy consumption by industry from various sources. The analysis also relies heavily on decomposition analysis, enabling the change in energy intensity to be split between changes in the structure of economic activity and changes in the within-industry energy intensity.

The first research problem compares the energy intensity performance in Indonesia to other ASEAN-6 countries from 1971 to 2016. In terms of structure and industry effects on aggregate energy intensity, all the ASEAN-6 countries showed a shift in industry value added to more energy-intensive industries, which was to varying degrees offset by falling within-industry energy intensity. However, the analysis shows that both element of this trend was most pronounced in Indonesia. As the energy intensity of manufacturing and, particularly, transport, is much higher than that of the rest of the economy, by 2016 over 90% of total final energy consumption was from the manufacturing and transport sectors. For this reason, this study concentrates more detailed analysis on the manufacturing sector and transport sector.

The second research problem discusses energy intensity in the manufacturing sector from 1980 to 2015. The overall energy intensity of Indonesia’s manufacturing sectors has seen a strong and continuous decline, with a reduction of 65% over the 35 years, reinforced by some limited changes in industry structure towards lower intensity. Over the whole period, this reduction was dominated by increases in energy efficiency

within industries, as indicated by a 62% fall in the within-industry intensive index. By contrast, the effect of moving to a less intensive industry structure was much less important (a 9% fall in the structural index). The greatest rise in energy efficiency within the industry happened before the Financial Crisis (from 1980 to 97). The shock of the Financial Crisis saw an unexpected reaction when value-added fell by 13% but energy use remained largely unchanged, implying a rise in energy intensity. From 2000 to 2015 the earlier trends resumed, but at a more subdued pace, where over this period aggregate intensity fell by 23%.

The third research problem presents a review of energy intensity in the transportation sector from 2000 to 2016. Energy use in transport grew more slowly than overall energy use in Indonesia for about 30 years after 1971, falling from 58% of the total in 1971 to only 38% in 2000, but since surged back to 51% by 2016. Over 2000 to 2016 total final energy consumption in transport has grown by 10% per annum so that transport now provides a large and rapidly growing component of total energy use. In 2016, almost all passenger kilometres are travelled on roads (95.6%), with virtually no rail (0.5%) or water (0.3%) passenger travel, but with a small but rising share of air travel (3.6%). Rail is also absent in freight movements in Indonesia, accounting for only 0.2% of total tonne-kilometre movements in 2016, which are mainly divided between road for 41.1% and water for 53.6% in 2016, although air freight is rising rapidly, reaching 5.0% in 2016.

The fourth research problem investigates the disparities of energy usage levels specifically in energy intensity amongst 33 provinces in Indonesia from 2010 to 2015. The results capture the existence of a convergence process and the shrinking in energy usage disparities across the 33 provinces in Indonesia from 2010 to 2015. In addition to the inequality measures, the decomposition analysis was also applied to explore the driving forces of the energy intensity across provinces in Indonesia. The results show that the structural effect was the main factor resulting in the increase in energy intensity in most provinces, while the role of intensity effect has differed in different provinces.

Regarding policy in the transport sector, the government needs to encourage rail, discourage air and continue to focus on the reduced energy intensity of road (prices, vehicle technology, and better roads). In freight, the central dynamic over 2000 to 2016 has been the modal shift from the energy-efficient water and rail to road and air. Energy efficiency policy should encourage continued freight movements by water, discourage the rise of air freight and encourage rail developments. By comparison with transport, manufacturing has seen, over the period since 1971, a steady fall in overall energy intensity, and this has continued after 2000. This has been due to strong declines in within-industry energy-intensive, with falling energy intensity across most industries at the three-digit level, and some structural changes (such as the falling share of value-added in the high energy using cement and lime sector) and more general industry upgrading. Continued attention to the modernisation of industrial technologies and structure seems necessary.

Declaration

"I, Dhani Setyawan, declare that the PhD thesis entitled "Energy Intensity in Indonesia: Four Empirical Studies with Policy Implications" is no more than 100,000 words in length including quotes and exclusive of tables, figures, appendices, bibliography, references and footnotes. This thesis contains no material that has been submitted previously, in whole or in part, for the award of any other academic degree or diploma. Except where otherwise indicated, this thesis is my own work".

Signature [redacted] Date: 9 August 2019

Dhani Setyawan

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Alhamdullillaahi rabbil ‘alamiin

(Praise be to Allah, Lord of the Worlds)

Quran 1:1

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To me and hopefully to my children, this thesis is a testimony to the belief that nothing is impossible with God’s will and our perseverance. Importantly, this journey has not only been about advancement at an academic level, it has also offered many life lessons. On that note, I would like to thank everyone who has helped me complete not only this thesis, but also a part of my journey in life.

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Acronyms

ACE	ASEAN Centre for Energy
ADB	Asian Development Bank
ADO	Automotive diesel oil
AEI	Aggregate energy intensity
AISI	Asosiasi Industri Sepeda Motor Indonesia/ Indonesia Motorcycles Industry Association
ASEAN	Association of South East Asian Nations
Bappenas	Badan Perencanaan Pembangunan Nasional/ Indonesia's National Development Planning Agency
BAU	Business-As-Usual
BCC	Banker, Charnes and Cooper
BoE	Barrels of Oil Equivalent
BP	British Petroleum
BPS	Badan Pusat Statistik/ the Indonesian Statistic Bureau
BRICS	Brazil, Russia, India, China and South Africa
CCR	Charnes, Cooper, and Rhodes
CNG	Compressed Natural Gas
CO2	Carbon dioxide
CRS	Constant Returns to Scale
CV	Coefficient of Variation
DEA	Data Envelopment Analysis
DEN	Dewan Energi Nasional/ National Energy Council of Indonesia
DINT	Intensity effect
DMU	Decision Making Unit
DSTR	Structural effect
DTOT	Aggregate energy intensity
EIA	United States Energy Information Administration
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
ESCO	Energy Conservation Services Companies
ESPC	Energy Saving Performance Contract
EU	European Union
EU-27, EU-15	Twenty-seven or fifteen member states of the European Union
FDI	Foreign Direct Investment
FO	fuel oil
GDP	Gross Domestic Product
GHG	Greenhouse Gas Emissions
GRDP	Gross Regional Domestic Product
IDA	Index Decomposition Analysis
IDO	industrial diesel oil
IEA	International Energy Agency
IFR	International Federation of Robotics
IIB	Indonesia Investment Board/ Badan Koordinasi Penanaman Modal

IMF	International Monetary Fund
I-O datasets	Input-output datasets
IRENA	International Renewable Energy Agency
ISIC Codes	International Standard Industrial Classification codes
ISO 50001	Company level certification based on a standard published by the International Organization for Standardization (ISO)
KEN	Kebijakan Energi Nasional/ National Energy Policy of Indonesia
KToE	Kilotonne of Oil Equivalent
LMDI-II	Logarithmic Mean Divisia Index II
LPG	Liquid petroleum gas
MBoE	Million Barrels of Oil Equivalent
MEMR	Indonesia Ministry of Energy and Mineral Resources
MEPS	Minimum Energy Performance Standards
MNC	Multinational corporation
MToE	Million tonnes of oil equivalent
OECD	Organisation for Economic Co-operation and Development
Perpres	Peraturan Presiden/ President Regulation
PKM	passenger per kilometre
PPP	Purchasing Power Parity
PT KAI	Perusahaan Terbatas Kereta Api Indonesia/ Indonesian Railways Company
RIKEN	Rencana Induk Konservasi Energi Nasional/ the National Master Plan for Energy Conservation of Indonesia
Rp	Rupiah (Indonesian Currency)
RUEN	Rencana Umum Energi Nasional/ National Energy Plan of Indonesia
SBM	Slacks-Based Measure
SDA	Structural Decomposition Analysis
SFA	Stochastic Frontier Analysis
SLoCaT	Sustainable, Low Carbon Transport
SOE	State-owned enterprise
ST-IDA	Spatial-Temporal Index Decomposition Analysis
TFC	Total Final Energy Consumption
TFEE	Total-Factor Energy Efficiency
The G7	Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States.
TJ	Terra joules
TKM	Tonne per kilometre
ToE	Tons of Oil Equivalent
UEE	Underlying Energy Efficiency
UNSD	United Nations Statistics Division
US$	United States Dollars
USA	United States of America
VRS	Variable Returns to Scale
WRI	World Resources Institute

Chapter 1
Introduction

1.1. Background

Amongst Southeast Asia countries, Indonesia has the largest energy consumption at over 36% of the region's total energy demand (IEA 2017a). Since 2003, Indonesia's energy consumption has increased rapidly every year, from 840 million barrels of oil equivalent[1] (BOE) to 1,293 million BOE in 2014 (MEMR 2015), with an average growth of 4.9% per year over the last five years (BP 2018), while economic growth averaged 5.2% per year during the same period (WorldBank 2018a). The oil source still dominates the total energy mix, even though there has been a decline in oil source consumption from 60 per cent in 2000 to 46 per cent in 2015 (MEMR 2015). This decline in consumption of oil together with an increase in coal and natural gas consumption, potentially a result of government programs aimed at reducing fossil fuel dependency by conducting energy conservation and diversification programs.

Several studies by international energy organizations have shown that Indonesia is facing critical energy security problems (Nugroho 2015). Energy demand in Indonesia has been dominated by fossil fuel. In 2015, fossil fuels have accounted for approximately 95.8% of total energy consumption, where oil accounts for around 46 per cent, natural gas 23 per cent, coal around 26 per cent, with the remaining 5 per cent being sourced from renewable energy (Peraturan Presiden 2017). The use of renewable energy is still far from the government projected expectations (Nugroho 2015), where the government aims to increase the use of renewable energy up to 23% in 2025 (Peraturan Presiden 2017). In other words, as the share of renewable energy consumption is still low, the goal of reducing the use of fossil energy has not yet been met. The Indonesian Government has set out to make the country more energy efficient (Nugroho 2015), in the process reducing energy use per unit of real gross domestic product (GDP) (that is, the energy intensity), while reducing the reliance on fossil fuels. Formulating a good energy conservation program and fostering economic growth are essential in reducing energy consumption in Indonesia. For this reason, energy conservation policies were initiated with Government Regulation No. 70 of 2009 for Energy Conservation. This required every energy user above 6,000 Tons of Oil Equivalent (ToE) per year to implement

[1] A barrel of oil equivalent (BOE) is an energy unit approximating from how much energy is released from burning one barrel (or 158.99 litres) of crude oil.

energy management, with energy conservation activities becoming a pillar of national energy management aimed at improving energy use in an efficient way (Peraturan Pemerintah 2009). As reduction of energy consumption needs to be in line with a balanced implementation of established energy efficiency policies and energy conservation programs, the government has recently enacted Regulation Number 79 of 2014, setting the Indonesian target for 2025 for reducing energy intensity by 1% per year and energy elasticity to less than 1 and increasing the share of renewable energy usage throughout the country (Peraturan Pemerintah 2014). Even though these regulations have been enacted, the government still needs to develop relevant infrastructure in order to invite the active participation of those key sectors that consume large scales of energy.

Indonesia historically has maintained consumption subsidies for domestic retail fuel consumers, with products being sold at a discount from world market prices (Nurdianto and Resosudarmo 2012). Indonesia's high energy subsidy is considered to be the major barrier to energy conservation programs. Low energy prices are considered as a potential hindrance to shift to cleaner sources of energy and fossil fuel subsidies are disincentives for the development of many energy efficiency programs (Resosudarmo, Alisjahbana and Nurdianto 2012). For instance, subsidies for electricity and petrol products (that is, kerosene and diesel which are mostly used in the industrial sector) have encouraged inefficiency and overconsumption of those resources (Gunningham 2013; Mourougane 2010). In addition, subsidized energy prices also discouraged investment in energy diversification and drawbacks for energy suppliers building new infrastructure (IEA et al. 2010; McHugh 2012). As a result, many research studies have concluded that under-priced energy is a major factor hindering energy efficiency programs in Indonesia (IMF 2013; Mourougane 2010; Savatic 2016).

Indonesia is a large energy user, with energy supply heavily based on fossil fuels and with a long history of subsidies to energy use (Resosudarmo, Alisjahbana and Nurdianto 2012; Resosudarmo and Tanujaya 2002). At the moment the Indonesian Government had periodically adjusted the energy prices by reforming the energy subsidies. There are some reasons behind this subsidy reform (IEA 2015a; WorldBank 2014b). First, energy subsidies encourage inefficient energy consumption and contradict the government's objectives to reduce the oil share in the national energy mix. Second, energy subsidies discourage the development of new renewable energy and energy efficiency investment. Last but not least, it severely increased air pollution and jeopardizes the environment (Davis, LW 2014).

In 2014, the highest portion of energy consumption was in the manufacturing sector (43.84%) followed by transport (37.72%), residential (12.01%), commercial (4.15%) and others (2.28%). From the period of 2000 to 2013, the transportation sector experienced the highest growth, which gained on average 6.72% annually, followed by the commercial sector at around 4.66% and industry at 3.34%. In addition to energy issues, Indonesia also has a problem related to high emissions. Based on recent data from the World Resources Institute (WRI 2014), Indonesia has been classified as one of the largest emitters in the world, ranking sixth with 1,981 megatons of CO2 in 2012. This report also pointed out that since the 1960s, its emissions growth has reached an average of around 6.6 per cent per annum. In addition, the IEA (2014) reported that the largest sectoral emissions in Indonesia were coming from the manufacturing sector where growth amounted to 6.9% per year between 1990 and 2012 on average. Following this sector, the second-largest emissions was from transportation, followed by household, agriculture and services.

Tharakan (2015) found Indonesia's energy intensity[2] at around 565 ToE (tonnes of oil equivalent) per million US$ of GDP, which means that for each increase of $1 million of GDP, Indonesia requires the energy of around 565 ToE. As a comparison, Malaysia's energy intensity is around 439 ToE, while the average energy intensity of the OECD countries is only 139 ToE (Tharakan 2015). In other words, the greater the energy intensity is in a country, the less efficient its energy consumption will be. The role of energy efficiency is of great significance in hindering the pace of Climate Change (Ürge-Vorsatz & Metz 2009). Therefore, Climate Change is one of the essential issues facing the Indonesian economy. This can be seen through the commitment of former Indonesia's President Susilo Bambang Yudhoyono which he delivered at the Copenhagen Accord in Denmark, 2009 (Resosudarmo, Alisjahbana and Nurdianto 2012). In this Conference of Parties 15, he pledged Indonesia's commitment to reduce its Greenhouse Gas Emissions (GHG) by 26% by 2020 against Business-As-Usual levels (BAU). Moreover, with international assistance, Indonesia would be able to reduce its emissions by 41% in 2020 against BAU.

Given the above, investigating Indonesia's energy efficiency and energy consumption trends will help to provide knowledge into the factors affecting the low efficiency and high energy use and potential improvement. Nevertheless, there has been very limited research in Indonesian context measuring the performance of energy efficiency which, to the author's knowledge, less interest have been put in investigating energy intensity and its driving forces specifically evaluating the energy efficiency trends of Indonesia looking at different point of views, including international, sectoral and interprovincial comparisons. The insights from this study does not only aim to understand the underlying causal factors associated with the changes in energy intensity in

[2] The ratio between the total energy consumption and Gross Domestic Product (GDP).

Indonesia but can also be applied to forecast its future trend and to design sound policy measures to reduce the level of energy intensity.

1.2. Objectives, Research Questions and Methods

Energy use not only plays an important role in the environmental sustainability of Indonesia but also in addressing Climate Change. One of the negative effects of using fossil fuels is an increasing of GHG emissions in the environment. As a result, one of the main objectives of Indonesia's energy policy is to reduce energy usage, especially from high-emission energy sources. Therefore, in-depth analysis is needed to determine the different policy options that are required to reduce energy consumption. In order to achieve this goal, a decomposition method of energy intensity is required to distinguish between different factors influencing the level of energy efficiency. By applying this method, this study attempts to provide a robust understanding of the implications of energy consumption. Results from this study will also provide an overview of the variations of energy use in the various sectors and regions across Indonesia and ASEAN countries.

This thesis compares and analyses economy-wide energy efficiency in Indonesia. A significant portion of this dissertation investigates the level of Indonesia's energy efficiency and analyses the various driving forces influencing changes in energy intensity. In order to do this, this study seeks to answer four specific research questions:

1. How does energy usage performance of Indonesia compare to other ASEAN countries?
2. What is the energy usage performance of the manufacturing sector?
3. What is the energy usage performance of the transportation sector?
4. What are the characteristics of energy use across provinces in Indonesia? And how they change over time?

In answering these questions, this study also provides policy recommendations related to energy conservation programs from investigating the changes in energy intensity in Indonesia over time.

In order to answer the proposed research questions, this study employs decomposition analysis methodologies. First, this research measures the level of energy efficiency in Indonesia at the national level (cross-country analysis) employing Spatial-Temporal Log Mean Divisia Index. Since research related to energy efficient economies and determinants in the Indonesian case are limited, this study attempts to fill the gap by utilizing an Index Decomposition Analysis (IDA) analysis to make comparisons across countries. The application of this methodology is expected to investigate the factors that have not been examined in energy studies in Indonesia, and to analyse the performance of energy efficiency.

Second, this study examines the driving forces affecting changes in aggregate energy intensity and value-added performance in various levels of Indonesia's industries, particularly at the manufacturing and transportation sectors. Different factors are examined using IDA to identify the effects and significance levels on energy intensity performance in the manufacturing and transportation sector. This methodology separates the influence of intensity and structural effects.

Third, another purpose of this study is to examine energy usage disparities at the regional level across provinces of Indonesia over a period of time. Energy efficiency is assessed not only employing inequality indicators but also applying the index decomposition analysis to provide a robust analysis of the characteristics of energy usage performance across 33 provinces in Indonesia. It will also determine the factors that have affected energy intensity performance in the provincial levels of Indonesia.

This thesis sets out to analyse changing trends in energy intensity in Indonesia relative to its ASEAN neighbours, to improve understanding of changes in energy use and energy intensity in key industries within Indonesia, to document variations in energy intensity across Indonesia’s 33 provinces and to draw from these analyses some lessons about the future direction of energy policies in Indonesia.

1.3. Contribution to Knowledge and Statement of Significance

Empirical research related to the relationship between energy consumption and other economic factors in Indonesia is limited (Jafari, Othman & Nor 2012; Zhu, H et al. 2016). As previous related research in developing countries has resulted in different findings, this study attempts to close the gap in the literature by using index decomposition analysis to shed more light on the contributing factors for the changes of energy consumption and efficiency in Indonesia. The major contribution of this thesis to the related literature lies in its broader scope in examining the trend of energy consumption and efficiency not only across sectoral level but also across the regional level. The generalisability of available published research on this issue in the Indonesian context has only decomposed the Indonesian economy into the sectoral level. Such expositions are now unsatisfactory because they do not represent the context of Indonesia, which also encounters large disparities as an archipelagic country. Therefore, this thesis will adjust prior studies by adapting them to the current context of Indonesia, while introducing various new policies that have been recently implemented by the government, particularly in energy conservation.

Apart from analysing the changes of energy intensity in Indonesia, this study will also identify sectors that are more energy efficient, distinguish the driving forces of changes in energy intensity and analyse the factors that affect the energy efficiency. Unlike previous research, this study employs a decomposition method that analyses the determining factors for the changes in energy intensity in Indonesia. Results of this study are expected to provide information on the dynamics of energy intensity in Indonesia, and on which factors have the greatest effect on energy intensity changes in Indonesia. This research is also expected to provide information for the government to formulate policies that help reduce energy usage and minimize the adverse impacts of Climate Change. Moreover, this study is expected to extend the knowledge base related to energy conservation programs in Indonesia. This study can also be utilized as a basis for further research into energy consumption and emissions in other developing countries.

1.4. Research Methodology

Energy intensity is generally been measured by employing two methods, namely (1) the ratio of energy use to output/activity (the energy/output ratio) and (2) a decomposition index/method as summarized in Chapter 2.

The energy/output ratio computes energy intensity at the aggregate level by dividing energy consumption and economic activity (value-added). As this study investigates end-use sectors, final energy consumption is employed to compute the energy/output ratio. This measure is computed by dividing final energy consumption per sectoral value-added. Total final energy consumption indicates the energy that is actually used by final consumers, including the energy consumed in residential, the commercial sector and transportation. Final energy consumption in this study excludes energy consumed in conversion activities such as electricity generation, petroleum refining and coal product manufacturing. In particular, this study quantifies the contribution of energy efficiency improvements and structural changes to Indonesia’s energy intensity and provides a deeper analysis of specific effects within subsectors over various period.

This study investigates two sectors in Indonesia including the manufacturing and transportation sectors, whereas both sectors accounted for more than two-thirds of Indonesia's energy usage during the study period. For the manufacturing sector, this study employs industrial gross value-added, while for the transportation sector, this study uses turnover measures (that is, passenger kilometre (PKM) for Passenger transportation and tonne per kilometre (TKM) for freight transport).

Value-added in industry, in general, is the share or contribution of government, private business or industry to the aggregate gross domestic product (GDP), also described as GDP by industry or GDP by sector. The sum of value added at all levels and/ or the total of all levels of production occurring inside a country is computed and defined as GDP. The total value-added is defined as the market price of services or the final product, which only calculates production within a specified period.

Industry gross value-added quantifies the output value at base price subtracted by the total intermediate value at purchasers' price, where it eliminates energy and other intermediate inputs employed in the production process. The energy/output ratio is an aggregate measure that provides information related to economic trends in energy intensity. Without having further disaggregated analysis and data, it is difficult to examine the reason for the energy intensity trend. Thus, to investigate this trend, it is necessary to further investigate at the sectoral or sub sectoral level to recognize the driving factors inducing these trends, for instance, shifts in the economic structure and/or energy efficiency improvements.

Three effects are conventionally measured in many energy intensities studies (Ang 2004, 2015): (1) the structural effect. This is utilized to measure changes in energy consumption as a result of changes in activity mix by the subsector. This effect can determine changes in the energy intensity resulting from changes in the composition of various economic sectors, (2) the intensity effect. This is employed to measure changes in the energy intensity caused by the improvement of technical efficiency in each sector of the economy. This relates to changes in the economic sector that involve both thermodynamic and economic efficiency (Jimenez & Mercado 2014) and employed to estimate changes in energy consumption as a result of changes in the subsector energy intensities and (3) the activity effect. This is used to measure the effect of changes in energy consumption as a result of changes in the sector's overall activity level.

In this study, the structure effect of the productive sectors will be used to measure the changes in energy intensity that result from a transition of economic sectors such as agriculture and industry. Meanwhile, the efficiency effect determines the changes in energy intensity resulting from efficiency improvements within subsectors of the economy (that is, agriculture and industry).

Research into energy intensity decomposition in Indonesia is still relatively limited. Therefore, to answer the research questions, this study will mostly utilize the Index IDA. The IDA methodology can be used to obtain information from energy indicators that are acquired at each level of the energy hierarchy for the analysis of energy usage trends (Choi & Ang 2012). There are specific reasons why the IDA is appropriate for application in this proposed research. For example, according to Ang and

Zhang (2000), Ang and Liu (2001), and Ang (2006), IDA can be utilized to quantitatively decompose energy intensity into several 'effects' including structural, intensity, and activity effects. Another benefit is that this method can be used for the decomposition of multiple factors with zero residual errors and incomplete parts of data sets (Xu, S-C, He & Long 2014). IDA can also be applied to perform comparative analyses within a time series to observe past energy intensity changes and identify any potential energy efficiency improvement programs (Ang 1994).

The proposed research is expected to provide an understanding of the various factors that affect the level of energy efficiency and energy intensity changes in Indonesia. By understanding the various determinants, it is expected that the energy efficiency policies in Indonesia can be better formulated with more robust knowledge. This study attempts to provide an overview for conceptualizing the complexity of energy issues and capture driving forces that substantially affect energy intensity at sectoral levels in Indonesia and across countries. By presenting the various factors of energy efficiency and input factors, this study is expected to provide better policy-making measures in the future, which take into account the environmental impact in order to achieve the target of energy consumption reduction.

1.5. Outline

The first research problem (see Chapter 3) is to compare the energy intensity performance in Indonesia to other selected ASEAN countries. This chapter decomposed the changes in total energy intensity in the ASEAN-6 countries (i.e. Indonesia, Vietnam, Thailand, Singapore, The Philippines and Malaysia) for the period from 1971 to 2016. For this goal, this chapter employs a multiplicative Log Mean Divisia Index II (LMDI-II) method and Spatial-Temporal Index Decomposition Analysis (ST-IDA). It is demonstrated in this chapter that the aggregate trend of the changes of ASEAN-6 energy intensity in the past forty-five years has been decreasing. In terms of structure and industry effects on aggregate energy intensity, all of the ASEAN-6 countries showed a shift in industry value added to more energy-intensive industries which also offset by falling within-industry energy intensity.

The second research problem (see Chapter 4) discusses energy intensity performance in the manufacturing sector. The manufacturing sector is the second-largest energy-consumer in Indonesia (after the transportation sector) and one of the largest contributors to Indonesia's output. Thus, it is important to know the energy usage performance of this sector. This chapter discusses the factors affecting changes in energy consumption in various subsectors of Indonesia's industry and investigate the energy intensity across manufacturing subsectors. This chapter analyses the specific characteristics of energy intensity in the manufacturing sector in Indonesia from 1980 to 2015. This has not been investigated a great deal in the past, particularly when employing the LMDI-II method.

The third research problem (see Chapter 5) presents a further review of energy intensity in the transportation sector. Indonesia's transport sector has experienced rapid growth that has caused excessive fossil fuel energy consumption. As the highest energy-consuming sector in Indonesia, it is important to investigate the performance of the transportation sector. This section analyses the specific characteristics of energy intensity in the transportation sector in Indonesia from 2000 to 2016 by employing a multiplicative LMDI-II. This study examines passenger and freight transport in Indonesia, including the four modes of road, rail, Water and air.

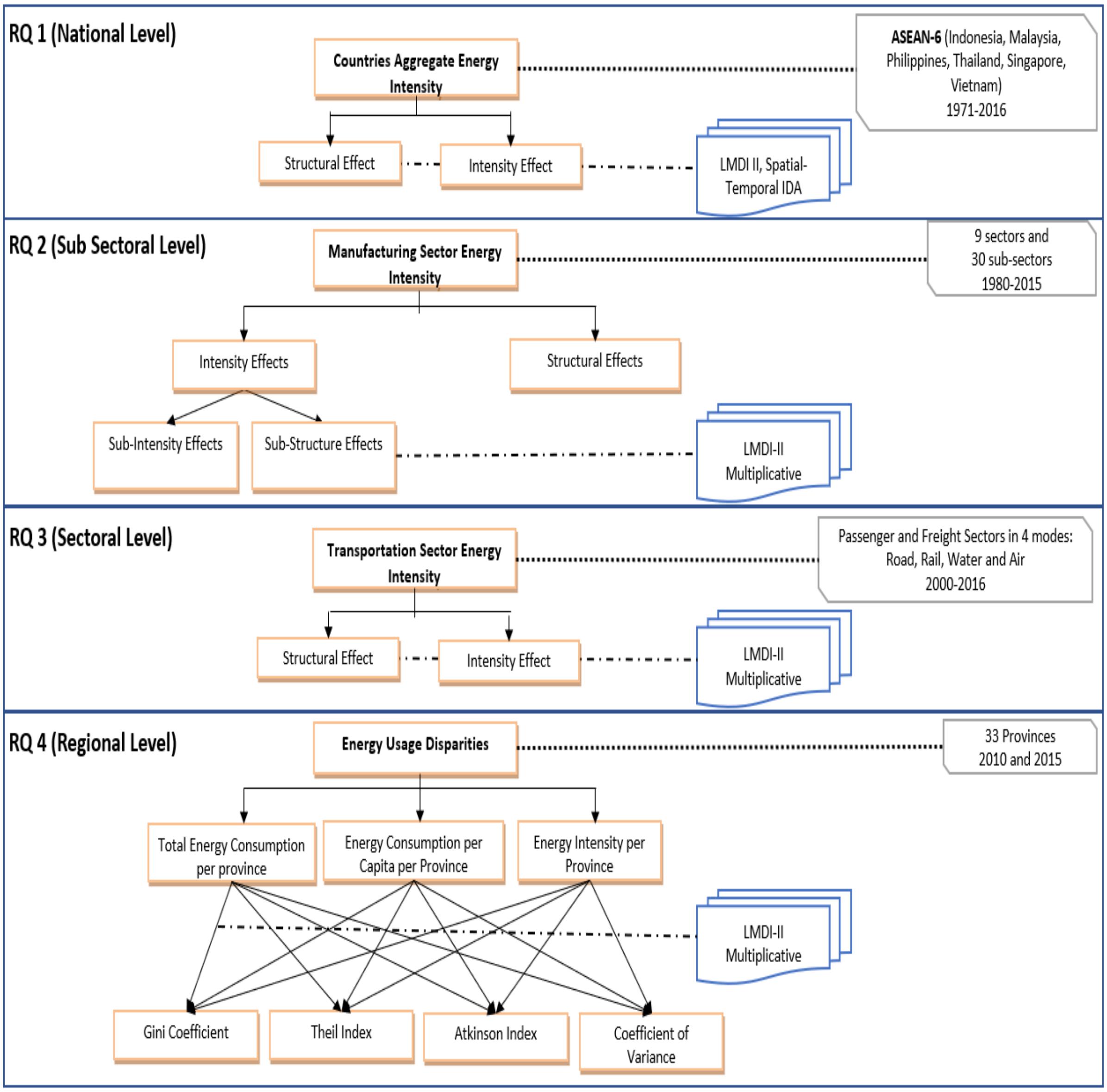
The fourth research problem (see Chapter 6) deals with the issue of regional comparisons. Since Indonesia comprise a vast geographic region where a noticeable imbalanced of natural resource allocations have been impacting a significant economic disparity amongst regions. Some research has been conducted to measure income inequality in Indonesia, however, there is no study conducted to measure energy usage disparities in Indonesia, specifically at the provincial level. To bring down energy intensity efficiently, it is essential to recognize differences across regions in Indonesia's energy intensity. This study investigates the disparities of energy usage levels specifically in energy intensity amongst 33 provinces in Indonesia from 2010 to 2015. This study employs several indicators including Gini Coefficient, Theil Index, Atkinson Index, and the Coefficient of Variation, as well as the LMDI-II across the provincial level.

1.6. Thesis Organisation

The overall structure of this thesis is shown in Figure 1.1. There are altogether seven chapters in this dissertation which includes four analytical chapters. The chapters are connected under the wide category of energy efficiency, but distinct in the context of establishing literature and identifying particular research issues. Each analytical chapter provides some details on the techniques used and sources of data.

The analysis is based on final energy consumption rather than total final energy supply, and hence excludes energy used in the production of final energy (for example, energy lost in the process of producing electricity from coal). It excludes energy used in conversion activities such as electricity generation, petroleum refining and coal product manufacturing. This study draws mainly on data on real value-added and energy consumption by industry from various sources, particularly Indonesia's central statistical agency (Badan Pusat Statistik/BPS), although considerable work has been required, with the collaboration of officers of BPS, to obtain disaggregated energy data of acceptable quality. The analysis in this study also relies heavily on decomposition analysis, enabling the change in energy intensity to be split between changes in the structure of economic activity and changes in the within-industry energy intensity. This methodology is outlined in Chapter 2.

Figure 1. 1. Thesis Structure



This chapter (Chapter 1) introduced the background of the research, the significance of the study and the objectives. Chapter 2 presents a review of the literature on the concept of energy efficiency and explores the methods to measure energy intensity. Chapter 3 deals with issues related to factors that affect changes in energy intensity of Indonesia and ASEAN-6 countries. Chapter 4 continues the analysis from Chapter 3 by providing a further discussion of the manufacturing sector. Chapter 5 is the third analysis chapter that serves a further discussion of the transportation sector. Chapter 6 focus on energy intensity across the provincial level in Indonesia. A comprehensive regulation related to energy efficiency development in Indonesia, followed by a discussion of the implications of several policies are presented in Chapter 7. Chapter 7 also summarises the overall study, concluding key findings and policy implications. The limitations of this dissertation are also provided in this chapter.

Chapter 2
Approaches to Measuring Energy Efficiency: A Review

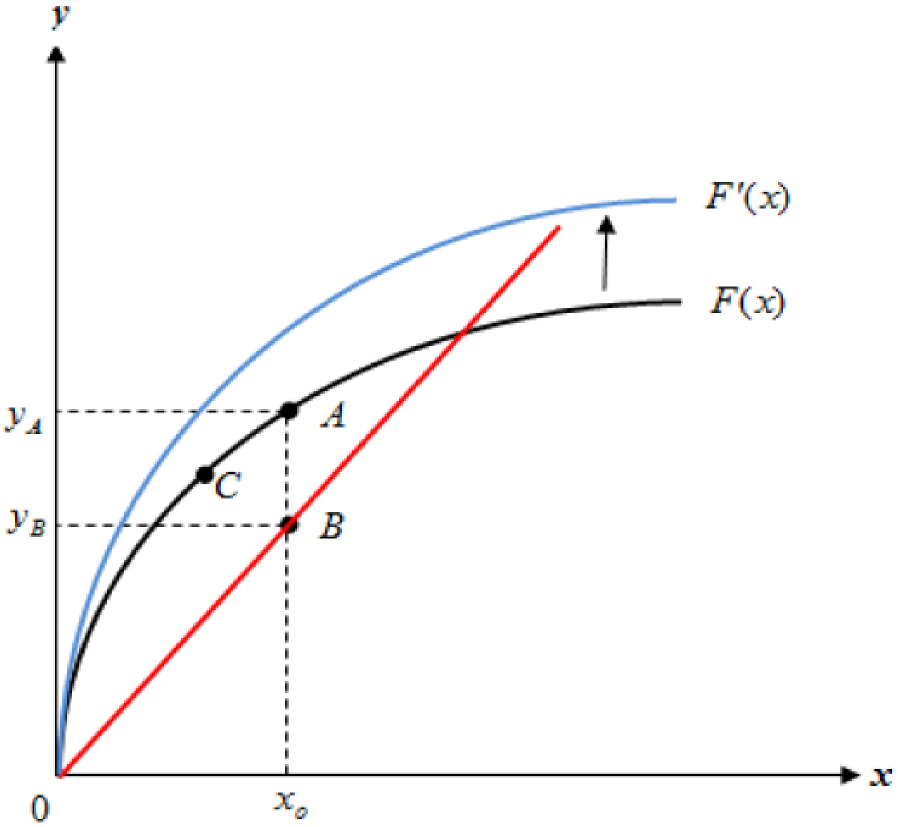
This chapter offers an overview of the literature about the concept of efficiency, energy intensity and methodologies comparison to measure energy efficiency. This chapter starts by explaining the concept of productivity and efficiency and follows with explaining the concepts of energy efficiency. This chapter also discusses the recent methodologies which have been used to measure energy intensity and efficiency.

2.1. Concept of Productivity and Efficiency

The concepts of productivity and efficiency have been employed in many studies as interchangeable for measuring performance, despite the fact that these two concepts are not the same (Coelli 2005). Productivity is a measurement of how much ratio of output can be produced from a single unit of input. For instance, labour productivity measures the amount of output which can be obtained from every labourer. Methodologies such as the Fisher Index, Index Decomposition Analysis and Tornqvist Index can be used to formulate inputs and/or outputs into indicators. On the other hand, efficiency is a measurement that compares current performance with best practice, which can be determined from the technology of production. Farrell (1957) first proposed the measurement of economic efficiency, where economic efficiency can be determined by both allocative (or pricing) efficiency and technical (or productive) efficiency. Allocative efficiency is the ability to produce at the lowest cost (or the ability of a company to optimally use its production factors to produce output within a certain cost and given technology), while technical efficiency is the ability to generate maximum output from a set of factors of production measured by input-oriented or output-oriented approaches (Lovell 1993).

Through the output-oriented approach, the measurement of technical efficiency can be attained by comparing the observed output of a company with the maximum output that can be generated (best practice) using current technology and employing the same number of inputs (Coelli 1995). For example, as shown in Figure 2.1., when an output represented by *y* is on the vertical axis, and input is denoted by *x* on the horizontal axis, the production frontier *F*(x) can show the current technological production. The *F*(x) curve shows the level of the maximum amount of output that can be generated at each level of the inputs employed, while the technological change can be described as the shifting in production frontier from *F*(x) to *F** (x).

Figure 2. 1. Technical Efficiency and Technological Change in the Production Frontier



The above Figure 2.1. shows that when a company uses a number of inputs (x_0) and produces a number of outputs (y_A), the company will be operating at point A on the frontier curve, which means that it is technically efficient. However, if the company is only able to produce outputs as y_B, while the number of input is x_0, the company is operating at point B below the frontier curve of *F*(x), which indicates that the company is technically inefficient. Using this output-oriented approach, the technical efficiency ratio can be measured by $0y_B$ / $0y_A \leqslant 1$. The level of productivity of the firm operating at point B is measured by $0x_O$ / 0_B.

The efficiency concept is not only concerned keeping the cost low but also to managing the factors of production (input) so that optimal results (output) can be delivered (output). A company can be categorized as efficient, depending on the level of efficiency in management processing input into an output. An efficient company is one that can produce more output than its competitors while consuming the same number of inputs or consume lower inputs in order to produce the same amount of output (Zhu

2015). This efficiency can be regarded as a relative concept as it depends on the definition of best performance (best practice) of the production frontier (relative to the use of the same technology of other companies). Hence, the level of efficiency of a company is basically a ratio of output to input.

In contrast to efficiency, productivity is an absolute measure which depends on the notion of the growth of production. Growth in productivity can be related to technological improvements by shifting the production frontier upward (Figure 2.1), by improving the technical efficiency, or by adjusting the scale of production (the company operates at point C, Figure 2.1.).

2.2. Energy Intensity and Energy Efficiency

Energy efficiency is generally quantified as the ratio of output or activity to energy inputs. Improvements to energy efficiency can be attained by raising the activity level by using the same amount of energy or employing a smaller amount of energy to produce a similar level of output/ activity. An inverse relationship between definitions of energy intensity and energy efficiency can be established.Energy intensity is defined as the ratio of energy consumed per unit of output or activity. In this definition, energy intensity measures the changes in energy productivity and efficiency. An improvement in energy productivity can be observed from the decreasing energy intensity.

Changes to energy intensity are defined by many driving factors including selection of production process, price of energy, technology advancement and innovation, fuel mix and government policy measures (Sun 1998). Shifting within energy-intensive sectors or changes in the economic structure can also generate changes in energy intensity. At the lowest of sectoral disaggregation or individual process, energy intensity can simply be measured as the change in energy consumed per unit of output. Nevertheless, this measurement might not adequately explain the energy intensity at the aggregate level as there are other driving forces, such as structural shifts, that can lead to economic changes in energy intensity (Shahiduzzaman & Alam 2013). For instance, when the structure of the economy shifts over a period of time from the less energy-intensive agriculture sector to the more energy-intensive manufacturing sector, then energy intensity may increase without any decline in energy efficiency.

These indicators of energy efficiency have been developed and utilized for measuring, observing and evaluating energy performance across countries. Energy efficiency is usually estimated with either physical or monetary indicators. One of the monetary based indicators that are mostly used to estimate energy efficiency is energy intensity, where in this term the energy efficiency is measured by how much energy is required or needed per unit of output (in the economic context, it is measured by dividing the total energy consumption with total GDP). The International Energy Agency (IEA) defines energy efficiency as an effort to control energy consumption and to attain economic growth.

In determining the causes of changes in a country's energy intensity and CO_2 emissions intensity, the quantitative approaches used in decomposition methods are usually employed, particularly when assessing the drivers of energy intensity changes resulting from economic development. Many researchers in this area have used the decomposition analysis method of the Log Mean Divisia Index (LMDI) due to its advantage of providing simple interpretations without leaving any unexplained residuals. This method also allows the sub-sector aggregation and multi-level aggregation of multiple factors. Furthermore, the results of decomposition will be more accurate when using disaggregated data, as the more disaggregated the data is, the more accurate the measurement of the energy efficiency levels are (Ang & Lee 1994).

Over the past decades, many studies, for example Ang (2015); Ang and Zhang (2000), have examined the relationship between carbon emissions and energy consumption at sectoral and cross-country levels. Ang and Zhang (1999) conducted comparative studies of the decomposition methods used in measuring changes in energy consumption and CO_2 emissions in several OECD countries. By using decomposition analysis, they concluded that there are many variations in the contribution of aggregate energy intensity, depending on the population and per capita income. Diakoulaki and Mandaraka (2007), using Laspeyres Refined Model for fourteen European Union (EU) countries, also found changes in the energy intensity, structure effect, utility mix, fuel mix and output from 1990 to 2003. Moutinho, Moreira and Silva (2015), conducting an analysis of four groups of countries in EU countries from 1999 to 2010, found that changes in carbon emissions associated with energy consumption are influenced by changes in population. However, the problem with using comparative country studies is the difficulty of objectively assessing the determinants in each country due to differences in each country such as production structure, level of development and domestic resources.

Other studies have also measured the decoupling relationship between carbon emission and economic development. The International Resource Panel of the United Nations Environment Programme (UNEP-IRP) observed the decoupling of economic growth and human well-being to the negative environmental impacts (Schandl, et al., 2016; UNEP 2014). Other scholars also emphasis on sectoral level decoupling, like agriculture (Luo et al, 2017), manufacture (Ren et al, 2014) and tourism (Tang et al, 2014). Further Zhang and Da (2015) examined decoupling of energy intensity in curbing carbon emissions in China, and Zhou et al (2017) observed more focus on decoupling of carbon emissions from economic growth in eight major provinces of China, whereas both studies further investigated driving forces of carbon emissions by employing LMDI method. These studies concluded that energy intensity played an important and positive role in accelerating decoupling process.

Even though decomposition analysis has been widely employed in many researches of energy-economic issues across countries, there is only few studies employs decomposition of energy in Indonesia. Amongst the first to conduct a study of energy intensity was Sitompul (2006). By employing Sun (1998) approach and ISIC three-digit level classification of thirty subsectors and nine sectors of manufacturing in Indonesia from 1980 to 2000, Sitompul (2006) found that the highest contributor to change the level of energy intensity in Indonesia's manufacturing sector is technical effect. Moreover, Hartono, Irawan and Achsani (2011) investigated the energy intensity in the manufacturing sector of Indonesia from 2002 to 2006 and observed that the energy intensity level was influenced by large enterprises, capital share, wages and capital intensity.

Furthermore, employing data high energy consuming industries in Indonesia from 2001 to 2007, Vivadinar, Purwanto and Saputra (2012), concluded that the factor affecting the changes in energy intensity in these industries were technology factor. Another recent study in decomposition of energy intensity were conducted by Ramstetter and Narjoko (2014). In this study, they employed survey data of medium and large industries from 1996 to 2006 and concluded that there was no clear evidence of energy intensity spill overs in Indonesia's manufacturing sector. However, although the aforementioned studies have focused on measuring the effects of energy consumption on economic growth and analysing energy consumption in industrial sectors, no attempt has yet been made to investigate the effects of changes in energy use at a sectoral level associated with the current policies in Indonesia. Therefore, my study will attempt to fill this gap in the current literature.

2.3. Approaches to measuring energy efficiency

There are at least four methodologies used in measuring energy efficiency. First, energy intensity denotes the ratio of energy consumption to Gross Domestic Product (GDP) (IEA 2009). Second, Decomposition Analysis divides energy intensity changes into several driving forces. Third, Data Envelopment Analysis computes the Total Factor Energy Efficiency using production functions. Last, Stochastic Frontier Analysis measures Underlying Energy Efficiency by using econometric techniques. The last two methods are the frontier analyses used to provide the target for reaching energy efficiency improvement.

2.3.1. Decomposition Analysis

The energy decomposition method measures the changes in energy consumption over time and breaks them into different driving forces, including changes in the structure of the economy or sector and examines essentially the role of energy intensity changes. This study employs the Log-Mean Divisia Index approach. This is well-established in the literature and has been previously applied by many studies, including Ang and Liu (2001), Ang, Liu and Chew (2003) and Sandu and Petchey (2009).

Changes in energy intensity are influenced by many factors. One way to isolate and explore these factors is decomposition analysis. Decomposition analysis measures the effect of various factors on energy consumption. Identifying the elements affecting energy consumption is important to define as it identifies which elements substantially reduce energy consumption and the areas that need to be prioritised for the development of energy efficiency policies. Decomposition of energy consumption trends are generally divided into three main elements: structural effect, intensity effect and activity effect (Ang 2004, 2015; IEA 2018).

1. **Structural Effect**

   "Structural effect" refers to changes in the structure of production or mix of activities within a sector. For example, the share of production across a subsector of an industry, vehicles modal share in passenger and freight transport sector, and home size changes in the residential sector.

2. **Intensity Effect**

   "Intensity effect" (is generally described as energy efficiency improvement) is the amount of energy consumed per unit of activity. Changes in this effect generally can be used as a proxy for energy efficiency developments (IEA 2018).

3. **Activity Effect**

   "Activity effect" represents the economic activities that drive energy consumption in a specific sector. For example, the population in the residential sector, value-added output in the industrial sector, passenger-kilometres and ton-kilometres in passenger and freight transport sector.

There are two main methods that can be used to isolate and explore the factors influencing the use of energy. They are the Index Decomposition Analysis (IDA) and Structural Decomposition Analysis (SDA). The IDA method decomposes variable changes at sectoral level employing aggregate data, while the SDA method employs the input-output model (I-O datasets). Both approaches have been employed to measure the effect of technology changes, sectoral shifts and economic growth on a series of economic indicators (Roinioti & Koroneos 2017). A detailed comparison between IDA and SDA by Hoekstra and Bergh (2003) observed that SDA utilizes a more complicated model and data requirements, which makes it difficult to conduct a time-series analysis. On the contrary, IDA employs less detailed data, but it is less able to carry out a detailed decomposition of the economic structure. The result from the IDA method is highly dependent on the level of disaggregated data. A further study conducted by Su and Ang (2012), described the number of studies employing IDA far beyond that of SDA and deals better with a broader field of energy economics. Therefore, IDA has been noted amongst researchers as an effective analytical tool for measuring the drivers of energy intensity changes (Ang 2015; Ang & Zhang 2000; Xu, XY & Ang 2013).

The IDA approach is usually employed to measure the factors affecting changes in energy consumption and aggregate energy intensity. According to Ang and Zhang (2000), the changes in energy intensity can be interpreted as one of the indicators of changes in energy efficiency. The objective of decomposing energy consumption is to separate sub-sectoral activities from the aggregate economy data (sectorial data), which will become very important if the energy intensity of each subsector is different. In other words, if one of the sub-sectors has high energy intensity, this will affect the aggregate energy intensity to increase as well or vice versa. Three of the changes that can be identified by using the decomposition method include structural effects (changes in the structure of production), the effect of sectoral energy intensity and the activity effect (changes in aggregate production).

The IDA method was first employed to examine the impact of energy consumption in industrial sectors in the 1970s (Park, Dissmann & Nam 1993). Since then, the use of IDA has been extended from the industry sector energy analysis to an economy-wide level energy analysis by adding sectoral and sub-sectors data (Ma & Stern 2008b). To date, there are extensive studies have been carried out to measure the changes in energy intensity and to analyse the difference across countries and sectors (Ang 2005; Ang, Liu & Chew 2003; Ang & Liu 2006; Ang, Su & Wang 2016; Ang, Xu & Su 2015; Ang & Zhang 1999, 2000; Winyuchakrit & Limmeechokchai 2016; Xu, XY & Ang 2014).

IDA is a bottom-up framework that can be employed to create economy-wide energy efficiency indicators (Ang 2006; Ang & Liu 2006). This approach can measure changes through time in order to identify the underlying indicators that contribute to the changes (Ang & Zhang 2000). With the IDA methodology, information obtained from energy indicators that are acquired at each level of energy hierarchy can be utilised for the analysis of energy usage trends (Choi & Ang 2012).

To calculate the effect of structural change and energy intensity change, this study applies the multiplicative form of Logarithmic Mean Divisia Index method to energy intensity and not to energy consumption. Even though the investigation on energy consumption is relevant, this study concentrates on energy intensity rather than energy consumption. The reason for this is that, according to Ang (1994) and Andrés and Padilla (2015), to prevent the problem that arises when examining a long period of analysis, where the Activity Effect tends to be very significant and dominates the other two effects, including Structural and Intensity effects, thus choosing the IDA method is the most suitable approach for this study.

To determine changes in energy intensity trends, the following approach is generally employed (Ang 2015):

$$I_t = \frac{E_t}{Y_t} = \sum_{k=1}^{n} \frac{Y_{kt}}{Y_t}\frac{E_{kt}}{Y_{kt}} = \sum_{k=1}^{n} S_{kt}\, I_{kt}$$

where:

I_t (aggregate energy intensity at time t), E_t (energy consumption in all sectors at time t), Y_t (economic activity of all sectors at time t), Y_{kt} (economic activity in sector k at time t), E_{kt} (energy consumption in sector k at time t), I_{kt} (energy intensity of sector k at time t), S_{kt} (share of sector k in economic value of all sectors at time t).

Using multiplicative decomposition, the relation of two time periods are described as

$$D_{Tot,T} = \frac{T_T}{I_0} = D_{Int,T} \times D_{Str,T}$$

where:

$D_{Str,T}$ is the structural effect at time T (an index that determines the effect of the structural shift), and $D_{Int,T}$ is the intensity effect at time T (an index that determines the changes in sectoral energy intensity effect), which are computed as

$$D_{Str} = exp\left\{ \sum_{k=1}^{N} \frac{L(\frac{E_{k,T}}{E_T}\frac{E_{k,O}}{E_O})}{\sum_k L(\frac{E_{k,T}}{E_T}\frac{E_{k,O}}{E_O})}\, ln\left(\frac{S_{k,T}}{S_{k,O}}\right) \right\}$$

and

$$D_{Int} = exp\left\{\sum_{k=1}^{N} \frac{L(\frac{E_{k,T}}{E_T}\frac{E_{k,O}}{E_O})}{\sum_k L(\frac{E_{k,T}}{E_T}\frac{E_{k,O}}{E_O})}\ ln\left(\frac{I_{k,T}}{I_{k,O}}\right)\right\}$$

The LMDI-II multiplicative method is employed because of its desirable properties as described earlier and its theoretical foundation (Andrés & Padilla 2015; Ang 2004, 2015; Ang, Liu & Chew 2003). Log Mean Divisia Index is a perfect decomposition method where no residual terms appear in the results, thus it copes with the test of reversibility. Additionally, this method overcomes the time reversibility test, whose results are identical when this method is operated backwards or forwards in time. Moreover, it passes the aggregation test, therefore this method is reliable in aggregating the results of subgroup decomposition. Further, the robustness test reveals to value zero (0) which means it performs properly when substituted by a very small value. This method can still be employed, although the data includes zeros (or missing data), negative values, which in many cases a very small number performs properly to replace missing data. Therefore, this method is considered to be an easy method to apply and the results are easily interpreted.

The properties of different kinds of decomposition methods are discussed further in Ang and Zhang (2000), Sun and Ang (2000), Ang and Liu (2007) and Ang (2015). Based on various literature, Table 2.1. below provides the characteristics, benefits and drawbacks of the IDA method

Table 2. 1. Characteristics of the IDA method

Characteristics of IDA	
➢ IDA can be used to track the changes within sector energy intensity and changes in sectoral shares of value added/GDP ➢ IDA is used to decompose changes in energy intensity into technical efficiency (measuring subsector energy intensity) and structural change effects (resulting from changes in sectoral composition).	
Strengths	**Weaknesses**
➢ IDA is a descriptive method. ➢ IDA can be used to distinguish technological efficiency and structural effects. ➢ IDA doesn't make any assumptions related to the underlying economic	➢ IDA requires a specific and high-quality sector or subsector level data. For instance, research of the industrial or transportation sector will involve subsector level data that compose the industrial or transportation sector.

and/or production structure. This method provides a clear structure, by observing energy intensity changes as a result of the structure change. ➢ By employing IDA, the disaggregation of energy inputs can be easily exercised, which can provide information about how changes in fuels inputs affect energy intensity changes.	➢ IDA results of technical efficiency and structural effects will be varied and relies on the level of energy inputs disaggregation. ➢ IDA doesn't provide an energy efficiency benchmark (frontier). Therefore, it can't be used by the policymakers to measure the potential benefit of implementing certain energy policy. It can't measure how inefficient a unit is compared to best practice (Proskuryakova & Kovalev 2015). ➢ IDA has limitations in investigating the function of economic variables, including prices.

2.3.1.1. Literature on LMDI

Many scholars employ the decomposition analysis to measure the driving forces of energy intensity (Hasanbeigi et al. 2013; Ke et al. 2012; Su & Ang 2015; Wang, J, Hu & Rodrigues 2018; Wood 2009). This method is also an effective tool to observe factors that influence changes in carbon emissions, which also may provide analyses of the effects of related policy measures (Ang 2004). Shrestha and Timilsina (1996) examined the carbon intensity of the power sector in 12 Asian countries and found that fuel changes were the main driver affecting changes in carbon intensity. Schleich et al. (2001) explored Germany’s emission reductions in 1990 and argued that population growth, GDP and energy supply mix were the main drivers for the emission changes. Davis, WB, Sanstad and Koomey (2003) investigated carbon intensity in the USA from 1996 to 2000 and suggested that the declining carbon intensity was driven by the warming climate. Bhattacharyya and Ussanarassamee (2004) observed energy and carbon intensities in the manufacturing sector in Thailand from 1981 to 2000 and argued that energy intensity and industry structure were the main factors driving the changes in carbon intensity. By investigating 14 EU countries from 1990 to 2003, Diakoulaki and Mandaraka (2007) examined carbon emission changes and suggested five main factors: energy intensity, output, fuel mix, structure and utility mix. Further, Ma and Stern (2008a), suggested that scale, technological and energy mix were the main factors affecting the changes in carbon emissions in China from 1971 to 2003. Employing structural decomposition analysis, Zhang, Y (2009) argued that demand pattern, energy intensity and input mix drove the changes in energy and carbon intensity in China from 1992 to 2006. By employing structural decomposition analysis, Xu, M et al. (2011) investigated carbon emissions in China's export from 2002 to 2008 and suggested four main factors drove the changes in carbon emissions: export composition, emission intensity, economic production structure and total export volume. O'Mahony (2013) argued that structure, intensity and scale are the main factors driving the changes in carbon emissions in energy consuming sectors in Ireland from 1990 to 2007. Similarly, Robaina Alves and Moutinho (2013) argued that energy intensity, energy structure and industry structure were the drivers of changes in Portugal's carbon intensity from 1996 to 2009 (employing 36 economic sectors). By utilising the industrial sector panel data of China from 2005 to 2009, Cao and Karplus (2014) argued that the main driving force to reduce energy and carbon intensity in China was the reduction of coal usage. Further, Chang and Chang (2016) and Wang, Z, Zhang and Liu (2016) investigated carbon intensity changes in regional level and suggested that carbon intensity changes were driven by several factors including economic activity level.

2.3.2. Data Envelopment Analysis (DEA)

Productive efficiency measurement was firstly performed by Farrell (1957). He measured empirically the efficiency of a production unit by defining an ideal isoquant frontier and determined the technical efficiency by using linear programming. The technique was later employed by Charnes, Cooper and Rhodes (1978) which has influenced the development of Data Envelopment Analysis (DEA). The use of DEA in terms of methodology, theory and applications has developed rapidly (Førsund & Sarafoglou 2005).

As a non-parametric method, DEA measures the efficiency of a Decision-Making Unit (DMU) by employing numerous inputs and outputs. It measures the relative productivity of one DMU to other homogenous units (Kokkinou 2012). The Decision-Making Unit's role is important in managing the decision-making and process of production at every level of daily operations, as well as formulating short-term and long-term strategies.

In building its frontier, this methodology does not posit a particular functional form but based on the input-output ratios derived from the linear programming techniques. The level of efficiency frontier is determined from the best performance producers (Cooper, Seiford & Tone 2006). This methodology includes all combinations of inputs and outputs to gain the best performance frontier in order to determine the contribution of technological change and the accumulation of inputs to productivity growth. Therefore, the efficiency scores from DEA to specific production units are not absolute, but relative to other units within the data sets. This feature distinguishes the DEA method from the other parametric approach (i.e. Stochastic Frontier Approach) that requires a definite functional form for the cost function and production (Cooper, Seiford & Tone 2007).

Data Envelopment Analysis can also be employed to analyse efficiency by using numerous inputs and outputs but cannot develop the aggregate weighting of the inputs and outputs. Since DEA does not apply the functional form of the data, DEA can overcome some disadvantages such as the appearance of a functional form of technology, market structure assumptions and the perfect market hypothesis. DEA analysis assumes the existence of frontier technology that is described in a piecewise linear hull. All observations that are efficient will appear on the frontier, while the inefficiency will be below the frontier.

Data Envelopment Analysis is a non-parametric method that makes no distributional assumptions about the distribution of efficiency. Efficiency is set as the gap between the “best practices” of production frontier as measured by the DEA (Kao 2005). Best practice within the frontier is described as the benchmark of calculating the estimated energy savings compared with those potential energy saving that is not on the frontier. By computing the relative inputs and outputs in different countries, the DEA will calculate the amount of targeted energy savings. Therefore, the best economic performance can serve as a benchmark to evaluate a particular country's economy (Hu & Kao 2007). In this method, the energy efficiency is estimated utilising slack-based methods in order to ensure the energy input is on the frontier (Hu & Wang 2006).

$$\min_{\alpha} \theta$$

Subject to $$-y_{it} + Y_t\alpha \geq 0$$

$$\theta x_{it} + X_t\alpha \geq 0$$

$$\alpha, X_t, Y_t \geq 0$$

where:

Y_t is a vector of activity for N countries in period t , y_{it} is value added or output for country *i* at time *t*, X_t a vector of all inputs for all countries, x_{it} is inputs (for instance capital, energy, labour for country *i* at time *t*), α is a vector of country intensities and θ is the overall measure of input-oriented efficiency.

Energy efficiency is identified by calculating how much energy input can be reduced (up to the minimum level with consideration of other inputs in the production process) without changing the amount of output.

The DEA method can determine the target inputs of the proposed developing countries compared to the annual efficiency frontier of the whole sample of those countries. The objective level of energy use, called the *target of energy input*, is calculated when the total amount of adjustments is decreased from the actual amount of energy consumption (Honma & Hu 2008). In DEA, energy efficiency index is named as Total-Factor Energy Efficiency (TFEE) which is formulated as the ratio of the input energy targets. In this index, total-factor productivity improvement represents energy efficiency improvement (Honma & Hu 2014a). The index incorporates TFEE energies, labour and capital stock as multiple inputs to produce economic output (GDP). Table 2.2 below provides the characteristics, strengths and weaknesses of employing the DEA method.

Table 2. 2. Characteristics of the DEA method

Characteristics DEA	
➢ Energy efficiency measures calculated with DEA is usually called as Total Factor Energy Efficiency (TFEE). ➢ TFEE determine how much the energy input can be reduced (to the minimum level) without altering the output level (this concept is similar to the economic concept of "technical efficiency"). ➢ In DEA, the technical efficiency is calculated by employing linear programming algorithms. ➢ By applying an aggregate production frontier approach, this method estimates energy efficiency as the deviation from a best practice frontier. It computes energy efficiency as the difference between the production frontier and the actual energy use, for a given level of output.	
Strengths	**Weaknesses**
➢ DEA estimates a range of production factors to be examined simultaneously and a benchmark efficiency level to be estimated. ➢ DEA specifies a frontier (benchmark) that can provide policymakers with targets and goals to be achieved. ➢ DEA can measure efficiency at the subsector level if sufficient data exists.	➢ DEA may establish a wrong assumption since the aggregation ignores the characteristics of the sector economy (Parker 2015). For instance, the aggregation across industries requires different energy requirements, various energy efficiency conversions assume that a standard production process is applicable for all units being studied. ➢ DEA uses a static concept of efficiency. It is assumed that other factors are homogeneous (including prices, capital, production processes), which they are likely to change in the economy.

	➢ DEA needs a large number of observations to estimate the frontier (benchmark) accurately. Generally speaking, "if the number of DMUs (n) is less than the combined number of inputs and outputs (m + s), a large portion of the DMUs will be identified as efficient and efficiency discrimination among DMUs is questionable due to an inadequate number of degrees of freedom. Hence, it is desirable that (n) exceeds (m + s) by several times" (Cooper, Seiford & Tone 2006; Xie, Bai & Wang 2018). ➢ DEA has limitations in exploring the role of economic variables including prices (Parker 2015). ➢ DEA does not consider statistical noises (Xie, Bai & Wang 2018; Zhou, Ang & Zhou 2012). ➢ Since the DEA results are sensitive to model selections (i.e. CCR, BCC, etc.) and variable sets in the hypothesis setting, therefore the correct choice of DEA model (i.e. VRS, CRS, Additive, SBM, etc.) must be considered (Cooper, Seiford & Tone 2006). Expert judgements are usually needed in selecting the specific DEA model that fits with the situation in the research.

2.3.2.1. Literature on DEA

The DEA method has been employed in many studies to examine the relationship between energy efficiency and economic performance which formulates an index of Total-Factor Energy Efficiency (Honma & Hu 2008, 2013, 2014a; Hu & Kao 2007; Hu & Wang 2006; Xiaoli, Rui & Qian 2014). Furthermore, Sözen and Alp (2009) investigated energy efficiency performance in Turkey and some EU countries and associated variables including emissions, energy consumption and local pollutants. Lozano and Gutiérrez (2008) added more variables into the DEA model to measure the maximum GDP, including energy intensity, population and carbon intensity. Goto, Otsuka and Sueyoshi (2014) examined energy efficiency in Japan's manufacturing and non-manufacturing sector. Liu, W and Lin (2018) observed the energy efficiency performance in China's provincial level particularly in transport sector.

Many researchers applied the DEA model at a regional level (i.e. across countries or across provincial level) to determine the energy efficiency of different regions and create a more precise energy-saving target. Makridou et al. (2016) argued that technological effect is the key factor of energy efficiency in EU industries. Similarly, Camioto et al. (2016) also examined energy efficiency in BRICS and G7 countries to find the factors affecting energy efficiency. Further, Rojas-Cardenas et al. (2017) investigated the energy efficiency of the steel industry in Mexico and found that the level of energy intensity in China's and USA's steel sector are lower than Mexico's. Additionally, Qin et al. (2017) explored the energy efficiency progress in China's coastal regions and concluded that technological effect is the key factor in driving overall energy efficiency improvement.

Many studies have observed energy efficiency in the context of regions and sectoral. By observing six energy efficiency of US manufacturing industries, Mukherjee (2008) argued that the paper sector consumed energy more efficiently compared to the metallurgy sector. Azadeh et al. (2007) investigated energy efficiency in the manufacturing sector of Iran and OECD countries, and suggested that DEA needs to be combined with other approaches to specifically identify the relationship amongst output growth, structural change and energy consumption in the industrial sector. Zhang, N, Zhou and Choi (2013) examined carbon emissions and energy efficiency in South Korea power plants and observed that coal power plants are more energy efficient than the oil-fired ones. Lin, Boqiang and Tan (2016) suggested that there were substantial regional differences in energy efficiency performance across Chinese industry.

2.3.3. Stochastic Demand Frontier Approach

Aigner, Lovell and Schmidt (1977) and Meeusen and Van Den Broeck (1977) formulated a robust statistical methodology to measure efficiency which is now known as the Stochastic Frontier Analysis (SFA). This methodology has been widely developed in the literature (Coelli 2005; Coelli, Prasada Rao & Battese 1998; Lovell 1993).

In SFA, the frontier is derived through econometric techniques and represented through a functional form (such as a Trans log function or Cobb-Douglas). The stochastic frontier is calculated from the best performance producers in the data sets, while all of the other producers that are outside of the frontier will be categorised as inefficient. By using the statistical technique, the deterministic frontier is obtained from the frontier which is all of the deviations are assumed as a result of the inefficiency. The parametric approach assumes the functional approximation of the underlying technology in order to build the parameters for the model (Fried, Lovell & Shelton 2008).

Battese and Coelli (1995) state that the stochastic frontier production allows the inputs elasticity and technical efficiency to change over time in order to measure alterations in the production structure. The technical inefficiencies are used as a function of the explanatory variables to estimate the stochastic frontier. In this approach, it is possible for the producers to not be on the frontier due to random shocks or inefficiency. Efficiency is measured by separating the overall error term from the efficiency component. The SFA may perform decomposition of the residual of production function into its efficiency component. SFA offers a unique interpretation for combining inefficiency.

There are two approaches to measuring efficiency in the SFA: the output-oriented approach and input-oriented approach. The technical efficiency can be measured based on the production frontier, whereas cost efficiency is measured based on the cost frontier (Kumbhakar & Lovell 2000). In the production function, efficiency is measured by taking into account the maximum output level that can be achieved with a combination of a particular number of inputs. While the role of cost efficiency is measured by the level of minimum costs that can be obtained by the company with a degree of output. Production efficiency is defined as the relationship between the amounts of production output with the quantity of input. Production efficiency occurs if the company produces optimum production as a result of a combination of a particular number of inputs.

Bhattacharjee, Castro and Jensen-Butler (2009) mention that the SFA is a popular methodology to measure the Total Factor Productivity at the firm level, describes the technological frontier, analyse error term, or as a function of measuring the level of investment. Some models of the SFA use a fixed or random effect to measure the components of inefficiency, where the model can reduce the efficiency of the respective producers. SFA has been used extensively at the industry level because of its consistency as employed in Fried et al. (2008) and Fried, Lovell and Shelton (2008).

In the framework of the energy demand function, the frontier establishes the required (minimum) level of energy that is needed for an economy to provide some degree of energy outputs. In essence, the objective here is to employ the frontier concept in calculating the baseline energy demand, where the frontier shows the countries energy demand which employs efficient production process and equipment. The frontier identifies whether a country is on the frontier or not (efficient or not). For instance, if a country consumes more energy than the baseline demand, then the country will not be on the frontier, which means the country uses energy inefficiently.

Based on Filippini and Hunt (2011) and Filippini and Hunt (2012, 2013), it is assumed that an aggregate energy demand relationship exists of the form:

$$e_{it} = \alpha + \alpha^y y_{it} + \alpha^p p_{it} + others + v_{it} + u_{it}$$

where:

e_{it} is the natural log of energy consumption, y_{it} is the natural log of GDP, p_{it} is the natural log of the real price, $others$ are variables affecting energy consumption, v_{it} is asymmetric disturbance capturing the effect of noise, and u_{it} represents the underlying energy level of efficiency.

Table 2.3. below provides the characteristics, strengths and weaknesses of employing the SFA method.

Table 2. 3. Characteristics of the SFA method

Characteristics SFA	
➢ Energy efficiency measures estimated with SFA is usually called as Underlying Energy Efficiency (UEE). ➢ UEE calculates how much the energy input can be reduced (to the minimum level) controlling for the level of output and energy price level. This method is similar to the cost minimizing approach in production economics ("cost efficiency" — how much inputs can be changed to find the lowest cost combination of all inputs). ➢ In SFA, energy efficiency is calculated by using stochastic frontier econometrics. ➢ By employing an input demand approach, this method estimates energy efficiency as the difference between the actual energy used and the minimum energy requirement (which determines the minimum input requirement). It measures energy efficiency as the deviation from a best-practice frontier.	
Strengths	**Weaknesses**
➢ SFA specifies a frontier (benchmark) that can provide policymakers with targets and goals to be achieved. ➢ SFA estimates a range of production factors to be considered simultaneously (include prices) and a benchmark efficiency level to be estimated. ➢ SFA can control for the effects of shocks and price changes and allow testing of hypotheses (Parker 2015). ➢ SFA consider unobserved heterogeneity and statistical noises (Zhou, Ang & Zhou 2012), that takes into account data errors and omitted variables.	➢ As SFA is a new approach, very few studies have tested its use in predicting energy efficiency. ➢ SFA uses a static concept of efficiency. It is assumed that other factors are homogeneous (including prices, capital, production process), which they are likely to change in the economy. ➢ SFA needs a large number of observations to estimate the frontier (benchmark) accurately.

2.3.3.1. Literature on SFA

There are a limited number of studies employing SFA to examine the impact of energy efficiency policy measures to energy efficiency level. Filippini and Hunt (2011) analysed the energy efficiency level employing a panel data of 29 OECD countries from 1978 to 2006 to examine energy efficiency in the residential sector. In addition, Filippini and Hunt (2012) observed the USA's residential energy demand examining 48 states from 1995 to 2007. Both studies Filippini and Hunt (2011, 2012) provided a tool that can be used by policymakers to allow policy target and cross regions benchmark. A further study from Filippini, Hunt and Zorić (2014) combines the frontier approach and energy demand modelling methods to examine the energy efficiency level of residential sectors of EU-27 countries from 1996 to 2009. They observed that the residential sectors in EU-27 have not yet succeeded in promoting energy savings. In addition, they also implied that energy performance standards and financial incentives improved energy efficiency, while other measures did not provide a significant impact. Adom et al. (2018) examined the causes of energy efficiency in Africa in 22 countries panel data from 1988 to 2014 and found that energy efficiency convergence across countries was driven by country-specific factors such as the level of technology. Overall, these studies (Adom et al. 2018; Filippini & Hunt 2011, 2012; Filippini, Hunt & Zorić 2014) suggested caution for policymakers of employing energy intensity as an indicator for energy efficiency.

Stochastic Frontier Analysis is an approach that has been employed to examine the level of energy efficiency for industry. Feijoó, Franco and Hernández (2002) investigated the energy efficiency of industries in Spain and found that energy policy reduced emissions substantially. Buck and Young (2007) examined energy efficiency in Canada's commercial buildings and found that economic activities and building ownership affected the level of energy efficiency. Stern (2012) examined the energy efficiency of 85 countries from 1971 to 2007 and concluded that technological change is the most essential factor affecting energy consumption and emissions. Several Chinese studies conducted by (Lin, B. & Long 2015; Lin, Boqiang & Wang 2014; Lin, Boqiang & Xie 2013) found that energy efficiency in the thermal power industry, iron and steel industry, and the chemical industry have improved over time. Hu and Honma (2014) analysed energy efficiency by observing 10 industries in 14 countries from 1995 to 2005. Honma and Hu (2014b) examined energy efficiency in Japan using panel data parametric technique. Lundgren, Marklund and Zhang (2016) observed energy demand and energy efficiency in company level of Swedish manufacturing sectors. Otsuka (2017) investigated Japan's residential sector's energy efficiency in 47 prefectures from 1990 to 2010 and argued that electricity energy efficiency can be improved by forming an urbanised city. Ouyang et al. (2018) analysed energy efficiency in 30 provinces in China to observe factor price distortions.

2.4. Conclusion

The significance of energy intensity or energy efficiency is its ability to reduce the usage of energy and thus it is imperative to provide precise observations of energy efficiency. This chapter has noted that there are various definitions for energy efficiency and energy intensity. In addition, various procedures and methods can be employed to examine energy efficiency including the decomposition methods that define single input performance illustrations or frontier methods that define total factor interpretations. Every quantification method has different advantages and drawbacks. Nevertheless, all of these measurements involve substantial quality data as inputs.

For analysis across the entire economy, the index decomposition method has several advantages. As this method is a descriptive method, it does not create assumptions regarding the production structure and the underlying economy. This method is able to isolate a proxy for energy usage improvements (intensity effect/ technological efficiency) and structural effects (changes in the economic structure) which also can be enhanced with secondary analysis. In general, this method differentiates the efficiency change at the micro-level from the economic structural change at the macro-level. However, on the contrary, the results from this method differ depending on the level of disaggregation; it is limited when investigating the role of economic factors like capital stock as this method cannot establish a benchmark for efficiency and requires a high level of subsector data.

Both frontier methods of SFA and DEA have several benefits, including simultaneously examining a series of production factors (for SFA these incorporate prices), whereas they can also estimate benchmark efficiency level. However, there are also several limitations, specifically related to heterogeneity and the dynamics of the capital stock over time. For instance, these relate to the postulation of a single production function, over sectors or countries or over time (Parker 2015). These methods employ a static concept of efficiency that derives from perfect information, competitive input and output markets. Thus, in a dynamic world, the value of this efficiency concept is limited, whereas knowledge generates changes in the input factors in production, based on availability and costs. Additionally, these methods empirically bear questionable efficiency measures, i.e. between determining technological progress and efficiency.

Given the strengths and weaknesses of these efficiency measurements, this study perceives that the decomposition method is superior compared to the frontier methods. The decomposition method provides straightforward answers to the questions relating to the effects of subsectors changes on the aggregate, whereas a great extent of policy literature employs the decomposition method in investigating energy efficiency. Currently, the LMDI method has been widely used, not only in academic studies, but in national statistical agencies and international organizations (Liu, N & Ang 2007).

However, even though there are variations in the results of the various methods in measuring energy efficiency, the exegesis and the argument of much of the literature do not rely on the methods applied but are robust to the measured output of energy efficiency.

Chapter 3
Measuring Energy Efficiency Performance in Indonesia and ASEAN countries

3.1. Introduction

The consumption of energy is necessary to drive the economy (Ozturk 2010). Energy consumption in Asia Pacific countries has been rapidly increasing. According to the ADB (2013) projection, energy demand in the Asia Pacific region will rise by 2.1% per annum from 2010 to 2035, which is more than a 70% increase over this period. This growth rate is higher than the predicted world average growth rate of 1.5% (ADB 2013). The ASEAN (Association of Southeast Asian Nations) countries,[3] which is centred in the Asia Pacific region, is leading the global energy trend with a massive increase of 50% over the period from 2000 to 2013 due to its increased population and economic growth in the region. The economic growth within ASEAN countries has increased remarkably since 1999, from US$577 billion in 1999 to US$2.5 trillion in 2016, where in 2018, it has an averaging 5.3 per cent growth (OECD 2019).

ASEAN's increasing population is also been inherent to its economic growth. Based on *the World Economic Outlook* (IMF 2017), ASEAN's working-age population has increased from an average of approximately 63% in 2000 to 67% in 2015. The population in ASEAN countries in 2013 reached more than 615 million people, or around 8.5 percent of the world's population, that used approximately 4.5% of the world's primary energy (ACE 2015a). Energy demand in these countries has increased two and a half times more than it was in 1990 (IEA 2015b). This trend is predicted to rise even higher in the coming decades and forecast to increase by 80% from 2011 to 2035 (Shi 2016). With ASEAN economies expanding steadily, energy demand is considered to surpass its supply unless a significant policy is enacted to manage energy demand. This situation necessarily creates challenges for sustainable development.

Currently, ASEAN has a medium-term target to reduce its energy intensity by 20% by 2020 and a long-term target of 30% by 2025, compared to the base year 2005 (ACE 2015b). Up to this time, the majority of ASEAN countries have developed some energy savings targets by enacting a variety of energy efficiency policies, with more than half having enacted a common standard of energy efficiency measures. Moreover, most

[3] The ten ASEAN member countries are Indonesia, Malaysia, Brunei Darussalam, Thailand, Singapore, Vietnam, Myanmar, Cambodia, the Philippines, and Lao PDR.

of these countries have implemented energy labelling programs for all electric and gas appliances (IEA 2013). The first noticeable fact concerning the energy sector within ASEAN countries is that some energy prices are considerably different, namely due to various distortion policies, within these countries. Some of the recent energy policies and targets in ASEAN countries are as follows:

Table 3. 1. ASEAN-6 Energy Policies and Targets

Country	Policies and Targets	References
Indonesia	Energy intensity reduction by 1% per year until 2025	Government Regulation No. 79/ 2014
Malaysia	Reduction in electricity consumption of 8% in residential, commercial and manufacturing sectors by 2025	The 11th Energy Efficiency Action Plan
Thailand	Energy intensity reduction by 30% compared with 2010 by 2036.	Energy Efficiency Development Plan 2015-2036
Singapore	Energy intensity reduction by 30% by 2030 (from a baseline of 2005)	Sustainable Singapore Blueprint 2015
The Philippines	Forty-five per cent energy intensity improvement by 2035 (from a baseline of 2005)	National Energy Efficiency and Conservation Program
Vietnam	Energy saving by 3 to 5% from 2006 to 2010 and 5 to 8% from 2011 to 2015	Vietnam National Energy Efficiency Program 2005 to 2015

Source: ASEAN Centre for Energy (ACE 2017)

Although some progress has been achieved by ASEAN in the last decade, the progress in energy efficiency is still relatively conservative compared to other groups of countries. From 1980 to 2011, the energy intensity of ASEAN only improved by 12%. This growth is still low compared to the improvement of the OECD (38%) or China (74%) (Shi, 2016). Based on the IEA (2013), the reason for the small improvement of energy intensity in ASEAN is due to the lack of energy efficiency regulations in buildings, mandatory regulations in appliances, and the absence of market-based energy prices in some countries. In addition, targets to reduce energy intensity in the ASEAN region are also hampered due to some countries not making a concrete policy about energy efficiency measures, specifically Myanmar, Laos and Cambodia, while other countries such as Malaysia, Thailand and Singapore have developed a variety of energy efficiency policies (Shi 2016).

The remarkable economic growth of ASEAN countries could lead to inefficient energy usage. The ASEAN's economy collectively has grown substantially by more than

125% since 2000, reaching US$7.4 trillion in 2016 (IMF 2017). The ASEAN-6[4] countries have had substantial growth in their economy compared with the rest of the ASEAN members. Based on the recent WorldBank (2019) data, the highest per capita income within ASEAN-6 in 2018 is Singapore at US$64,581, followed by Malaysia (US$11,239), Thailand (US$7,273), Indonesia (US$3,893), the Philippines (US$3,102) and Vietnam (US$2,563). According to IMF (2015), ASEAN countries have shown strong economic growth in the last decades, which almost doubled since 2000 (to around $6.1 trillion in 2013). The high growth of these six ASEAN countries evokes an intriguing question about the performance of energy consumption, since the growing per capita income may also lead to higher energy consumption, which may result in inefficient energy usage. Given the remarkable growth rate of these ASEAN-6 countries, examining the performance of these countries is essential.

Energy efficiency improvements can be a result of more efficient technologies (intensity effect or changes within industry energy intensity) or changes in economic structure composition (structural effect/shifting to less energy-intensive sectors, for example, from the industrial sector to the services sector). This study employs Log Mean Divisia Index (LMDI) techniques to examine the trend of each of nine ASEAN countries' energy intensity to measure the contribution of within-sector efficiency improvements (intensity/technology effects) and structural changes (structural effects). By classifying the interaction amongst these two effects, this study attempts to explain the main driving force behind recent energy efficiency improvements of each ASEAN countries over time. In addition, this study also attempts to examine whether the decline in energy intensity in one country is similar within the same sector across other countries.

This chapter examines the energy intensity performance in Indonesia compared to other selected ASEAN countries from 1970 to 2016. Although decomposition analysis has been widely used in studies of energy-related issues in many countries, there is a lack of research into the decomposition of energy in Indonesia, particularly when comparing Indonesia to other countries. The selected ASEAN countries for analysis in this study are Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam while Brunei Darussalam, Cambodia, Myanmar, and Lao PDR have not been included due to lack of data.

The aims of this chapter are essentially two. First, this chapter aims at examining the development of energy efficiency and discovering energy intensity changes amongst selected ASEAN countries. Second, this study proposes to capture both temporal

[4] The six ASEAN countries usually known as ASEAN-5 including, Indonesia, Thailand, Singapore, the Philippines, Malaysia and Vietnam.

improvements within individual countries and spatial changes amongst selected countries employing the model developed by Ang, Su and Wang (2016). This study expects to provide a robust description of the overtime performance of the selected ASEAN country since it incorporates the abovementioned spatial and temporal approaches within a single analysis structure.

This study attempts to close the gap in the literature by using index decomposition analysis to shed more light on the contributing factors for the changes of energy consumption and efficiency in Indonesia compares to other ASEAN countries. The major contribution of this study to the related literature lies in its broader scope in examining the trend of energy consumption and efficiency not only across sectoral level but also across the regional level. Providing longer historical trend of data would provide insights about the progress of energy efficiency development in each ASEAN-6 Countries.

3.2. Literature Review

Decomposition analysis has been widely used in studies of energy-related issues in many countries; however, there is a lack of research into the decomposition of energy in ASEAN, specifically focusing on Indonesia. Studies related to energy in ASEAN have generally focused on energy consumption and forecasts of national energy needs. For example, Masih and Masih (1996), examined six Asian countries; for Indonesia, they found a co-integration and causality between income and energy consumption. Furthermore, a recent study by Azam et al. (2015) concluded that in Indonesia economic growth, human development index, trade openness, urbanization and FDI inflows significantly affect energy consumption. This study explores the determinants of energy consumption from 1980 to 2012 in three ASEAN countries: Malaysia, Thailand and Indonesia, employing least square methods to estimate their parameters.

Further research regarding energy policies in ASEAN includes Yoo (2006), who investigated causality amongst economic growth and electricity consumption in the ASEAN countries of Malaysia, Singapore, Thailand and Indonesia from 1971 to 2002. He shed light on the unidirectional causality between electricity consumption and economic growth in Thailand and Indonesia. Nurdianto and Resosudarmo (2011) address the issues of ASEAN integration from an energy policy perspective. It uses a modified version of Kaya's Identity by augmenting it with energy decomposition index. They found the structure of energy consumption and prices varies among ASEAN countriesMost energy decomposition studies in ASEAN countries are carried out individually for single country analysis rather than as a group. Some studies have investigated Thailand, including Bhattacharyya and Ussanarassamee (2004), Chontanawat, Wiboonchutikula and Buddhivanich (2014), Winyuchakrit and Limmeechokchai (2016), while other studies have been conducted on the Philippines, for example, Lopez, Chiu and Biona (2018). By employing Log Mean Divisia Index, Bhattacharyya and Ussanarassamee (2004) analysed energy and CO_2 intensities in Thai industries from 1981 to 2000 into two factors including intensity effect and structural effect. They carried out analysis into four different periods over twenty years and conclude that both energy intensity and CO_2 intensity have decreased. Employing a similar method with Bhattacharyya and Ussanarassamee (2004), Chontanawat, Wiboonchutikula and Buddhivanich (2014), decomposed Thailand's energy intensity in the manufacturing sector from 1991 to 2011. Their study confirmed to the Bhattacharyya study that energy intensity in the manufacturing sector declined after recovering from the 1997 economic crisis. Using a different approach to the previously mentioned studies on Thailand, Winyuchakrit and Limmeechokchai (2016) investigated energy intensity specifically in the transportation sector in Thailand from 1990 to 2007. They employed decomposition into three factors: structural effect, fuel share effect and intensity effect. By employing a multilevel decomposition method, they concluded that the aggregate energy intensity declined in consequence of decreased in both intensity and structural effects. One of the most recent studies on ASEAN countries was investigated by Lopez, Chiu and Biona (2018). They examined energy intensity in the transportation sector in the Philippines and concluded that transport activity, energy intensity and population growth were the contributing factors to the changes in energy consumption.

However, although the aforementioned ASEAN studies (in group of ASEAN) and within ASEAN (individual country analysis of ASEAN) have focused on measuring the effects of energy consumption on economic growth and analysing energy consumption in industrial sectors, no attempt has yet been made to investigate Indonesia's recent energy efficiency development comparing to the ASEAN-6 countries over a given period of time, where both spatial and temporal changes in each country are captured simultaneously. In this regard, my study will attempt to fill this gap in the current literature.

3.3. Methodology

In terms of the focus of energy assessment performance, IDA can be classified into two types: temporal and spatial analysis (Ang 2015; Ang, Su & Wang 2016). The temporal IDA analysis assesses the changes in energy consumption or the aggregate energy intensity in a country over a period of time, while spatial IDA investigates variations of energy indicators amongst a group of regions within a specific year.

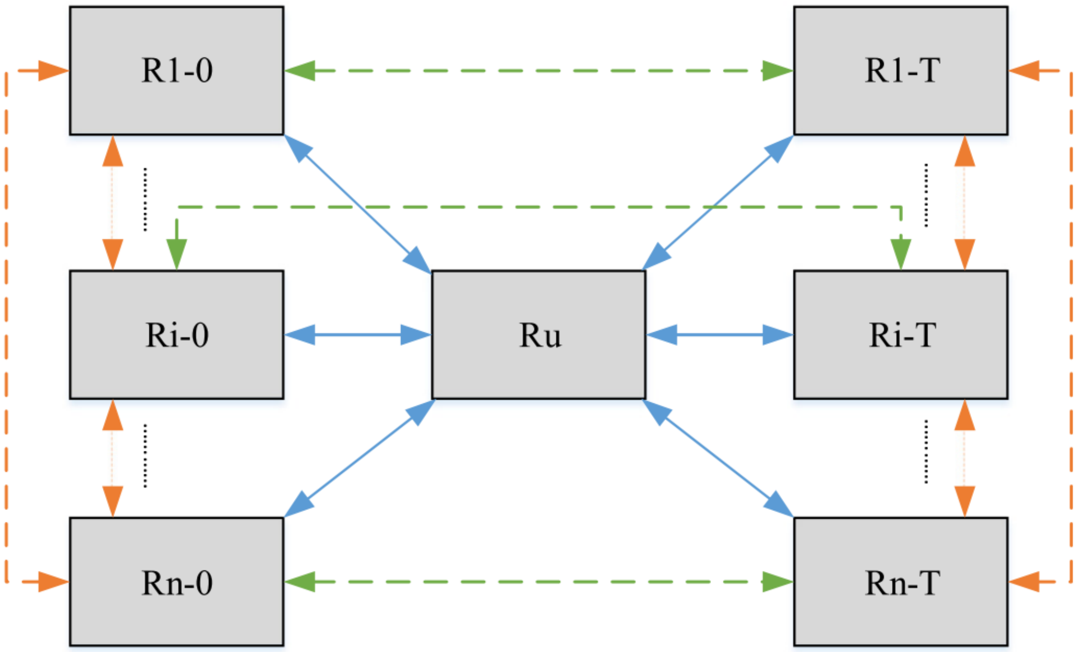
To aim a spatial-temporal decomposition, first, this research employs the basic LMDI method. According to Ang (2004, 2005), this approach is preferable since it provides consistent aggregation and exact decompositions without leaving a residual term. Additionally, this method effectively controls zero values and the results produced from both multiplicative and additive decompositions are easy to understand since it requires a simple formula.

This research will first decompose changes in aggregate energy intensity into two fundamental factors: structural and technical effects. It will adapt the LMDI-II multiplicative energy intensity approach (Ang & Choi 1997). Once the two effects have been computed, this study shall proceed one step further to calculate the spatial-temporal index of all ASEAN countries.

There are two effects that are conventionally measured in many energy intensities studies (Ang 2004, 2015), namely: 1) structural effect utilised to measure changes in energy consumption as a result of changes in the activity mix by sub-sectors. The structure effect of the productive sectors will be used to measure the changes in energy intensity that result from a transition of economic sectors such as from less energy-intensive to a more energy-intensive sector (for example, changes from agriculture sector to industry sector). This effect can determine changes in the energy intensity resulting from changes in the composition of economic sectors, and 2) intensity effect employed to measure changes in energy intensity caused by the improvement of technical efficiency in each sector of the economy. This effect is generally interpreted as changes in energy intensity resulting from efficiency improvements within sub-sectors of the economy.

In order to determine changes in energy intensity trends, this study employs the LMDI-II Multiplicative as referred in Chapter 2. Following the LMDI-II Multiplicative, this study also uses the ST-IDA as Ang, Su and Wang (2016) recommends. According to Ang, Su and Wang (2016), before conducting a Spatial-Temporal Index Decomposition Analysis study (ST-IDA), the benchmark countries must be selected first. Since this study, having no preference in selecting the study period and country reference, following Ang, Su and Wang (2016), this study specifies the reference country by using a weighted average of all countries in all the years of specified study period in order to provide a neutral description of the country performance. As the performance analysis involves n countries (C1 to Cn) and will be evaluated for year 0 and year T, with assumptions of k sectors. Cu will be taken as the benchmark region (Cu is the benchmark country).

A spatial Index Decomposition Analysis concept is illustrated as follows (as provided in Ang, Su and Wang 2016). The solid lines denote direct comparisons for each of the n regions in year 0 and year Twith respect to the reference region. The results obtained are then used for indirect spatial and temporal comparisons, respectively between any two regions for a particular year and between two years for a particular region, as denoted by the dashed lines.



Source: Ang, Su and Wang (2016)

The ratio changes in energy intensity between two countries (Country 1 and Country 2/ C1 and C2) in year 0, is indirectly constructed as follows:

$$\frac{I^{C1,0}}{I^{C2,0}} = \frac{I^{C1,0}/I^{Cu}}{I^{C2,0}/I^{Cu}}$$

The structure and intensity effects are computed as

$$D_{Str}^{C1,0-C2,0} = \frac{D_{Str}^{C1,0-Cu}}{D_{Str}^{C2,0-Cu}} = \frac{exp\left(\sum_k w_k^{C1,0-Cu} ln\frac{S_k^{C1,0}}{S_k^{Cu}}\right)}{exp\left(\sum_k w_k^{C2,0-Cu} ln\frac{S_k^{C2,0}}{S_k^{Cu}}\right)}$$

$$D_{Int}^{C1,0-C2,0} = \frac{D_{Int}^{C1,0-Cu}}{D_{Int}^{C2,0-Cu}} = \frac{exp\left(\sum_k w_k^{C1,0-Cu} ln\frac{I_k^{C1,0}}{I_k^{Cu}}\right)}{exp\left(\sum_k w_k^{C2,0-Cu} ln\frac{I_k^{C2,0}}{I_k^{Cu}}\right)}$$

where $w_k^{C1,0-Cu} = \frac{L(\frac{E_k^{C1,0}}{E^{C1,0}}, \frac{E_k^{Cu}}{E^{Cu}})}{\sum_k L(\frac{E_k^{C1,0}}{E^{C1,0}}, \frac{E_k^{Cu}}{E^{Cu}})}$ and $w_k^{C2,0-Cu} = \frac{L(\frac{E_k^{C2,0}}{E^{C2,0}}, \frac{E_k^{Cu}}{E^{Cu}})}{\sum_k L(\frac{E_k^{C2,0}}{E^{C2,0}}, \frac{E_k^{Cu}}{E^{Cu}})}$

For the ratio difference of a country's energy intensity (C1) between two time periods (year 0 and year T), is formulated as:

$$\frac{I^{C1,T}}{I^{C1,0}} = \frac{I^{C1,T}/I^{Cu}}{I^{C1,0}/I^{Cu}}$$

and

$$D^{C1,T-C1,0} = \frac{D_{Str}^{C1,T-Cu}}{D_{Str}^{C1,0-Cu}} = \frac{exp\left(\sum_k w_k^{C1,T-Cu} ln \frac{S_k^{C1,T}}{S_k^{Cu}}\right)}{exp\left(\sum_k w_k^{C1,0-Cu} ln \frac{S_k^{C1,0}}{S_k^{Cu}}\right)}$$

$$D_{Int}^{C1,T-C1,0} = \frac{D_{Int}^{C1,T-Cu}}{D_{Int}^{C1,0-Cu}} = \frac{exp\left(\sum_k w_k^{C1,T-Cu} ln \frac{I_k^{C1,T}}{I_k^{Cu}}\right)}{exp\left(\sum_k w_k^{C1,0-Cu} ln \frac{I_k^{C1,0}}{I_k^{Cu}}\right)}$$

where $w_k^{C1,T-Cu} = \frac{L(\frac{E_k^{C1,T}}{E^{C1,T}}, \frac{E_k^{Cu}}{E^{Cu}})}{\sum_k L(\frac{E_k^{C1,T}}{E^{C1,T}}, \frac{E_k^{Cu}}{E^{Cu}})}$ and $w_k^{C1,0-Cu} = \frac{L(\frac{E_k^{C1,0}}{E^{C1,0}}, \frac{E_k^{Cu}}{E^{Cu}})}{\sum_k L(\frac{E_k^{C1,0}}{E^{C1,0}}, \frac{E_k^{Cu}}{E^{Cu}})}$

Subscripts str and int denote the structure effect and the intensity effect, respectively. These two effects give the contributions arising from the differences between region R1 and the reference region in economy structure and in sectoral energy intensity to the overall difference in the aggregate energy intensity between them.

3.4. Data

Data in this study is gathered from two databases: The United Nations Statistics Division (UNSD) datasets and International Energy Agency (IEA). The UNSD supports databases in international industrial statistics. Although this database provides a substantial coverage of statistics across industries, it only comprises output/activity data and does not incorporate energy use data. Both output and energy consumption data are essential for this research to observe the level of energy efficiency development across the selected countries. Therefore, this study employed energy use data sourcing from the IEA that includes energy balance and energy consumption data across each sector of the economy.

The GDP data in this study include the four main sectors of the economy for the six ASEAN countries: manufacturing, transportation, commercial and agriculture. The total energy consumption data is obtained from the energy balances of OECD and non-OECD economies data sets. In order to prevent double accounting, this study only employs final energy consumption in energy intensity measures. According to Koechlin (2002), two approaches to overcoming the problems of data comparability are employing Purchasing Power Parity (PPP) as measured in the OECD and utilising the average rates of exchange. As with many other cross-country studies measuring GDP, this study utilises the Value Added by Economic Activity, at constant 2010 prices in US dollars.

The classification for value added sectoral data for its sector in this thesis is as follows:

a. Commercial sector includes value added from wholesale and retail trade; repair of motor vehicles and motorcycles, transportation and storage; information and communication; financial and insurance activities; real estate activities; professional, scientific and technical activities; administrative and support service activities; public administration and defence; compulsory social security; and education.
b. Agriculture sector includes value added from agriculture, hunting, forestry and fishing.
c. Transportation sector includes value added from transport, storage and communication
d. Manufacturing sector includes value added from Iron and steel; Chemical and petrochemicals; Non-ferrous metals; Non-metallic minerals; Transport equipment; machinery; Mining and quarrying; food and tobacco; Paper pulp and print; wood and wood products; construction; textile and leather and other industries.

3.5. Comparative Analysis of the Energy-Intensity amongst ASEAN Countries

Overall, in ASEAN countries, the Total Final Energy Consumption (TFC) per GDP or defined as Energy Intensity, fluctuated during the period of this study. Indonesia's energy intensity was average compared to the other ASEAN countries, where it started increasing moderately and peaked in 1999, followed by a decreasing trend of aggregate energy intensity for the rest of the period.

3.5.1. The trend of Energy Intensity amongst ASEAN Countries

Figure 3.1 shows the energy-intensity changes in the six ASEAN countries from 1971 to 2016. Overall, energy intensity in Indonesia was higher in 2016 than in 1971, it increased fairly consistent from 1971 to 1989, with a significant increase occurring from 1989 to 1990 and had a peak during 1997 and 1999, before had some fluctuations during 2000 to 2005 and a steady decline after 2005 until 2016. Singapore had the lowest and most stable energy intensity compared to other ASEAN countries, where energy intensity remained unchanged during the study period. It was markedly stable during 1971 to 1984, although it had a moderate decline from 1985 to 1999, which was followed by a fairly stable period after 2000. The trend of energy intensity in the Philippines was markedly lower in 2016 than in 1971; it fell moderately from 1971 to 1981, then had a gradual increase after 1989 to 1998 before falling steadily from 1999 to 2016.

Although energy intensity in Thailand went through a period of moderate volatility at the beginning of 1971 to 1981, it remained steady in the middle period before increasing after 1984 and peaking in 1998 and followed with moderate fluctuations until the end of the study period. In Malaysia the period between 1971 and 1977 showed a declining trend of energy intensity, which was followed by consistent growth from 1978 until 1988, and then followed by a period of increase during 1989 to 2006 before falling towards the end of the study period. Vietnam had the highest trending energy intensity compared to other ASEAN countries, although it had a significant drop from 1973 to 1979, but it substantially surged in 1980 and peaked in 2016 as the highest energy intensity of all ASEAN countries.

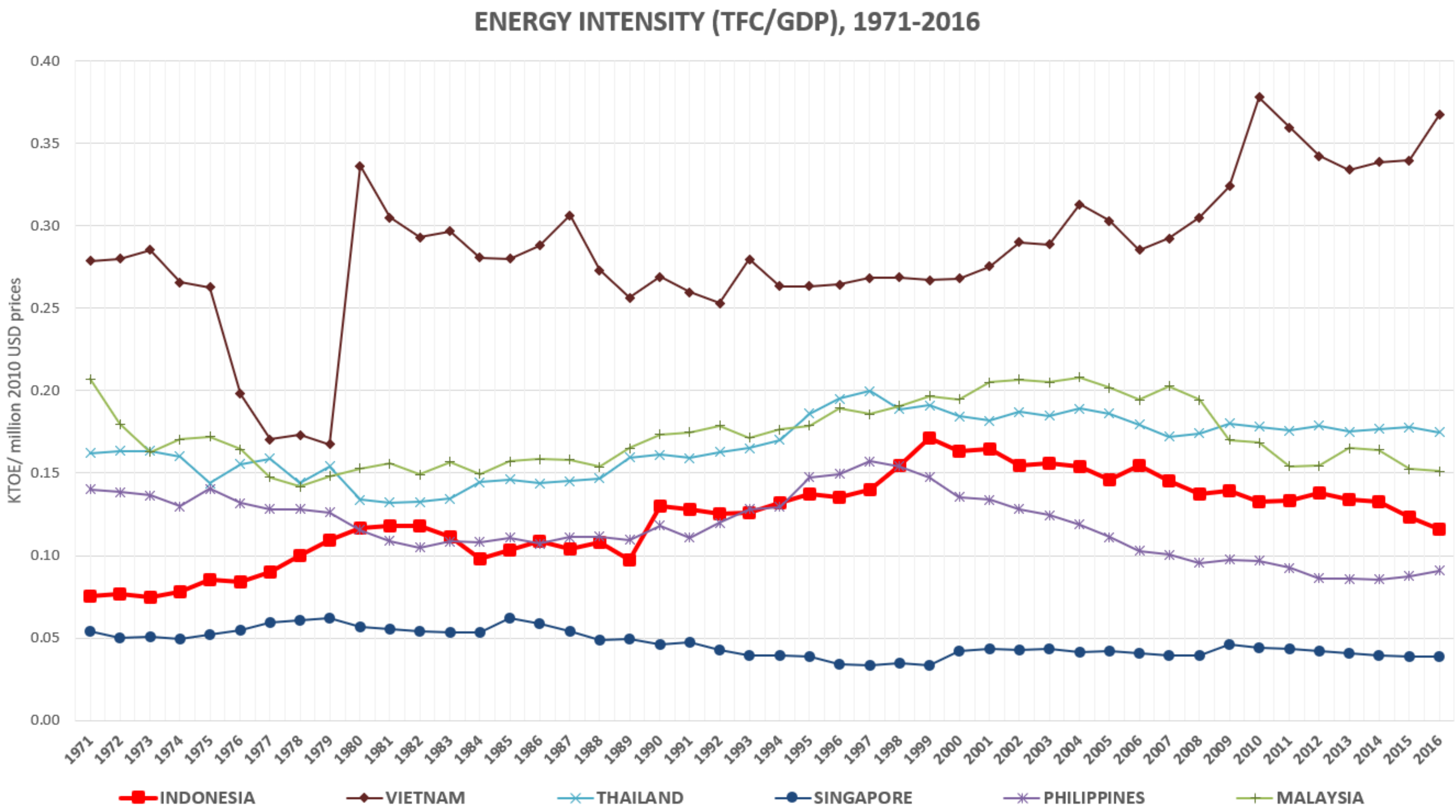


Figure 3. 1. Energy Intensity Comparison for six ASEAN countries, 1971-2016.[5]

[5] Energy intensity is calculated as the ratio of total final energy consumption to GDP.

3.5.2. Economic Structure (sectoral share to GDP, 1971–2016)

Indonesia's industry has grown significantly over the past forty-five years. The total value of industrial output increased from US$61.6 billion in 1971 to US$801.9 billion in 2016 at 2010 prices, with an overall annual average growth rate of 8.95%. The largest output shares in Indonesia in 1971 came from the agriculture sector with approximately US$30.3 billion (49% of total value added), followed by the commercial (US$24.6 billion — 40%), manufacturing (US$5 billion — 8%) and transport (US$1.7 billion — 3%) sectors. However, in 2016 the largest output shares in Indonesia was coming from the commercial sector with approximately US$35.5 billion (44%), followed with manufacturing, agriculture and transport sector for around US$22.2 billion (28%), US$13.3 billion (17%) and US$9.1 billion (11%), respectively. In the 1970s to the beginning of 1990s, industrial growth averaged approximately 7% per year. However, this phenomenal period of growth was followed by a short period during the economic crisis from 1997 to 1998, where industrial growth dropped sharply by negative 1% from 1997 to 2001. The commercial sector suffered a severe drop of negative 2% growth annually from 1997 to 2001. However, after the 2000s, industrial growth started to increase, although, the growth rate was slower compared to the early 1990s.

All economic activity in the key end-use sectors of the ASEAN-6 economy increased at an annual average rate of greater than 4% from 2011 to 2016 (Table 3.2). The manufacturing, transport and commercial sectors contributed the most to growth in the total industrial value-added. While economic activity increased over the period of study in all sectors, rates of economic growth varied across the sectors. In particular, annual growth in activity in the manufacturing, transport and commercial sectors was considerably greater than the rate of growth in the agriculture sector. The decline in the share of total economic activity of the agriculture sector and the increasing shares of the manufacturing, transport and commerce sectors indicate a change in the structure of ASEAN-6 economies over the period of study.

Despite the increasing growth of economic activity in ASEAN-6, during 1997 to 2001, ASEAN-6 countries also experienced a slowing growth of industrial activity, where its growth followed a lower trajectory compared to the period before the economic crisis (see Table 3.2.). For instance, industrial growth in Malaysia and Singapore was around 8% to 9% in the early 1990s but, after the crisis, the growth rate plummeted to around 3% from 1998 to 2001. During the economic crisis, the manufacturing and commercial industry in ASEAN suffered the most. In Malaysia, the manufacturing and commercial sector growth declined from around 10% to 12% in the early 1990s to around 3% from 1997 to 2001.

The key factors driving structural change in the ASEAN-6 economies include economic reform, technological innovation, high commodity prices and increasing demand for services. Technological improvements are changing how and where products are produced. Policies connected to globalisation, including tariff reduction, has exposed industries to highly competitive in international markets. Expansion in manufacturing and exports has been driven by the fast pace of urbanisation and industrialisation of emerging economies in Asia. This has underpinned the commodity booms in the early 1980s, which increased the output's contribution from the manufacturing sector.

The Table 3.2 summarises ASEAN countries' value-added shares and annual growth rate of value-added from 1971 to 2016.

Table 3. 2. Gross value-added shares and annual growth rate of ASEAN-6

Country	Sectors	Annual Growth Rate Value Added (%)						Share of Total (%)						
		71-81	81-91	91-97	97-01	01-11	11-16	71	81	91	97	01	11	16
Indonesia	**Manufacturing**	14	12	10	0	5	5	8	15	25	30	31	29	28
	Transportation	13	7	8	0	13	9	3	4	5	5	5	10	11
	Commercial	9	7	7	-2	6	5	40	45	45	45	42	44	44
	Agriculture	4	3	3	1	4	4	49	36	25	20	22	18	17
	AGGREGATE	**7**	**7**	**7**	**-1**	**6**	**5**							
Vietnam	**Manufacturing**	4	4	12	10	8	9	13	13	11	14	17	20	23
	Transportation	4	5	8	6	8	6	4	4	4	4	4	6	6
	Commercial	4	6	10	5	6	7	41	41	45	49	48	48	49
	Agriculture	4	5	5	4	4	3	41	41	40	32	31	26	22
	AGGREGATE	**4**	**5**	**8**	**5**	**5**	**6**							
Thailand	**Manufacturing**	10	10	7	2	5	3	17	22	28	31	30	32	31
	Transportation	6	10	8	6	5	5	5	4	5	6	7	8	9
	Commercial	7	7	6	1	4	5	49	52	51	50	48	48	51
	Agriculture	4	4	3	4	3	–1	29	22	15	13	14	12	10
	AGGREGATE	**7**	**7**	**6**	**2**	**4**	**3**							
Singapore	**Manufacturing**	10	7	7	4	8	1	20	25	22	21	21	23	20
	Transportation	14	8	9	6	5	4	7	13	13	14	15	13	13
	Commercial	6	8	9	3	7	4	71	62	64	65	64	64	67
	Agriculture	2	-6	-2	-7	-1	1	2	1	0	0	0	0	0
	AGGREGATE	**8**	**8**	**8**	**3**	**7**	**3**							
Philippines	**Manufacturing**	6	1	3	2	4	7	29	31	27	27	26	24	25
	Transportation	5	3	5	7	6	7	4	5	5	5	6	7	7
	Commercial	5	3	4	3	6	7	44	44	49	50	51	55	57
	Agriculture	4	1	2	3	3	1	22	21	18	17	17	14	10
	AGGREGATE	**5**	**2**	**4**	**3**	**5**	**6**							
Malaysia	**Manufacturing**	11	10	12	3	5	5	14	18	26	32	31	28	28
	Transportation	13	8	11	5	6	8	4	7	8	9	10	10	11
	Commercial	9	6	10	3	7	6	39	41	41	43	44	49	51
	Agriculture	5	3	1	1	4	0	44	34	25	16	15	12	10
	AGGREGATE	**8**	**6**	**9**	**3**	**6**	**5**							

The structural changes in the economy can be analysed in terms of the changes in the share of sectoral GDP over time. The value-added shares in Table 3.2. show the changes in the structure of the economy in ASEAN countries over the last forty-five years from 1971 to 2016. The common features in all ASEAN countries value-added shares are that the agriculture sector had a declining value-added share, while the other sectors, such as the manufacturing and commercial sectors, had increased their share in the economy.

There are two trends that stand out from the value-added shares in Table 3.2, First, the industry sector (manufacturing) and commercial sector played a key role in the overall economic structures that accounted for around 60% to 80% of the total ASEAN economic output from 1971 to 2016. This sector continued to yield a large output in the fifteen-year span from 2001 to 2016. In Indonesia in 2016, the manufacturing and commercial sector output were around two-thirds of the economy, followed by agriculture and transportation sector accounted for 17% and 11%, respectively. Thailand, the Philippines, Vietnam and Malaysia had similar trend to Indonesia, where the commercial and manufacturing sectors dominated the overall economic structure, although the proportions have differed considerably amongst them. In contrast to other ASEAN countries, the commercial sector in Singapore held the prominent role over other sectors in its economic structure, where it contributed to around two-thirds of Singapore's economy.

The second trend apparent in Table 3.2 is the declining share of the agricultural sector to the total economic output of all ASEAN countries. The primary reason for this decline is that the rate of growth in this sector was far slower than the other sectors. Although the role of this sector was prominent at the beginning of the 1970s, as most ASEAN countries have expanded their economies, their reliance on agriculture sector decreased slightly over time, except for Singapore which had minimal reliance on agriculture. In Indonesia and Malaysia, the role of the agriculture sector accounted for around a half of the economic structure at the beginning of the 1970s, but it decreased to less than 20% by 2016.

The overall industrialisation process of this 45-year period can be seen in the changes in economic structure in the ASEAN countries, especially in Indonesia. For instance, Table 3.2 shows that the manufacturing and commercial sector share of the economy in Indonesia increased gradually during the study period. This increase in the manufacturing and commercial sectors substituted for an overall decline in agriculture, which decreased from around two-thirds in 1971 to less than one-third in 2016. This demonstrates that Indonesia rapidly shifted from a reliance on the natural resources of agriculture to industrial development in the last four decades of its economic development.

Indonesia shifted from a predominately agricultural economy to a predominately manufacturing economy in quite short time period (Jacob 2005). Since the 1990s, the domination of manufacturing sector has exceeded the contribution of the agriculture sector. The contribution of manufacturing sector increased quite significantly, from 8% in 1971 to a peak of around 31% in 2001, before it fell to 28% in 2016. On the other hand, the contribution of agriculture sector dropped from 49% in 1971 to approximately 17% in 2016. The greatest contribution in the economy came from the commercial sector, which was relatively steady at around 40% on average during the study period. Meanwhile, the transportation sector had the smallest contributor to Indonesia's economy. The structural changes in Indonesia from an agricultural to a mainly manufacturing economy demonstrates a significant development in its economic policies. This structural shift is the key indicator of the successful transition to industrialisation in Indonesia.

3.5.3. Composition of Total Energy Consumption by Sector

Total energy consumption in ASEAN-6 accounted for around 276 million tonnes of oil equivalent (MToE) in 2016. In 2016 (see Table 3.3), total energy consumption in the manufacturing and transportation sectors accounted for more than 80% of all consumption in ASEAN-6 countries. The trend of total energy consumption from 1971 to 2016 clearly demonstrates the dominance of these two sectors' share compared to the remaining sectors. The increase in energy consumption from manufacturing and transportation is potentially due to advances in technology, while the increase in the commercial sector is a result of increasing incomes due to economic development.

Energy consumption in Indonesia increased from 4,648 KTOE in 1971 to 92,946 KTOE in 2016, with an average annual growth rate of 7.18%. For the same period, total energy consumption in both manufacturing and transportation sector also increased from 1,625 KTOE and 2,692 KTOE in 1971 to 37,732 and 47249 KTOE in 2016 with an average annual growth rate of 8.32% and 6.74%, respectively. Indonesia's manufacturing and transportation sector were responsible for the largest share of the country's end-use energy demand accounting for around 80 per cent (see Table 3.3.). Both the manufacturing and transportation sectors are the highest energy-consuming sectors in Indonesia (Resosudarmo and Tanujaya 2002) across the study period, where both sectors share approximately 90% of energy use across all sectors in 2016. In 1971, the largest levels of energy uses were in the transportation sector, which accounted for 58% of total energy use, followed by manufacturing sector for around 35%, the agriculture sector had 5% and commercial less than 3%. Thirty years later, energy use had substantially surged and there had been significant changes in its distribution across sectors. In the period of 2016, energy use by the transportation sector alone reached around 51%, followed by the manufacturing sector at around 41%.

Table 3.3 shows the summary of ASEAN-6 countries' energy consumption shares and an annual growth rate of energy consumption from 1971 to 2016.

Table 3. 3. Energy Consumption shares and annual growth rate of ASEAN-6

Country	Sectors	Annual Growth Rate Energy Consumption (%)						Share of Total (%)						
		71-81	81-91	91-97	97-01	01-11	11-16	71	81	91	97	01	11	16
Indonesia	Manufacturing	17	12	8	3	3	0	35	49	56	56	52	46	41
	Transportation	9	6	9	3	6	5	58	44	38	38	38	45	51
	Commercial	13	12	15	9	5	5	2	2	3	3	5	6	6
	Agriculture	11	5	9	17	–1	–3	5	4	3	3	5	3	2
	AGGREGATE	12	9	8	4	4	2							
Vietnam	Manufacturing	9	2	7	5	8	8	66	83	71	63	61	59	63
	Transportation	8	11	16	7	11	4	34	12	20	26	27	33	29
	Commercial	N/A	34	16	13	4	8	0	2	5	7	9	6	6
	Agriculture	N/A	16	11	0	4	3	0	3	4	4	3	2	2
	AGGREGATE	8	4	9	6	8	7							
Thailand	Manufacturing	5	8	11	1	4	5	51	47	42	42	44	45	48
	Transportation	6	11	10	–2	4	4	34	38	43	43	40	38	39
	Commercial	10	17	13	1	6	0	3	4	7	8	8	10	8
	Agriculture	4	6	8	2	3	–4	12	11	8	7	8	7	5
	AGGREGATE	5	10	10	–1	4	3							
Singapore	Manufacturing	10	2	6	36	10	2	27	30	20	25	45	56	60
	Transportation	7	5	1	1	4	–3	65	59	54	49	36	28	23
	Commercial	17	22	3	3	5	2	8	11	26	26	20	17	18
	Agriculture	N/A	6	3	9	70	136	0	0	0	0	0	0	0
	AGGREGATE	8	6	2	11	7	1							
Philippines	Manufacturing	4	2	8	-5	3	3	36	43	38	35	30	36	31
	Transportation	0	4	12	0	–1	8	54	42	49	55	56	47	50
	Commercial	16	3	7	10	4	7	3	9	9	8	12	16	17
	Agriculture	2	-4	7	–7	2	8	7	6	3	2	2	2	2
	AGGREGATE	2	2	10	–1	1	6							
Malaysia	Manufacturing	5	6	9	4	2	3	60	57	50	48	46	41	38
	Transportation	6	9	10	7	3	8	36	38	43	42	44	44	50
	Commercial	7	12	12	10	6	2	4	5	7	7	9	12	11
	Agriculture	98	N/A	119	–28	54	–11	0	0	1	2	0	3	1
	AGGREGATE	5	8	10	5	3	5							

Similarly, to Indonesia, the manufacturing and transportation sectors in the Philippines and Thailand also consumed the largest share that accounted for around 80% of the aggregate energy consumption. As shown in Table 3.3, energy consumption in the transportation sector of the Philippines between 2011 and 2016 increased for about 8%, where this sector accounted for a half of the aggregate energy consumption. In Thailand in 2016, the manufacturing and transportation sectors consumed around 48% and 39% of total energy consumption, respectively. During the study period, the share of agriculture sector in both countries was declining, which potentially occur as a result of economic expansion in both countries.

Final energy consumption in key end-use sectors of Vietnam and Malaysian economies increased by around 5 to 7 per cent a year from 2011 to 2016. In Vietnam, the highest rate of energy consumption growth occurred in the manufacturing and commercial sectors, which increased by around 8 per cent a year over the study period, while in Malaysia the highest growth rate came from the transportation sector. In contrast, the share of energy consumption in the agriculture sector in Malaysia decreased substantially over the same period.

Over the periods 1997 to 2001 and 2001 to 2011, the manufacturing sector in Singapore had the highest rate of annual growth in energy consumption, increasing by around 36 per cent and 10 per cent per annum, respectively. There was a substantial change in the energy consumption structure in Singapore. In the 1970s, the transportation sector was the largest energy consuming sector, that consumed for around 65%, followed by manufacturing sector for 27%. By contrast, in 2016, the manufacturing sector consumed the largest share for approximately 60%, while the transportation sector only consumed around 23% of the aggregate energy consumption.

Like other developing countries worldwide, the large transportation energy consumption in these ASEAN-6 countries is mainly due to rapid population growth and urbanisation. Here the growing numbers of vehicles, increased urbanisation and traffic congestion were the major causes of high energy consumption in the transportation sector. This tendency has also been apparent in all other ASEAN countries (ACE 2017).

3.5.4. Energy Intensity

Energy intensity reflects not only how much energy is utilised in the economy but also the changes in energy consumption across sectors. Aggregate energy Intensity in Indonesia has fluctuated moderately in a range of 0.08 to 0.16 oil equivalent per million dollars (constant 2010 US$ prices) from 1971 to 2016 (see Table 3.4). The highest energy intensity in Indonesia came from the transportation sector with 1.56 in 1971 that decreased to 0.51 in 2016. Following the transportation sector, the manufacturing sector was second highest at 0.32 in 1971 and declined to 0.17 in 2016. While the commercial and agriculture sectors had the smallest energy intensity ranging from 0 to 0.04 from 1971 to 2016.

Energy intensity in the ASEAN-6 economy mostly declined during the study period. The transport sector exhibited the largest decline in energy intensity, followed by the manufacturing, commercial and agriculture sectors. The transportation sector is the most energy-intensive sector in Indonesia as well as in all ASEAN-6 countries (see Table 3.4). In 1971, the transportation sector in Singapore required around 0.48 oil equivalent per million US dollars, but in 2016 the energy requirement declined to 0.07 oil equivalent per million US dollars. Similarly, to Singapore, the transportation energy intensity in Malaysia and the Philippines also decreased significantly from 1.76 and 1.70 in 1971 to 0.62 and 0.66 in 2016 oil equivalent per million US dollar, respectively.

Table 3.4 shows the summary of ASEAN-6 countries energy intensity from 1971 to 2016.

Table 3. 4. Energy Intensity Trend ASEAN-6

Country	**Sectors**	**Energy Intensity (KTOE/ million 2010 USD prices)**						
		1971	**1981**	**1991**	**1997**	**2001**	**2011**	**2016**
Indonesia	Manufacturing	0.32	0.38	0.29	0.25	0.27	0.22	0.17
	Transportation	1.56	1.18	1.05	1.12	1.24	0.62	0.51
	Commercial	0.00	0.01	0.01	0.01	0.02	0.02	0.02
	Agriculture	0.01	0.01	0.02	0.02	0.04	0.02	0.02
	Aggregate EI	**0.08**	**0.12**	**0.13**	**0.14**	**0.16**	**0.13**	**0.12**
Vietnam	Manufacturing	1.41	1.95	1.63	1.20	1.00	1.06	1.00
	Transportation	2.13	0.79	1.14	1.63	1.70	2.11	1.89
	Commercial	0.00	0.02	0.03	0.04	0.05	0.05	0.05
	Agriculture	0.00	0.02	0.02	0.03	0.03	0.03	0.03
	Aggregate EI	**0.28**	**0.31**	**0.26**	**0.27**	**0.28**	**0.36**	**0.37**
Thailand	Manufacturing	0.48	0.28	0.24	0.28	0.26	0.25	0.27
	Transportation	1.19	1.17	1.26	1.41	1.01	0.85	0.78
	Commercial	0.01	0.01	0.02	0.03	0.03	0.04	0.03
	Agriculture	0.07	0.07	0.09	0.10	0.10	0.10	0.08
	Aggregate EI	**0.16**	**0.13**	**0.16**	**0.20**	**0.18**	**0.18**	**0.17**
Singapore	Manufacturing	0.07	0.07	0.04	0.04	0.09	0.11	0.12
	Transportation	0.48	0.26	0.19	0.12	0.10	0.09	0.07
	Commercial	0.01	0.01	0.02	0.01	0.01	0.01	0.01
	Agriculture	0.00	0.01	0.01	0.02	0.03	0.00	0.00
	Aggregate EI	**0.05**	**0.06**	**0.05**	**0.03**	**0.04**	**0.04**	**0.04**
Philippines	Manufacturing	0.17	0.15	0.16	0.20	0.15	0.14	0.11
	Transportation	1.70	1.01	1.10	1.59	1.18	0.59	0.62
	Commercial	0.01	0.02	0.02	0.03	0.03	0.03	0.03
	Agriculture	0.04	0.03	0.02	0.02	0.02	0.01	0.02
	Aggregate EI	**0.14**	**0.11**	**0.11**	**0.16**	**0.13**	**0.09**	**0.09**
Malaysia	Manufacturing	0.91	0.49	0.33	0.28	0.30	0.23	0.21
	Transportation	1.76	0.87	0.96	0.87	0.93	0.66	0.66
	Commercial	0.02	0.02	0.03	0.03	0.04	0.04	0.03
	Agriculture	0.00	0.00	0.01	0.03	0.01	0.03	0.01
	Aggregate EI	**0.21**	**0.16**	**0.17**	**0.19**	**0.21**	**0.15**	**0.15**

From 1997 to 2016, the intensity of the two major energy-using sectors (manufacturing and transport) in Indonesia dropped significantly, although the aggregate energy intensity had not declined substantially. In 1997, the transportation and manufacturing sector energy intensity decreased from 1.12 and 0.25 to 0.51 and 0.17, respectively. However, the aggregate energy intensity only reduced from 0.14 in 1997 to 0.12 in 2016. The reason for this trend is that the level of the energy intensity of transport sector is three to four times that of the manufacturing sector, therefore the big shift to transport in output has increased the aggregate energy intensity, despite of the decline in the intensity of transport sector.

Overall, there was a significant drop in the manufacturing and transportation sectors aggregate energy intensity in most ASEAN-6 countries. For instance, in Indonesia, the manufacturing sector energy intensity in 2016 declined by 50% compared to the 1971 level. Indeed, the transportation energy intensity of Indonesia decreased even further compared to the manufacturing sector as in 2016 it dropped to one third compared to its level in 1971. These significant decreases not only occurred in Indonesia but also in Malaysia. Energy intensity in the manufacturing and transportation sector in Malaysia in 2016 dropped to one-fourth and less than a half, respectively, compared to its level in 1971.

3.5.5. Decomposition Analysis of Energy Intensity

Figure 3.2 summarises changes in energy intensity in the ASEAN-6 economies due to the changes within industry energy intensity (intensity effect), which also provides a proxy measure of energy efficiency activity at the sectoral level. Based on Figure 3.2, the general direction of the intensity effect in all ASEAN countries is downward. These decreasing intensity effects show that the trend towards technological changes in ASEAN countries has assisted significantly in increasing energy efficiency. Overall, all ASEAN countries had decreased their intensity effect. However, the intensity effect in Vietnam from the 1980s to 1996 showed an increase and quite high volatility, but this trend reversed at the beginning of 1997. Indonesia and the Philippines experienced a decreasing trend of intensity effect to the end period, due to experiencing higher levels of industrial development.

Figure 3. 2. The Trend of Decomposition Factors Energy Intensity from 1971 to 2016 (employing 1971 as the base year – Temporal Decomposition)

The results of the decomposition analysis show changes in aggregate energy intensity in the ASEAN-6 economies that are attributable to the structural effect and intensity effect over the period 1971 to 2016. Figure 3.2 summarises the changes in energy intensity explained by each of these effects. During the study period, final energy consumption in the end-use sectors grew significantly in all ASEAN-6 countries. Growth in economic activity is the major factor of the change in energy intensity over this period. The within industry energy intensity partly offset the changes in aggregate energy intensity attributable to the structural effect.

Overall, the high magnitude of the intensity effect (DINT) in the period 1971 to 2016 drove the aggregate energy intensity (DTOT) to decline in most ASEAN countries. However, while the intensity effect was falling, the industrial share (structural effect/DSTR) increased in most years. Indonesia and Malaysia showed a significant upward trend due to the structural effect. This surpassed the other ASEAN-6 countries that indicates that the industry mix in Indonesia and Malaysia was becoming more energy intensive and drove the aggregate energy intensity to increase. In Indonesia, the changes within industry energy intensity from 2006 to 2016 outperformed the structural effect and drove the overall energy intensity to decline. As shown in Figure 3.2, after 1999 there was a steady decline in aggregate energy intensity in Indonesia and the Philippines, although, the rate of reduction has differed. While Indonesia showed a more moderate rate of decline, the Philippines showed marked improvement. Thailand, Singapore and Malaysia showed a more stable energy intensity from of 2001 to 2016. As shown in Figure 3.2, Vietnam showed the highest rate of fluctuation in energy intensity.

In Indonesia, the structural effect increased energy intensity by around 200% compared to the base year of 1971. Structural shifts in the composition of the end-use sectors contributed to increasing energy intensity. The contribution of the intensity effect in Indonesia was relatively small during the study period, which has decreased the aggregate energy intensity by around 50% compared to the base year. This is likely to reflect greater energy efficiency activity in many sectors, including improved fuel efficiency in vehicles and improved efficiency and standards for buildings and appliances.

The above decomposition results are similar to most energy studies conducted in other contexts including Liu, N and Ang (2007); González, Landajo and Presno (2013) and Mulder and de Groot (2012). These studies conclude that the intensity effect (or technological improvements) has contributed more to reducing the total energy intensity than the structural effect.

3.5.6. Decomposition Analysis of Energy Intensity after the 1997 Financial Crisis[6]

The years from 1997 to 1999 were a period of economic turmoil for most of the ASEAN-6 countries due to the Financial Crisis. The impact of the crisis to the aggregate

[6] 1997 was employed as a base year because it is the year when the financial crisis hit ASEAN.

energy intensity trend in ASEAN-6 differed in each country (see Figure 3.3 below). In 1999 in Indonesia, the aggregate energy intensity soared to 122% compared to the base year of 1997. This high energy intensity occurred due to the high intensity effect that increased the energy intensity by 23%. However, after hitting a peak of energy intensity in 1999, the aggregate energy intensity in Indonesia in 2016 gradually declined to 17% below the 1997 level. This decline in Indonesia's energy intensity was due to the high-intensity effect that brought down the energy intensity by 37%.

Similarly, to Indonesia, the aggregate energy intensity in Malaysia in 1999 also increased by around 6% compared to the base level in 1997, due to an increase in intensity effect by 6%. However, after 2008, the energy intensity in Malaysia gradually declined, where in 2016, the energy intensity decreased to around 19% compared to 1997.

Different from Indonesia and Malaysia, the aggregate energy intensity trend in Thailand and the Philippines had seemingly not been affected by the Financial Crisis. In 2016, Thailand and the Philippines decreased their energy intensity by 13% and 42%, respectively, compared to the base level of 1997. These decreases in aggregate energy intensity were due to a large decrease in intensity effect. In 2016, the intensity effect in Thailand and the Philippines was strong enough to reduce energy intensity by 23% and 50%, respectively. While the structural effect in Thailand and the Philippines were only increased the energy intensity by 13% and 17%.

Compared to other ASEAN-6 countries, Vietnam and Singapore had a more volatile energy intensity trend. In 2016, Vietnam and Singapore had increased their aggregate energy intensity by 37% and 16%, respectively, compared to the 1997 base level. The increase in Vietnam's energy intensity was brought up by the increase in the structural effect of 46%, while in Singapore was a result of an increase in intensity effect for around 21%.

Figure 3. 3. The Trend of Decomposition Factors Energy Intensity, 1997–2016 (1997 as the base year – Temporal Decomposition)

From 1997 to 1999, Indonesia made various efforts at fossil fuel subsidy reform and experimented with the implementation of numerous policy measures (Savatic 2016). In addition, during this period the International Monetary Fund (IMF) assisted Indonesia to conduct a substantial industrial re-structure, where acquisitions and mergers across enterprises led to a decline in domestic production. During this short period, the intensity effect deteriorated (that is, drastically increased) and contributed to an increase in the overall aggregate energy intensity, while the structural effect slightly decreased until 1998 and then increased after 1999 (see Figure 3.3).

Aggregate energy intensity went through significant fluctuations in all ASEAN countries during the period 1971 to 2016. The main driving forces to these changes resulted from the substantial negative intensity effect outperforming the magnitude of the structural effect. Therefore, this situation indicates that behavioural changes from using less efficient to more efficient technologies, better innovation and modernisation, and improved research and development together became the main driving force in the overall decline of aggregate energy intensity. Thus, ASEAN has achieved significant energy intensity reductions by improving its technologies and devising supportive energy policy.

The changes within industry energy intensity continued to be the main driver to the declining trend of aggregate energy intensity in the region. The continuous development of an energy efficiency program in ASEAN-6 countries may provide a positive effect on the temporal decomposition of energy efficiency effect. However, the development of heavy energy-intensive industrial infrastructure demonstrated a strong trend towards a higher energy dependency, which resulted in a cumulative rise of aggregate energy intensity. The continuous development of energy-intensive industries played a crucial role in the ASEAN economic structures.

3.5.7. Sub-periods Decomposition

In addition to the previous decomposition, this study also examined ASEAN-6 energy intensity into sub-periods decomposition analysis. The analysis was conducted for seven sub-periods: 1971 to 1981, 1981 to 1991, 1991 to 1996, 1996 to 1998, 1998 to 2001, 2001 to 2011 and 2011 to 2016 (see Figure 3.4). This study conducted seven sub-periods analysis because the historical trend data was quite long for about 45 years from 1971 to 2016, thus, to capture the changes of energy intensity overtime, this study divided the period up to ten years. Additionally, this study also investigates the impact of 1997 financial crisis, thus, during the crisis period, this study make another time frame decomposition to capture this evidence, which can be seen during 1991 to 1996, 1996 to 1998, and 1998 to 2001. These sub-periods analyses aim to provide information about the changes that occurred in the ASEAN-6 economy during the study period; specifically, before and after the Financial Crisis.

Indonesia had a significant structural change throughout the first three sub-periods (1971 to 1981, 1981 to 1991 and 1991 to 1996), where the structural effect surged the aggregate energy intensity. During the period of crisis (1996 to 1998 and

1998 to 2001), the energy intensity increased by 14% and 7%, respectively. Both energy intensity increases were due to the increase in intensity effect. However, in the last two periods of 2001 to 2011 and 2011 to 2016, the aggregate energy intensity in Indonesia fell quite significantly to around 19% and 13%, respectively, compared to the base years of 2011 and 2016. Indonesia's energy intensity trend confirmed the previous result of Voigt et al. (2014) which showed that the structural effect peaked from 1999 to 2000 and decreased thereafter, shaping the overall trend of Indonesia's energy intensity.

Similarly, to Indonesia, Malaysia also had a significant structural change in the first three sub-periods (1971 to 1981, 1981 to 1991 and 1991 to 1996). During the period of crisis, aggregate energy intensity in Malaysia increased by 1% and 8%, respectively. However, in the last two sub-periods of 2001 to 2011 and 2011 to 2016, energy intensity declined by around 25% and 2%, respectively.

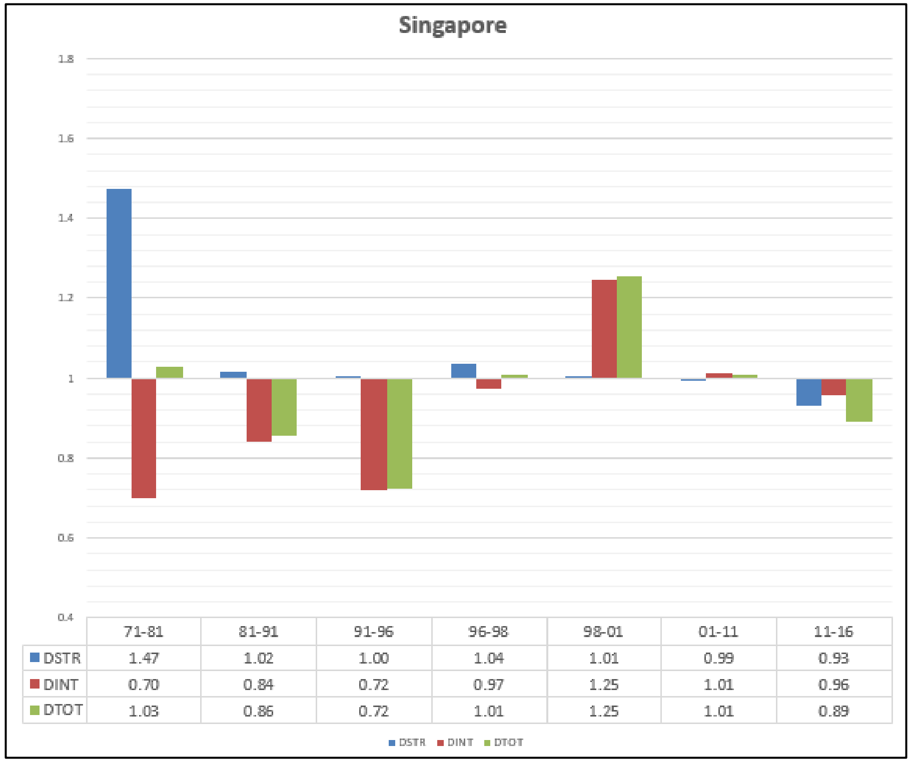
Singapore had the lowest aggregate energy intensity during the period 1981 to 1991 and 1991 to 1996 due to the high intensity effect. In Singapore, the role of structural effect was not as significant as intensity effect across the sub-periods analysis except in 1971 to 1981, where the structural effect brought up energy intensity to 147% of that prevailed in 1971, while the intensity effect led to a fall in aggregate energy intensity to 70%. During the period of crisis (1996 to 1998 and 1998 to 2001) energy intensity increased by 1% and 25%, respectively, compared to the 1996 and 1998 base levels. However, in the last period of 2011 to 2016, energy intensity decreased by 11% compared to the 2011 base level.

Thailand's energy intensity fell by 18% from 1971 to 1981, but the next two periods — 1981 to 1991 and 1991 to 1996 — the energy intensity increased by around 20% to 23%. Both increases in energy intensity were due to the increase in the structural effect and intensity effect. However, during the crisis period 1996 to 1998 and 1998 to 2001, the energy intensity declined by 3% to 4%, due to the decreasing intensity effect. The decrease in energy intensity also occurred until the end of sub-periods of (2001 to 2011 and 2011 to 2016).

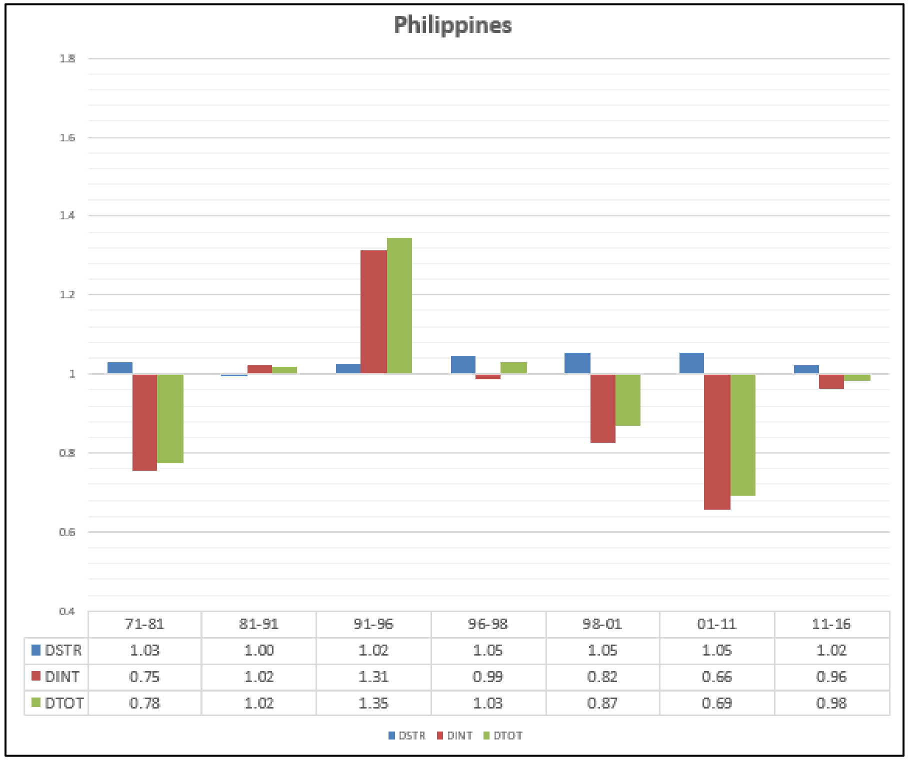
In the beginning period 1971 to 1981, Vietnam's energy intensity increased by 9% compared to the 1971 base level, due to an increase in the intensity effect. But in the period 1981 to 1991, the energy intensity decreased by 15% compared to the 1981 base level. During the crisis period of (1996-1998 and 1998-2001), energy intensity increased to around 2% as a result of an increase in the structural effect. The energy intensity peaked in the period 2001 to 2011 for around a 31% increase compared to the 2001 base level, due to the increase in both structural and intensity effect. However, at the end of the 2011 to 2016 period, energy intensity decreased about 2% compared to the 2011 base level; this occurred due to a decrease in the intensity effect.

Energy intensity in the Philippines from 1971 to 1981 decreased by around 22% compared to the 1971 base level, where this due to a decrease in intensity effect. From 1981 to 1991, energy intensity only increased by 2%, however, from 1991 to 1996, energy intensity surged by around 35% compared to the 1991 base level. This was due to an increase in the intensity effect. During the Financial Crisis, energy intensity only increased by 3% compared to the 1996 base level. In the last three periods: 1998 to 2001, 2001 to 2011 and 2011 to 2016, energy intensity decreased by 13%, 31% and 2%, respectively, due to the fall intensity effect.

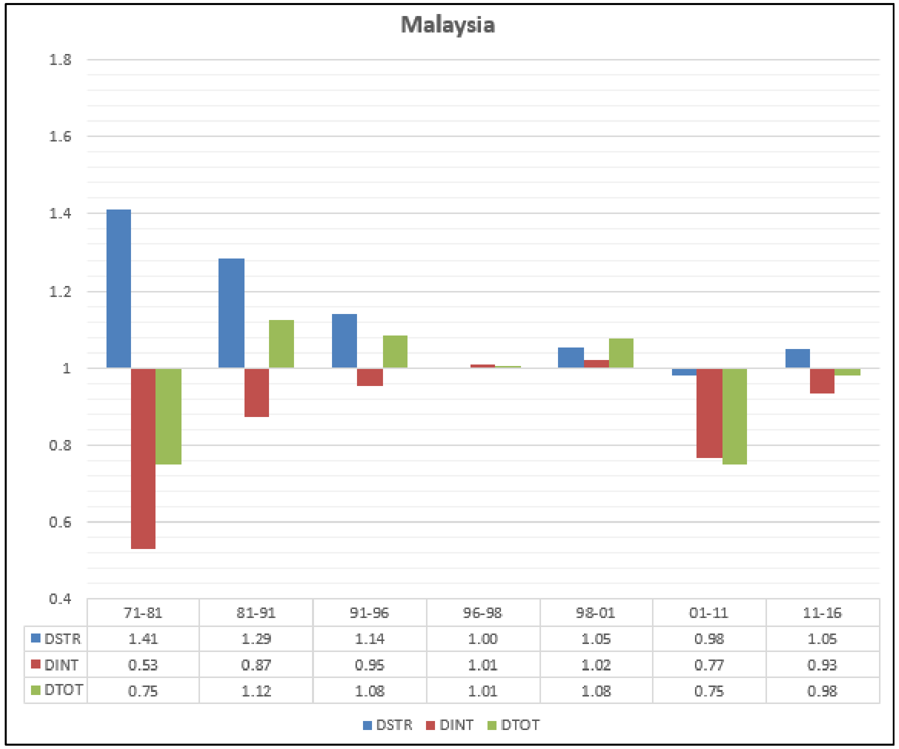
Figure 3. 4. Period wise Energy Intensity Decomposition



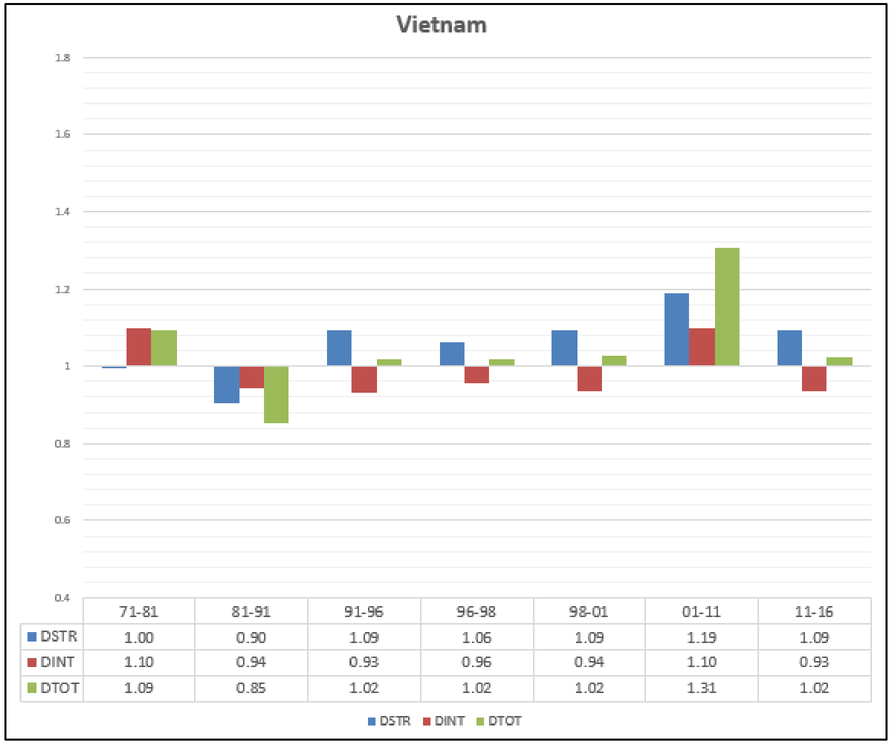
	71-81	81-91	91-96	96-98	98-01	01-11	11-16
DSTR	1.47	1.02	1.00	1.04	1.01	0.99	0.93
DINT	0.70	0.84	0.72	0.97	1.25	1.01	0.96
DTOT	1.03	0.86	0.72	1.01	1.25	1.01	0.89



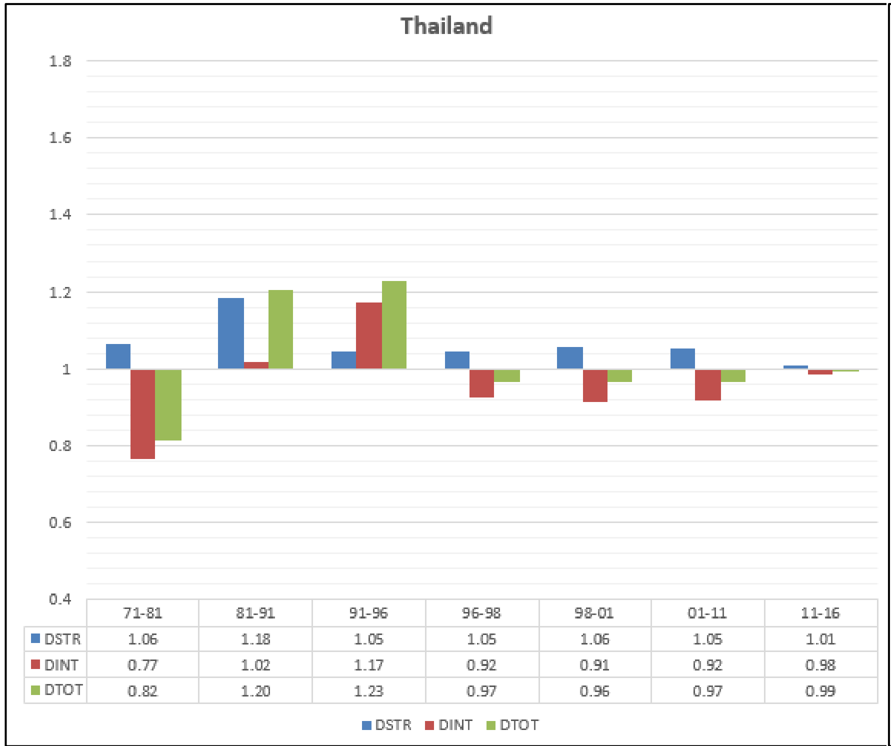
	71-81	81-91	91-96	96-98	98-01	01-11	11-16
DSTR	1.03	1.00	1.02	1.05	1.05	1.05	1.02
DINT	0.75	1.02	1.31	0.99	0.82	0.66	0.96
DTOT	0.78	1.02	1.35	1.03	0.87	0.69	0.98



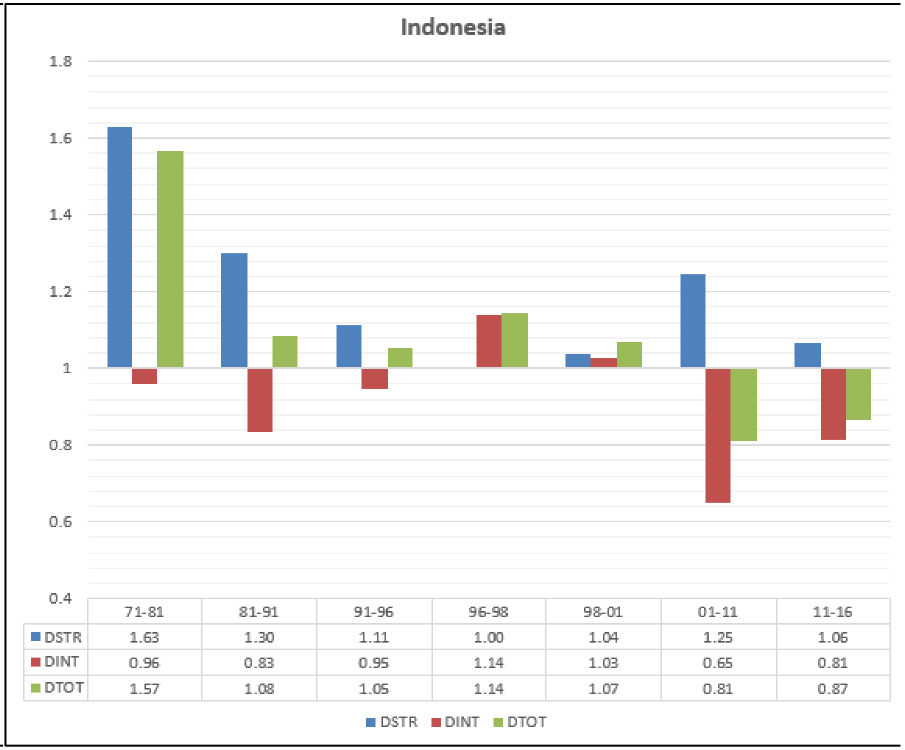
	71-81	81-91	91-96	96-98	98-01	01-11	11-16
DSTR	1.41	1.29	1.14	1.00	1.05	0.98	1.05
DINT	0.53	0.87	0.95	1.01	1.02	0.77	0.93
DTOT	0.75	1.12	1.08	1.01	1.08	0.75	0.98



	71-81	81-91	91-96	96-98	98-01	01-11	11-16
DSTR	1.00	0.90	1.09	1.06	1.09	1.19	1.09
DINT	1.10	0.94	0.93	0.96	0.94	1.10	0.93
DTOT	1.09	0.85	1.02	1.02	1.02	1.31	1.02



	71-81	81-91	91-96	96-98	98-01	01-11	11-16
DSTR	1.06	1.18	1.05	1.05	1.06	1.05	1.01
DINT	0.77	1.02	1.17	0.92	0.91	0.92	0.98
DTOT	0.82	1.20	1.23	0.97	0.96	0.97	0.99



	71-81	81-91	91-96	96-98	98-01	01-11	11-16
DSTR	1.63	1.30	1.11	1.00	1.04	1.25	1.06
DINT	0.96	0.83	0.95	1.14	1.03	0.65	0.81
DTOT	1.57	1.08	1.05	1.14	1.07	0.81	0.87

3.5.8. Comparing Regional Aggregate Energy Intensity

The aim of this sub-section is to measure regional disparities that can simultaneously capture both temporal changes and spatial differences in energy efficiency developments within each individual country in the ASEAN-6 by employing a Spatial-Temporal Index Decomposition Analysis (ST-IDA). The purpose of the spatial-temporal graph (as seen in Figure 3.5) is to show a better picture of each ASEAN-6 performance across countries over a given period. It (Figure 3.5) describes a multi-country performance and captures how the structural effect and the intensity effect changes over time amongst each ASEAN-6 countries.

The spatial-temporal analysis in this section provides a further explanation of ASEAN-6 performances, adding to the temporal analysis (as discussed in Figure 3.2 in the previous section). As in the temporal analysis, the analysis is created separately for each ASEAN-6 country and only shows a one-dimensional analysis of changes in energy intensity over time for a region/ country. The graph in the temporal analysis (Figure 3.2.) is obtained to study similarities and differences between ASEAN-6 countries. While, on the other hand, the spatial-temporal graph (as seen in Figure 3.5.) provides a full picture of the movements of intensity effect and structural effect of every ASEAN-6 countries over time compared to a reference region.

As this subsection aims to provide the performance and interpret the evolution of intensity effect and structural effect of each ASEAN-6 countries before and after the 1997 economic crisis, thus it analyses the variations of the aggregate energy intensity for all ASEAN-6 countries for three consecutive years including 1973, 1997[7] and in 2016. The Financial Crisis was considered as part of the study in order to interpret the evolution of energy intensity at an economy level in all ASEAN-6 countries during the study period.

Following the ST-IDA approach developed by Ang, Su and Wang (2016), the reference region is constructed based on the weighted averages of the energy intensity and value-added shares of the ASEAN-6 countries for the selected three-year period. The reference region serves as a benchmark for ASEAN-6 countries. As shown in Figure 3.5, the changes in aggregate energy intensity are described by the moves of points and arrows along with the plot diagram that depicts the changes in intensity effect and structure effect. The results of decomposition for every country for 1971, 1997 and 2016 are indicated by dots that are joined by arrows. For the reference country, the production

[7] The 1997 financial crisis happened as a result of economic bubbles and high inflation in most Asian countries, namely Thailand, Indonesia, South Korea, Philippines, Malaysia, Singapore and other Asian countries.

share values, and energy intensity are calculated employing the weighted averages of the six ASEAN countries over the three years period. The origin value of (1,1) describes the reference region with an aggregate energy intensity of 0.14 KToE per million US dollars (KToE/10^6 USD) at constant 2010 prices in US dollars.

This study utilises a multiplicative decomposition, therefore, the intensity and structure effects are conveyed in ratio estimations, where the measures in the y-axis and x-axis imply the ratio change from the benchmark country. Thus, a value of 1.1 means that the effect is determined to be 10% greater as compared to the benchmark country, while on the other hand, a value of 0.9 implies that the effect is 10% lower as considered to the reference country.

Figure 3. 5. Spatial-Temporal IDA, 1971–1997–2016

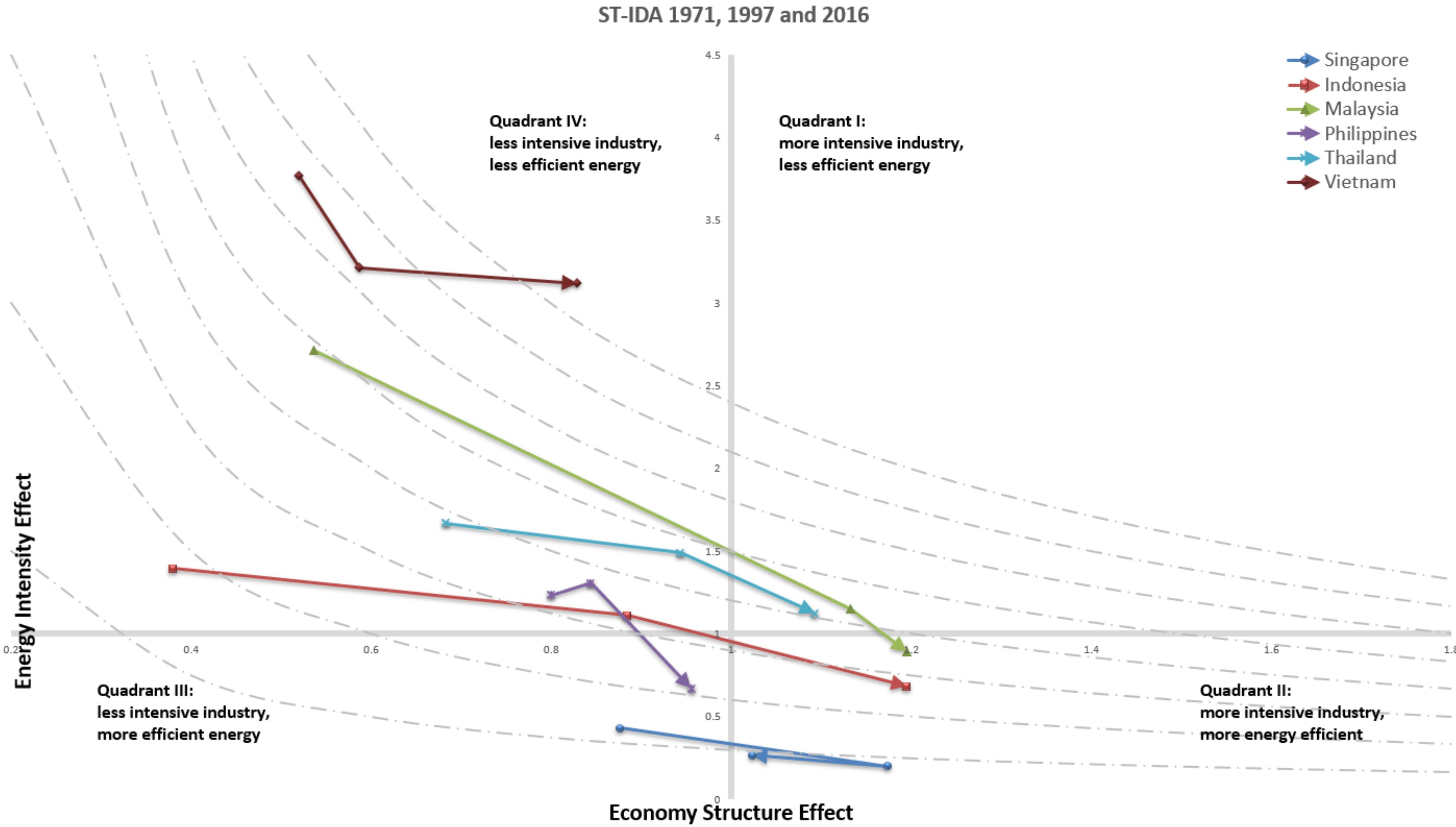


Diagram plot in Figure 3.5. can be divided into four quadrants, namely Quadrant I, II, III and IV. From this Figure, a positive improvement in either intensity or structural effects are represented by the country moving towards a smaller value along an axis over a period of time, which is related to the decreasing of aggregate energy intensity over time. On the other hand, a country shifting towards a greater value along an axis indicates a negative development, which contributes to an increase in aggregate energy intensity over time.

Quadrant III is set in the bottom left corner and represents the best quadrant (the most energy efficient countries), where the countries in this quadrant represent less intensive industries and more efficient energy usage compared to the benchmark country. During the three-year study period there are only two countries that are located in Quadrant III: Singapore (in 1971) and the Philippines (in 2018). The aggregate energy intensity in these countries showed a lower than the aggregate energy intensity of the reference country.

On the other hand, Quadrant I is located in the top right corner which represents the worst quadrant (or the least energy efficient nations). The countries in this quadrant have a higher structure effect (having a more intensive industry in the economic structure) and a higher intensity effect (using less efficient energy usage technology) compared to the reference country. There are two countries positioned in Quadrant I: Malaysia (in 1997) and Thailand (in 2016).

Additionally, Quadrant IV is positioned in the top left which depicts those countries with less intensive industries and less efficient energy usage compared to the reference country. Most of the ASEAN-6 countries had some time of aggregate energy intensity in this quadrant, except Singapore, since Singapore was more developed compared to the rest of the ASEAN-6 countries. This situation is consistent with the fact that most of the ASEAN-6 countries are developing countries; therefore, their economy uses less energy (using less energy-intensive sectors of the economy) in the beginning of their economic development. However, along with the advancement of its economy, their economic structure shifting from less energy-intensive to a more energy-intensive sector economy over time. The shifting of economic structure can be seen from the increasing value along the horizontal axis over time. Almost all of ASEAN-6 countries have shifted from Quadrant IV to another Quadrant, except Vietnam. Vietnam stayed in Quadrant IV, showing its economy comprises of less intensive industry and less efficient in energy usage compared to the rest of ASEAN-6 countries.

Last, Quadrant II is located in the bottom right corner. This describes the countries with a higher structure effect, but less intensity effect compared to the ASEAN-6 average. There are two countries located in this quadrant: Indonesia (in 2016) and

Singapore (in 1997 and 2016). It is interesting to note that Singapore went through less intensive industry (in 1971) to more intensive industry (in 1997), but in 2016, Singapore was approaching Quadrant III showing industry in Singapore become less intensive and more energy efficient.

From Figure 3.5., it is clear that all of the ASEAN-6 countries have improved their aggregate energy intensity (AEI) over time. The AEI of the ASEAN countries influenced by the structural and intensity factors. The graph showed that the developing countries develop their economies from less intensive energy sectors to more intensive energy sectors, for instance from agriculture to the manufacturing sector. The structural effects have improved over time; however, the magnitude is not as great as the intensity factors. This situation implies that the government economic policies are significant in determining the result of the overall energy efficiency over time in the ASEAN-6.

3.6. Discussion

The overall industrialisation process of the ASEAN-6 countries can be observed from the changes in its economic structure in all of the ASEAN-6 economies over the 45 years of analysis. Four trends can be observed from the ASEAN-6 economy in terms of structural changes (see Table 3.2). First, the commercial sector played a substantial role in the overall economic structures that accounted for more than 40% of the aggregate economic structure of the ASEAN-6 from 1971 to 2016. Second, the role of the manufacturing sector has increased almost two-fold in the ASEAN-6 countries, except for Singapore and the Philippines, whereas in Indonesia the share from this sector has increased almost four-fold. Third, the declining share of the agricultural sector to the total economic output of most of the ASEAN-6 countries, except Singapore. The share of the agriculture sector was prominent at the beginning of the 1970s, however, as most of the ASEAN-6 countries have expanded their economies, their reliance on agriculture sector decreased quite significantly over time, except for Singapore which had minimal reliance on agriculture. Fourth, the aggregate share of the transportation sector's output is the smallest during the study period, but the output from this sector increased slightly over time. The output from the transportation sector increased almost two-fold in almost all of the ASEAN-6 countries, whereas in Indonesia the share from this sector increased around four-fold. The ASEAN-6 countries increased their energy consumption substantially during the period of study. The trend of total energy consumption from 1971 to 2016 demonstrates the dominance of both manufacturing and transportation sectors that accounted for more than 80% of aggregate energy consumption in the ASEAN-6. In Indonesia, particularly, both sectors consumed approximately 90 per cent of total energy use during the study period, while energy consumption from commercial and agriculture sectors was negligible.

The impact of the 1997 Financial Crisis to the aggregate energy intensity trend in ASEAN-6 differed from country to country (see Figure 3.3). In Indonesia and Malaysia, the impact increased energy intensity in 1999 by around 23% and 6%, respectively, compared to the base level of 1997. However, in 2016, the energy intensity in both countries gradually declined to around 17% (Indonesia) and 19% (Malaysia) compared to the base year 1997. Different from Indonesia and Malaysia, the aggregate energy intensity trend in Thailand and the Philippines had seemingly not been affected by the Financial Crisis, as they still had a declining energy intensity trend after the crisis. In 2016, Both Thailand and the Philippines had decreased their energy intensity by 13% and 42%, respectively, compared to the base level of 1997. These decreases in aggregate energy intensity were due to a strong decrease in intensity effect. Compared to other ASEAN-6 countries, Vietnam and Singapore had a more volatile energy intensity trend. In 2016, Vietnam and Singapore had increased their aggregate energy intensity by 37% and 16%, respectively, compared to the 1997 base level.

Apart from the Financial Crisis, the ASEAN-6 economy experienced largely uninterrupted growth over the past three decades. Until the mid-1980s, the rate of economic growth moved in parallel with growth in energy consumption. Since then, growth in ASEAN-6 energy consumption has slowed and has generally remained below the rate of economic growth. Changes in the composition of energy use associated with structural shifts in the ASEAN-6 economy have contributed to a relative slowdown in the growth in energy use. Energy efficiency activity in individual sectors has also played a role. The substantial changes in energy intensity during the past three decades were evidently a result of the expansion in economic activity. The changes in economic structure (structural effect) towards more energy-intensive sectors such as shifting from agriculture economy towards the manufacturing sector has increased energy consumption. However, the intensity effect contributed to a reduction in energy intensity over the past three decades.

In general, the level of energy intensity in Indonesia had an average trend compare to other ASEAN countries. It increased moderately in the middle period but declined steadily at the end of the period. The increasing trend of energy intensity in Indonesia occurred mostly as a result of the high magnitude of the structural effect over the intensity effect which indicated the industry mix was becoming more energy intensive. The role of the agriculture sector was significant at the beginning of the 1970s and comprised around a half of the economic structure. However, as Indonesia's expanded its economy, the reliance on agriculture sector decreased slightly over time and reached around 20% of the economy in late 2016. On the other hand, the increasing share of manufacturing and commercial sectors in the economy played a significant role in the overall economic structural changes, where both sectors accounted for around 70% of the economy. This evidence shows that industrialisation in Indonesia has become a great influence on the overall economy.

Energy consumption growth in Indonesia has not coincided with the deteriorating of energy intensity, mainly because of structural shifts in the economy and new investment in the economic sector. From 2000 to 2016, the aggregate value-added was doubled, total energy consumption rose but less than the aggregate value-added growth, noting that the energy intensity improved (or decreased). Other ASEAN countries also experienced a similar trend, whereas the energy intensity has improved over time.

The average energy intensity in Indonesia rose during the periods 1975 to 1983, 1989 to 1999 and then declined again after 1999 when the severe impact of the economic crisis subsided. During the crisis period (see Figure 3.3), the intensity effect has worsened (increased) the aggregate energy intensity due to the substantial restructuring in industrial sector that occurred after the 1997 economic crisis. However, the intensity effect have improved (decreased) since 2000 during the period of higher oil prices, whereas the immense instability of international oil price had promoted the low carbon economy. Efficiency improvement (intensity effect) leads a dominant role in decreasing the aggregate energy intensity. The intensity effect of 2016 reduced the aggregate energy intensity for about 50% of its 1971 level, while structural change deteriorates aggregate energy intensity for about 208% compared to its level in 1971. Furthermore, the changes in the structure index indicates that the structure of economy periodically shifted away from the agriculture sector to the manufacturing sector in the 1980s.

The improvement in intensity effect in all ASEAN-6 countries has become the primary driving force for the aggregate energy intensity to decline, while the magnitude of the structural effect is limited. Based on the energy intensity patterns of ASEAN-6, Indonesia and Malaysia demonstrated a greater impact on structural changes than other ASEAN countries. The structural changes had a more significant impact on increasing the aggregate energy intensity in Indonesia and Malaysia than in the other ASEAN-6 countries. In other words, this shows that these countries made substantial industrialisation process by moving from less energy-consuming sectors such as agriculture to more energy-intensive sectors such as manufacturing.

3.7. Conclusion

This study decomposed the changes in aggregate energy intensity in the ASEAN-6 countries for the period 1971 to 2016. For this goal, this study employed a multiplicative LMDI-II method and ST-IDA. This study demonstrated that the aggregate trend of the changes of ASEAN energy intensity fluctuated moderately for all ASEAN-6 countries, where variations in energy intensity appeared in these countries. As an overall trend, energy intensity in Singapore was the lowest and markedly stable during the study period, while Vietnam had the highest and more fluctuating energy intensity. Indonesia, Malaysia, the Philippines and Thailand have more moderate energy intensity trend compare to other ASEAN-6 countries.

Two distinct periods are evident in terms of trends in aggregate energy intensity in Indonesia, and in some other ASEAN countries (Thailand, Malaysia and the Philippines). For Indonesia, aggregate energy intensity rose steadily by an average of 3% per year from 1971 to 1999, more than doubling over this period, while from 1999 to 2001 energy intensity fell by 1% per annum on average, falling by 17% overall. While this change in the trend after the Financial Crisis is also evident in the three countries mentioned, it is most pronounced in Indonesia and becomes a central theme of this analysis. By 2016 Indonesia's aggregate energy intensity was towards the bottom of the range of the five larger developing members of ASEAN-6, is below that of Thailand and Malaysia and well below that of Vietnam, but above that of the Philippines. Each of these countries has an energy intensity much higher than Singapore.

In terms of structure and industry effects on aggregate energy intensity, while all of the ASEAN-6 countries showed a shift in industry value-added to more energy-intensive industries offset by falling within-industry energy intensity, the analysis in this chapter indicates that this trend was most pronounced in Indonesia. Over the full period, Indonesia experienced a pronounced shift to a more energy-intensive industry structure but sustained falls in within-industry energy intensity. Before the Financial Crisis, Indonesia's move towards a more energy-intensive economic structure and was driven by the rise of manufacturing, which increased from 8% of GDP in 1971 to 30% in 1997, while the share of agriculture fell from 49% to 20%. But after the crisis, the manufacturing share fell somewhat to 28% by 2016, the decline in agriculture moderated (falling to 17% by 2016) and the shift a more energy-intensive industry structure was driven by the rise in transport, from 5% of total value-added in 1997 to 11% by 2016. As the energy intensity of manufacturing and, particularly, transport, is much higher than of the rest of the economy, by 2016 over 90% of total final energy consumption was in these industries.

Overall, observing the sub-period decomposition analysis result, the one per cent energy intensity reduction per year that has been set by mostly all of the ASEAN-6 government are seemingly too low. As each country in ASEAN-6 can easily reach the target of more than 1% of energy intensity reduction per year. For instance, the aggregate energy intensity of Indonesia during 2001 to 2011 has decreased by 19%, which means Indonesia has decreased its energy intensity by around 1.9% annually for 10 years period compared to the base level of 2001. This 2% energy intensity decrease is lower than Indonesia's pledge of 1% energy intensity reduction per year outlined in Indonesia's government regulation.

As observed in the analysis, the main energy consumer in all ASEAN-6 countries comes from the manufacturing and transportation sector, where these two sectors account for more than 70% of total national energy usage. In Indonesia these two sectors consumed more than 80% of total energy consumption during the study period. In addition to its consumption share, both manufacturing and transportation energy intensity in Indonesia had dropped significantly compared to its level in 1971. In 2016, the manufacturing energy intensity declined to a half and the transportation decreased up to one-third compared to its level in 1971. From the above findings, it can be observed that Indonesia experienced a substantial structural shift in its economy from less energy-consuming sectors (that is, agriculture) to more energy-intensive sectors (that is, manufacturing). In terms of sectoral energy intensity reduction, the manufacturing and transportation sectors were the two highest sectors that drove the aggregate energy intensity to decline. The significant drop in both transportation and manufacturing sector energy intensity needs to be further investigated. For this reason, this dissertation concentrates more detailed analysis of both sectors of manufacturing and transport and elaborate on the main factors affecting the decline in energy intensity in these sectors.

The following chapters of this dissertation build on the analysis in this chapter (Chapter 3) to investigate further changes in final energy consumption in the Indonesian economy in more detail using data at the sub-sectoral level, particularly in the Manufacturing sector (Chapter 4) and Transportation sector (Chapter 5). Besides those sectoral energy intensity analyses, this dissertation also explores the performance of regional energy intensity (Chapter 6), which provide a further investigation of the factors that drive the changes of the energy intensity across 33 provinces in Indonesia.

Chapter 4
Energy Intensity Changes in Indonesia's Manufacturing Sector

4.1. Introduction

Energy demand and greenhouse gas (GHG) emissions in Indonesia have increased rapidly in recent years (Tharakan 2015). The energy consumption in the manufacturing sector accounts for around 40% of total final energy consumption in Indonesia in 2016, which also the second highest energy consuming sector after the transportation sector. Based on IEA (2017a), energy consumption growth in Indonesia has not coincided with a deterioration of energy intensity, this is mainly due to efficiency improvements from new investment in the industrial sector and structural shifts in the economy.

The manufacturing sector is one of the most vital sectors in Indonesia as it contributes significantly to national energy consumption and output (GDP). According to the Indonesian Statistic Bureau (BPS), since the 1990s the manufacturing sector has become one of the largest contributors to Indonesia's energy consumption and national output (BPS 2019). The manufacturing sector has accounted for around 28% of Indonesia's GDP in 2016. In the last five years, the value added from this sector has grown averagely for 5% per annum. Along with the manufacturing output growth, the energy consumption also rose in the previous five years from 3% to 4% growth annually. Interestingly, the rate of growth in energy consumption is slightly smaller than the rate of growth in value-added. Based on this estimate, it can be said that the energy efficiency of the manufacturing sector has improved over time. Hence, looking at this trend, it is essential to examine and identify which sectors have the greatest potential to improve energy intensity in the manufacturing sector.

The aim of this chapter is to examine the driving forces affecting changes in aggregate energy intensity in various sectors of Indonesia's manufacturing industry and investigate the energy intensity and value-added performance across manufacturing sectors. This chapter analyses the characteristics of energy intensity in the manufacturing sector in Indonesia from 1980 to 2015. This area has not had a great deal of research in the past of Indonesia's literature particularly by employing the LMDI method. The analysis of industrial energy consumption has been conducted for several countries in the international context, but it is found insufficient in the Indonesian case. This study aims at filling this gap by focussing on identifying the factors affecting changes in energy intensity resulting from decomposition. However, as limitation in the manufacturing data, this study only focuses on medium and large manufacturing enterprises.

By conducting the decomposition method across Indonesia's manufacturing sector, this will provide further insight into the energy intensity performances. This study provides valuable evidence and information which adds to the literature of energy-economics in Indonesia. The findings will help subsequent researchers and policy makers to understand what driving forces affecting energy intensity in Indonesia, so this can inform policy aimed at reducing energy consumption in Indonesia in the manufacturing sector.

4.2. Literature Review

Many studies have been conducted to investigate the relationship between energy consumption, economic growth and environmental aspects in Indonesia (Azam et al. 2015; Hasan, Mahlia & Nur 2012; Heidari, Katircioğlu & Saeidpour 2015; Hwang & Yoo 2014). However, there are very few studies employing the decomposition method in Indonesia that measure the factors affecting energy intensity (Hartono, Irawan & Achsani 2011; Vivadinar, Purwanto & Saputra 2012) and environmental analysis (Sitompul 2006). Previous research generally focused on the manufacturing sector's energy consumption, while this study extends the investigation by adding sub sectoral data to provide further insight into the energy system.

The first attempt to investigate the factors affecting energy consumption in Indonesian manufacturing was conducted by Sitompul (2006) by using three digit level data disaggregation (9 sectors and 30 subsectors) from 1980 to 2000, Sitompul (2006) applied decomposition analyses developed by Sun (1998) to separate the energy intensity into technical effects and fuel mix effect. The result shows that the major contributor to the energy intensity changes in Indonesia is a technical effect.

Hartono, Irawan and Achsani (2011) decomposed the changes in energy intensity in the manufacturing sector into activity and efficiency effects from 2002 to 2006. In the analysis, they divided the industry into nine subsectors and divided the industry into two types: medium enterprises (firms that have less than 100 employees) and large enterprises (firms that have more than 100 employees). They found that the level of energy intensity in each industry level vary across subsectors and the changes in energy intensity in the national level are determined by large enterprises. They also found that the level of energy intensity is influenced by capital intensity, wages and capital share.

Vivadinar, Purwanto and Saputra (2012) measured the factors affecting energy intensity and consumption in the manufacturing sector, focusing on high energy consumption industries: steel, pulp and paper, cement and glass, chemical and non-metallic industries. They applied the decomposition method employing annual industry data from 2001 to 2007. They found that the changes in the energy demand and intensity were a result of technology factor, whereas the role of production output was relatively small. However, the structural effect significantly affected the energy intensity in the glass and pulp industries.

Ramstetter and Narjoko (2014) investigated whether multinational corporations (MNCs) were more energy efficient than state-owned enterprises (SOEs) in Indonesian industries, focussing on medium to large manufacturers over the period 1996 to 2006. By using a trans log production function model, they found that the relationship between energy intensities and ownership amongst Indonesia's manufacturing sectors were relatively weak.

4.3. Methodology

This study employs the Logarithmic Mean Divisia Index in multiplicative form, following the model developed by Ang (2004, 2015), to investigate Indonesia's manufacturing sector for the period from 1980 to 2015. The aggregated manufacturing energy intensity is defined by equation (1) below

$$I = \frac{E}{Y} \quad (1)$$

Where

I denotes Energy Intensity (terajoules/million Rupiah 1980), E is manufacturing sector energy consumption (terajoules) and Y represents manufacturing value-added at 1980 constant prices (in million Rupiah).

This study will refer to decomposition analysis described below, where Indonesia's energy intensity includes two factors: the intensity effect of each subsector in manufacturing (D_{int}) and the structural effect of manufacturing (D_{str}). The decomposition method is computed as follows:

$$D_{tot} = D_{str} \,.\, D_{int} = \frac{I_t}{I_0} \tag{2}$$

$$D_{str} = exp \sum_{i}^{n} \left(\frac{L(w_{i,t}, w_{i,o})}{\sum_{i}^{n} L(w_{i,t}, w_{i,o})} ln\left(\frac{S_{i,t}}{S_{i,0}}\right) \right) \tag{3}$$

$$D_{int} = exp \sum_{i}^{n} \left(\frac{L(w_{i,t}, w_{i,o})}{\sum_{i}^{n} L(w_{i,t}, w_{i,o})} ln\left(\frac{I_{i,t}}{I_{i,0}}\right) \right) \tag{4}$$

$$L(w_{i,t}, w_{i,o}) = \frac{w_{i,0} - w_{i,t}}{ln\left(\frac{W_{i,0}}{W_{i,t}}\right)} = \frac{\frac{E_{i,0}}{E_0} - \frac{E_{i,t}}{E_t}}{ln\left(\frac{\frac{E_{i,0}}{E_0}}{\frac{E_{i,t}}{E_t}}\right)} \tag{5}$$

$$S_i = \frac{Y_i}{Y} \tag{6}$$

where:

D_{tot} denotes total energy intensity change in year t, relative to the reference year; D_{int} denotes changes in aggregate energy intensity due to changes in each subsector energy intensity;D_{str} is change in aggregate energy intensity due to changes in the structure of the economy; S_i denotes ratio of output of-subsector i to the aggregate output; $w_{i,t}$ is a weight function with factor i in time *t*; $w_{i,o}$ is a weight function with factor i in time 0; L is the logarithmic average of two positive numbers..

This chapter divides the driving forces affecting energy intensity into two factors: (1) whether an increase in energy consumption in Indonesia is related to the shift to more or less energy-intensive industries (between sector changes/structural effect) or (2) whether it is a result of the improvement or deterioration of energy efficiency (changes within sector energy intensity/ intensity effect). Additionally, it will also determine which sectors have the most improved energy consumption, output and energy intensity. By employing energy intensity as an indicator of energy efficiency, this chapter will investigate whether there was an improvement in energy efficiency in Indonesia's manufacturing sector during the period 1980 to 2015.

4.4. Data

4.4.1. Description of Data Sources

The primary database used in this study is the Medium and Large Manufacturing Firms Annual Survey (Statistik Industri Perusahaan Menengah dan Besar Survei Tahunan), which is collected from the BPS from 1980 to 2015. The number of firms in the survey differs depending on the period of the survey, from the smallest number of firms at around 7,471 manufacturers in the 1970s to the largest number of firms at around 29,568 manufacturers in the 2000s. The BPS organized this survey to collect data comprising basic details of every manufacturer, such as total assets, total income, total expenditures, details in the productions process including total workers, labour expenses, total energy consumption, electricity use, material, value added, value of gross output, details of establishments including first year of production, industry classifications, locations, ownerships details (that is government, domestic or foreign). The summary report from this survey is published annually, where electronic data is provided with the authorization from BPS officials.

The manufacturing sector featured in this study follows the International Standard Industrial Classification (ISIC) codes with five-digit industrial codes for various economic activities, whereas the BPS modified the firm-level data considering the real situation of Indonesian manufacturing. Throughout the study period, the BPS made several changes in the manufacturing classification to adjust to the increasing number of manufacturers, while also accommodating the ISIC classification changes.

The BPS has conducted surveys of manufacturing annually since 1975. The most current data is available to 2015. From 1975 to 2015, there have been several reclassifications of industrial data, where adjustments are required to provide a reliable and consistent classification code. The BPS classification changes that occurred during the study period are as follows:

- For period 1980 to 1997, the data consisted of 30 subsectors of three-digit industry codes starting with 311 until 390 to the base class 24 sectors in two-digit industry codes from 31 to 39 (ISIC 2 classification).
- For period 1998 to 2010, the data consisted of 66 subsectors of three-digit industry codes starting with 151 until 372 to the base class 23 sectors in two-digit industry codes from 15 to 37 (ISIC 3 classification).

- For period 2011 to 2015, the data consisted of 71 subsectors of three-digit industry codes starting with 101 until 332 to the base class 24 sectors in two-digit industry codes from 10 to 33 (ISIC 4 classification).
- Industries refer to three-digit categories. In this study, the data were disaggregated into the two- and three-digit level.

For reasons of compatibility and consistency, this study follows the ISIC Revision 2 (code of 1990) for the data analysis by employing the special map provided by the BPS. As the changes in the ISIC code and reclassifications occurred in the dataset during the study period, this study only uses the dataset for 1980, 1990, 1997, 2000, 2010 and 2015. These different time periods were chosen to capture the effects before and after the Financial Crisis on the changes in aggregate energy intensity in the manufacturing sector.

As mentioned earlier, this study utilized a long data history analysis, therefore for compatibility and consistency reasons, this study follows the ISIC Revision 2 for the data analysis. The classification of ISIC revision 2 is as follows in Table 4.1. below:

Table 4. 1. ISIC-2 Indonesia's Economic Activities Classification

ISIC	Sectors	ISIC	Sub- sectors
31	**Food, Beverages and Tobacco**	311	Basic Food
		312	Other Food
		313	Beverage
		314	Tobacco
32	**Textile, Wearing Apparel and Leather**	321	Textiles
		322	Wearing apparel
		323	leather and leather products
		324	Footwear
33	**Wood and Wood Products**	331	Wood and wood and cork products
		332	Furniture and fixtures
34	**Paper and Paper Products**	341	Paper and paper products
		342	Printing and publishing
35	**Chemicals, Petroleum, Coal, Rubber and Plastic Products**	351	Industrial chemicals
		352	Other chemical products
		353	Petroleum refineries
		354	Miscellaneous products of petroleum and coal
		355	Rubber products
		356	Plastic products
36	**Non-Metallic Mineral Products**	361	Pottery, china and earthenware
		362	Glass and glass products
		363	Cement and Lime

		364	Clay products
		369	Other non-metallic products
37	**Basic Metal Industries**	371	Iron and steel basic industries
		372	Non-ferrous metal basic industries
38	**Fabricated Metal Products, Machinery and Equipment**	381	Fabricated metal products
		382	Machineries
		383	Electrical goods and appliances
		384	Transport equipment
		385	Measuring and controlling goods
39	**Other Manufacturing Industries**	390	Other Manufacturing Industries

The manufacturing sector in this study is limited to the medium8 and large9 scale industries, which accounted for nearly 90 per cent of aggregate manufacturing value-added. Medium and Large Manufacturing Firms Annual Survey contains samples of manufacturing enterprises or census of enterprises. Thus, as its only containing samples, then summation of these samples is not the same as the summation of the true population number. This study is limited to the manufacturing sector as this sector has comprehensive and detailed data (up to the subsector level disaggregation) that makes it easier to elaborate the effects of industrial restructuring. Data disaggregation is important in exploring the detail necessary to study the effect of changes in the structure and intensity within subsectors. It is also essential to identify energy-intensive industries among the manufacturing subsector.

4.4.2. Procedures in Constructing the Dataset

The BPS manufacturing dataset has been considered by many studies and researchers as one of the best datasets that provides a long period historical dataset in the manufacturing sector statistics (Amiti & Konings 2007; Bernadetta 2016; Narjoko & Hill 2007). Notwithstanding this, the BPS dataset has several drawbacks which need some adjustments to produce a valid and consistent data. Reliable empirical research results can only be obtained from a valid and consistent dataset (Leung 2015).

Therefore, in order to construct a consistent dataset, several adjustments have been adopted in this study, as below:

- Phase 1: Set definitions for each variable

  As the BPS changed the definition of each variable during the period of observation, this study verifies and compares each variable in the dataset (for the particular year of the study period) to ensure the consistency and validity of the variables. If there is

[8] Medium industries are establishments employing 20 to 99 workers.
[9] Large industries are establishments employing 100 or more workers.

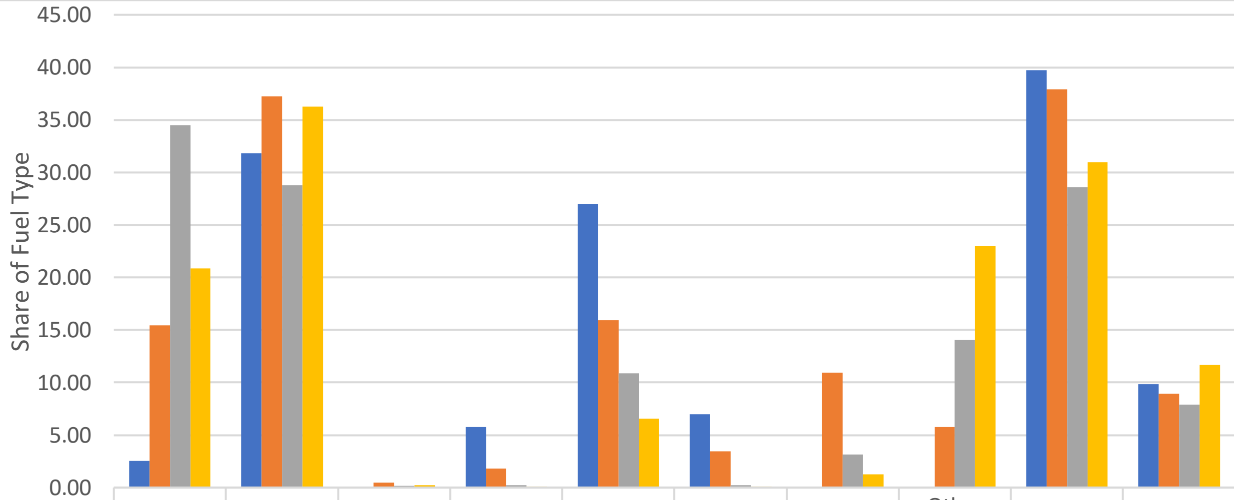
an inconsistency in the variables and definitions, then this study redefines the inconsistent variables to get a consistent definition over the selected period of study.

- Phase 2: Correcting for noise in the dataset
  In order to minimize the noise in the dataset, several steps are taken. First, all of the firms' data which have negative or nil value of energy and value added is removed. Second, to get a consistent data, all noticeable typo errors and mistakes in the dataset are adjusted. For example, if there are substantial and sharp changes in the value of energy consumption or output, where the overall trend of energy consumption and output in all years is 100% but nil for other years then adjustments are made by correcting the value of 0% to 100%.
- Phase 3: Computing total output/value added
  The ISIC codes provided by the BPS has five digits. This data needs to be aggregated into two-digit and three-digit industrial codes to make it comparable across the study period. Output in this study is measured as value-added of Indonesian Rupiah's (in million Rupiah at a constant 1980 price).
- Phase 4: Summation of input (energy consumption)
  Energy consumption in this study is the end-use energy consumption by the manufacturing sector. All data is in total fuel consumption, which is the sum of fuel used for manufacturing processes and power generation. The dataset provides different types of fuel used, which include ten types of energy primarily utilized in the manufacturing sector, including gasoline (in litres), kerosene (in litres), automotive diesel oil (ADO) (in litres), industrial diesel oil (IDO) (in litres), fuel oil (FO) (in litres), liquid petroleum gas (LPG) (in kilograms), coal (in kilograms), coke (in kilograms) and electricity (by kilowatt-hour). These fuel types' values were standardised and converted into a standard energy unit: terra joules (TJ).

4.5. Energy Consumption by Type in the manufacturing sector

The manufacturing sector has a substantial share of energy use in Indonesia at approximately 40% of aggregate final energy consumption in 2015, and its consumption has increased by around 4% per year since the 2000s. Figure 4.1 shows the proportion of coal used in manufacturing increased significantly from around 2.51% in 1980 and to approximately 34.51% in 2010, although there was a decrease after this period to around 20.86% in 2015. This decrease in coal consumption was followed by an increase in gas and electricity use during the same period from 28.8% and 7.89% in 2010 to 36.26% and 11.67% in 2015, respectively. Oil was the prominent fuel source in the manufacturing since the 1980s, however, its share decreased from 39.74% in 1980 to around 30.97% in 2015.

Figure 4. 1. Total Final Energy Consumption by Fuel in Manufacturing



	Coal	Gas	LPG	Kerosene	ADO	IDO	Fuel Oil	Other Petroleum Product	Total Oil Products	Electricity
1980	2.51	31.83	0.00	5.74	27.02	6.99	0.00	0.00	39.74	9.82
2000	15.46	37.22	0.46	1.81	15.93	3.43	10.96	5.76	37.89	8.94
2010	34.51	28.8	0.17	0.24	10.91	0.22	3.16	14.07	28.6	7.89
2015	20.86	36.26	0.23	0.08	6.54	0.08	1.26	23.01	30.97	11.67

One potential reason behind the changes in the manufacturing energy mix is Indonesia's limited natural resources that led to it restructuring its national energy mix policy. By revising the Presidential Regulation No. 5 of 2006 and adopting Government Regulation No. 79 of 2014 on National Energy Policy and further with Presidential Regulation No. 22 of 2017 on National Energy Plan, Indonesia's government has introduced a number of changes to its energy policy planning. The new regulation focuses on re-balancing energy mix to focus on indigenous energy supplies, which includes in reducing oil use, expanding the consumption of coal and renewable energy, and optimising the production and the use of gas and. This regulation provides the platform to achieve an energy mix transformation by 2025 to include 30% coal, 25% natural gas, 23% renewable resources and 22% oil.

4.6. Energy Consumption and Value-Added Share (ISIC-2 digit)

The BPS data at the two-digit level (Table 4.2) shows quite significant changes in the energy consumption share across sub sectors. In 1980, the share of Food (31), Textile (32), Non-metal (36) and Basic Metal (37) accounted for a large share of energy usage in the manufacturing sector, totalling more than 80% of total energy share. In 2015, the share of energy consumption in the Textile (32) and Non-metal (36) sectors reduced to around two-third and a half compared to 1980, respectively. On the other hand, in 2015, the share of energy usage of Food (31), Paper (34), Chemicals (35) and Fabricated metal (38) almost doubled compared to its level in 1980, where, according to the National Energy Council of Indonesia (DEN 2016), the Food, Chemicals and Non-metal sectors are referred to as high energy-consuming industries.

Table 4. 2. Share of Energy Consumption 1980-2015 (ISIC 2-digit)

Sectors	ISIC	Annual Growth Rate Energy Consumption (%)					Share of Total (%)					
		80-90	90-97	97-00	00-10	10-15	80	90	97	00	10	15
Food, Beverages and Tobacco	**31**	12.8	7.6	1.3	3.4	4.4	10.3	13.4	16.0	16.7	17.0	17.7
Textile, Wearing Apparel and Leather	**32**	7.6	3.2	2.1	2.4	3.6	16.1	13.1	11.7	12.5	11.5	11.6
Wood and Wood Products	**33**	8.7	7.5	1.1	2.3	1.2	2.5	2.2	2.7	2.8	2.5	2.3
Paper and Paper Products	**34**	14.3	8.7	2.3	4.7	4.3	3.4	5.1	6.6	7.1	8.1	8.5
Chemicals, Petroleum, Coal, Rubber and Plastic Products	**35**	10.5	7.6	3.2	6.8	6.9	9.0	9.6	11.4	12.6	17.7	20.8
Non-Metallic Mineral Products	**36**	9.3	2.5	-4.5	0.8	0.2	43.3	41.3	35.0	30.6	24.1	20.6
Basic Metal Industries	**37**	6.8	4.6	2.5	3.5	1.3	11.2	9.7	9.5	10.2	10.5	9.5
Fabricated Metal Products, Machinery and Equipment	**38**	12.9	8.5	1.8	4.5	4.8	4.1	5.4	6.9	7.3	8.2	8.8
Other Manufacturing Industries	**39**	15.1	15.7	4.1	2.3	4.6	0.1	0.2	0.3	0.3	0.3	0.3
AGGREGATE		**9.9**	**4.9**	**-0.1**	**3.2**	**3.5**						

From 1980 to 1990, energy consumption in the manufacturing sector grew, on average, by around 9.9% a year. Most of the growth in energy use occurred in Food (31), Paper (34), Chemicals (35), Fabricated Metals (38) and Other Manufacturing Industries (39) where each sector increased its energy consumption by more than 10%. In 1980, Non-metal Mineral Products (including cement and lime) was the largest energy user with total share reaching 43.3%, followed by textile around 16.1% and Basic Metal approximately 11.2%.

During the crisis period of 1997 to 2000, the growth of energy consumption in several manufacturing subsectors decreased quite significantly. During this period, the aggregate energy consumption growth slowed to around –0.1%, where Non-metal Minerals had the slowest growth compared to other sectors at around –4.5%. However, after the crisis period from 2000 to 2015, energy consumption had moderate growth in most sectors, where the Chemicals (35) experienced the highest growth. Energy consumption in the Chemical sector increase at around 6 to 7 per cent annually from 2000 to 2015 and its share in aggregate energy consumption was the highest in 2015 at around 20.8%, followed by Non-Metal (36) and Food (31) at approximately 20.6% and 17.7%, respectively.

The four largest shares of value-added in the manufacturing sector came from Food (31), Textile (32), Chemicals (35) and Fabricated Metal (38). These sectors accounted for more than 75% of aggregate value added in the manufacturing sector from the 1980s until 2015 (see Table 4.3). The food industry is one of the most prominent contributors to the aggregate value-added in the manufacturing sector. This potentially due to the government's policy aiming for this sector to achieve self-sufficiency. Fulfilling a sufficient food supply is an essential factor for economic development, hence the government’s action in prioritizing the food industry by enacting certain protecting government regulation. Developing resource-based industries like food and beverages is a significant target for Indonesia, like many other developing countries in Asia (Felipe & Estrada 2007).

After the Food sector, the second-largest value-added share in 2015 came from the Fabricated Metal sector. The value-added share of this sector increased quite significantly from 17.7% in 1980 to 23.3% in 2015. As with the Food sector, one explanation for the high contribution of Fabricated Metal (38) to the aggregate value-added industry is potentially because the government targeted this sector as one to be prioritized to become self-sufficient. Additionally, the third-highest value-added contributor was coming from the Chemicals industry (35) which accounted for around 19.3% of aggregate share in 2015. The significant share of this sector was also a result of the government boosting the domestic value-added for oil, gas and chemical products and reducing import dependence on petrochemical products (Bernadetta 2016).

Table 4. 3. Share of Value-added 1980-2014 (ISIC 2 digit)

Sectors	ISIC	Annual Growth Rate Value Added (%)					Share of Total (%)					
		80-90	90-97	97-00	00-10	10-15	80	90	97	00	10	15
Food, Beverages and Tobacco	31	13.4	6.9	3.5	4.4	9.4	31.4	25.9	19.6	24.7	24.2	28.1
Textile, Wearing Apparel and Leather	32	17.6	10.9	0.01	1.1	2.8	13.5	16.1	15.8	17.9	12.7	10.8
Wood and Wood Products	33	20.9	5.7	-12.1	0.2	1.1	7.5	11.8	8.3	6.4	4.1	3.2
Paper and Paper Products	34	22.1	15.0	0.45	3.6	1.2	2.8	4.8	6.0	6.9	6.3	4.9
Chemicals, Petroleum, Coal, Rubber and Plastic Products	35	13.6	11.9	0.3	5.7	6.4	17.1	14.4	15.0	17.2	19.0	19.3
Non-Metallic Mineral Products	36	10.3	14.8	-8.1	4.2	4.7	6.3	3.9	4.9	4.3	4.1	3.9
Basic Metal Industries	37	7.8	3.7	-6.2	5.3	7.1	3.3	9.0	5.5	5.1	5.5	5.7
Fabricated Metal Products, Machinery and Equipment	38	12.6	20.5	-14.8	8.1	6.3	17.7	13.6	23.8	16.7	23.2	23.3
Other Manufacturing Industries	39	17.2	25.4	-10.9	4.5	3.4	0.4	0.5	1.1	0.9	0.9	0.8
AGGREGATE		**15.6**	**11.2**	**-4.1**	**4.6**	**6.2**						

From 1980 to 2015, the value-added contribution of Food (31), Textile (32), Wood (33) and Non-Metal (36) decreased, which were followed by the increasing share of new emerging industries like Paper (34), Chemicals (35) and Fabricated Metal (38). The share of value-added for the textile sector (32) decreased from 13.5% in 1980 to 10.8% in 2015. In 1980, Textile (32) value-added share contributed quite significantly to the manufacturing industry, as the government at this period prioritized this sector to become self-sufficient. Like many other developing countries, Indonesia has employed many policies to enhance industrialisation which utilize labour-intensive and modest technology like garments and textile (Felipe & Estrada 2007). The output share of the textile industry increased from 1980 to 1990 from 13.5% to 16.1%, due to the growing export at the beginning of the 1980s and the increasing demand of Indonesia's domestic market (Aswicahyono 1998). Moreover, Pangestu (1997) listed several driving forces for the increased export opportunities, including the comparatively low labour cost, undervalued real exchange rate, under-utilized export quotas and various government incentives, such as, interest rate subsidies for credit exports and export subsidies. However, after it peaked at around 18% in 2000, the textile output share declined to around 11% in 2015. Dhanani (2000) and Patunru and Rahardja (2015) observed several reasons behind this declining share, including the strong competition amongst low-cost Asian textile producers, including India, China and Bangladesh, uncertainty in Indonesia's trade regulation after the Asian financial crisis, and Indonesia’s decreasing competitiveness as a result of changes in the minimum wage policy.

During the crisis period of 1997 to 2000, the aggregate value-added slowed down quite significantly to about –4.1% annually (Table 4.3), where Fabricated Metal (38) and

Wood (33) experienced a substantial decreasing growth to approximately –14.8% and –12.1%, respectively. However, after the crisis period of 2000 to 2015, the aggregate value-added rose by around 4 to 6 per cent a year on average, where the Fabricated Metal (38) recorded the strongest growth over the period for around 6% to 8% annually. Based on the Indonesia Investment Board (IIB 2017) and IEA (2017a) figures, the increase in the Fabricated metal sector was mostly driven by the increasing of Foreign Direct Investment (FDI) to around 37% from 2010 to 2016. All of the above changes in value-added showed the structural changes of Indonesia's manufacturing sector, whereby from 1980 to 2015, Indonesia's manufacturing sector transformed from labour-intensive to heavy capital-intensive manufacturers (Bernadetta 2016).

Table 4. 4. Energy Intensity of Manufacturing Sector (ISIC 2 Digit)

Subsectors	ISIC	Energy Intensity (Tera Joule/ Million Rp 1980)						EI Changes (%)
		1980	1990	1997	2000	2010	2015	1980-2015
Food, Beverages and Tobacco	31	0.017	0.016	0.017	0.016	0.015	0.012	–32.9
Textile, Wearing Apparel and Leather	32	0.063	0.026	0.016	0.017	0.019	0.020	–68.8
Wood and Wood Products	33	0.017	0.006	0.007	0.010	0.013	0.013	–27.0
Paper and Paper Products	34	0.065	0.034	0.023	0.024	0.027	0.031	–52.1
Chemicals, Petroleum, Coal, Rubber and Plastic Products	35	0.028	0.021	0.016	0.017	0.019	0.020	–28.6
Non-Metallic Mineral Products	36	0.363	0.332	0.151	0.169	0.121	0.097	–73.2
Basic Metal Industries	37	0.038	0.034	0.036	0.048	0.040	0.030	–20.0
Fabricated Metal Products, Machinery and Equipment	38	0.012	0.013	0.006	0.010	0.007	0.007	–44.1
Other Manufacturing Industries	39	0.012	0.010	0.006	0.009	0.008	0.008	–35.2
AGGREGATE		**0.053**	**0.032**	**0.021**	**0.024**	**0.021**	**0.018**	**-65.3**

Aggregate energy intensity in the manufacturing sector has improved (decreased) in all key industry subsectors, even though the trends are not similar (see Table 4.4). Over the 35 years of 1980 to 2015, the aggregate energy intensity in Indonesia's manufacturing sector decreased by around 65.3% compared to its base level in 1980. The highest energy intensity reduction occurred in the Non-metal Mineral industry for around 73.2%, from approximately 0.363 tera joule/million in 1980 to around 0.097 tera joule/million in 2015.

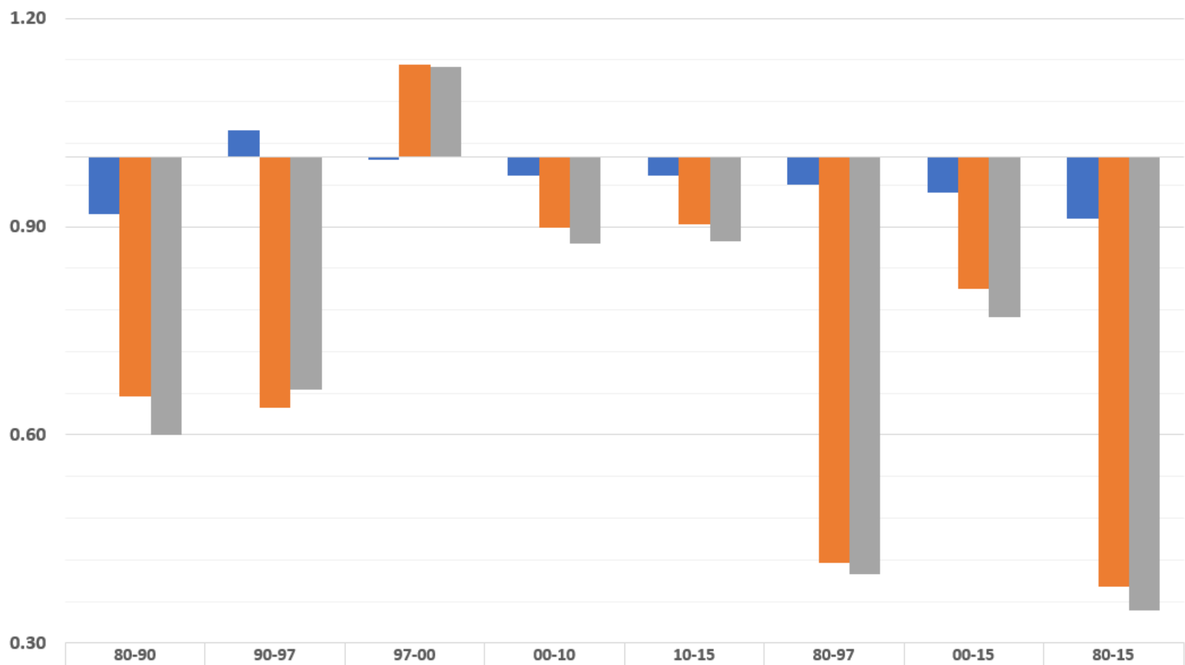
From 1980 to 1997, the aggregate energy intensity of the manufacturing sector decreased from 0.053 terra joule/million Rupiah to 0.021 terra joule/million Rupiah. The declining trend in this period was mainly driven by the declining energy intensity in Textile (32), Paper and paper products (34) and Non-metal (36) sectors from around 0.063; 0.065; 0.363, in 1982, to approximately 0.016; 0.023; 0.151 terra joule/million Rupiah in

1997, respectively. During the Financial Crisis period of 1997 to 2000, the aggregate energy intensity in the manufacturing sector increased quite significant from 0.021 terra joule/million Rupiah in 1997 to around 0.024 terra joule/million Rupiah in 2000. In this crisis period, the individual industry energy intensity also substantially increased, where Non-metal (36) and Fabricated Metals (38) had the strongest increase. However, after the period of crisis from 2000 to 2015, the aggregate energy intensity in the manufacturing sector had substantially improved (decreased), where, in 2015, the aggregate energy intensity reached approximately 0.018 terra joule/million Rupiah.

4.7. Result of Decomposition Analysis on Energy Intensity (ISIC-2 digit)

The decomposition results (see Figure 4.2) show that the main driving force reducing the aggregate energy intensity (DTOT) in the manufacturing sector is the intensity effect (DINT), while the structure effect (DSTR) only plays a small role in the changes of the aggregate energy intensity in Indonesia's manufacturing sector from 1980 to 2015.

Figure 4. 2. Decomposition of Energy Intensity in Manufacturing Sector (9 Sectors) in the period of 1980 to 2015



	80-90	90-97	97-00	00-10	10-15	80-97	00-15	80-15
DSTR	0.92	1.04	1.00	0.97	0.97	0.96	0.95	0.91
DINT	0.65	0.64	1.13	0.90	0.90	0.42	0.81	0.38
DTOT	0.60	0.66	1.13	0.88	0.88	0.40	0.77	0.35

From 1980 to 1990 and 1990 to 1997, the aggregate energy intensity (DTOT) in the manufacturing sector fell by 40% and 34%, respectively. Most of the fallings in energy intensity in these periods were attributable to changes within industry energy intensity/intensity effect for around 35% and 36%, respectively. The intensity effect (DINT) had the highest effect that caused the aggregate energy intensity in the manufacturing sector to decline (see Figure 4.2). Additionally, from 1980 to 1990 the role of structural effect (DSTR) contributed to decreasing the aggregate energy intensity by 8%, but from 1990 to 1997, the structural effect increased the aggregate energy intensity by 4% compared to the base period in 1990.

Throughout the crisis period from 1997 to 2000, the aggregate energy intensity increased to 13% compared to the base year of 1997. This increase occurred due to high changes within industry energy intensity/intensity effect that increased the aggregate energy intensity by 13%. In this period, energy consumption was found to not change much, while the total value added fell significantly. During this period the role of the structural effect was found to be negligible to the overall changes in the aggregate energy intensity. The increase of aggregate energy intensity in this period indicated the energy intensity became less efficient, which is a result of the decrease of overall value-added in the manufacturing sector.

Nevertheless, after the peak of energy intensity in 2000, the aggregate energy intensity in Indonesia from 2000 to 2010 and 2010 to 2015 gradually declined. In both of these periods, the aggregate energy intensity in Indonesia decreased for around 12% compared to the base year of 2000 and 2010, respectively. Indeed, the changes within industry energy intensity was found quite substantial to decrease the aggregate energy intensity in these periods by around 10 per cent. On the other hand, the role of the structural effect was found to be negligible with only a 3% decrease compared to the intensity effect. Overall, aggregate energy intensity during 1980 to 2015, declined. During the study period, the changes within industry energy intensity playing the greatest role, reducing the aggregate energy intensity by around 62%, while the structural effect only decreased by 9% compared to its base year in 1980.

From the above decomposition results, there are two periods that are notable. First, the period of improvement (decrease) of both intensity effect and structural effect before and after the crisis. Both trends of intensity effect and structural effect in the period of before the crisis (1980 to 1997) and after the crisis (2000 to 2015) showed a decreasing trend in aggregate energy intensity in the manufacturing sector. The decreasing of changes within industry energy intensity/intensity effect potentially be related to the advancement of energy-efficient technology in the key manufacturing industries, for instance, technology upgrades in the high energy intensity sector, such as Non-Metal and Textile sectors, where these two sectors showed a substantial improvement (decrease) in energy intensity. Indeed, the decreasing trend of structural effect in both period of 1980 to 1997 and 2000 to 2010 also affirmed the decreasing trend of aggregate energy intensity in the manufacturing sector, where the decreasing of structural effect showed a shift to less energy-intensive industry.

Second, the period of increase of changes within industry energy intensity/ intensity effect during the crisis period. The shock of the Financial Crisis (from 1997 to 2000) saw an unexpected reaction when value-added fell by 13% but energy use remained largely unchanged, implying a rise in energy intensity. During this period, the changes within industry energy intensity increased the aggregate energy intensity in the manufacturing sector. Table 4.2 and Table 4.3 show that the annual growth of value-added was slower than the annual growth of energy consumption, which results in deterioration in aggregate energy intensity in the manufacturing sector.

The historical trend of decomposition results reveals that the intensity effect reduction in the manufacturing sector had changed through different periods of time. This trend of decomposition demonstrates the consequences of the Financial Crisis on the changes of aggregate energy intensity which could limit the growth of certain manufacturing sectors from the point of view of structural and intensity changes.

4.8. Energy Consumption, Value Added share, and Decomposition Results (ISIC - 3 digits)

This study further analyses the five highest energy-consuming sectors in the manufacturing sector in Indonesia, which consumed more than 80% of total energy consumption in the manufacturing in 2015. The five key sectors are Food, Beverages and Tobacco (31), Textile, Wearing Apparel and Leather (32), Chemicals, Petroleum, Coal, Rubber and Plastic Products (35), Non-Metallic Mineral Products (36) and Basic Metal Industries (37).

4.8.1. Food, Beverages and Tobacco (31)

In the Food Industries, there were quite significant changes in the value-added share (see Table 4.5). In 1980, the Tobacco subsector (314) accounted for the largest share of value-added for around 60.2%, followed by Basic Food (311) for approximately 30.1%. However, in 2015, there was a substantial structural change in the Food sector, where the share of Tobacco industry decreased from around 60.2% of total Food sector value-added in 1980 to approximately 27.6% in 2015. The decrease in the Tobacco share was followed by an increase in Basic Food subsector from 30.1% in 1980 to around 67.1% in 2015.

Table 4. 5. Share of Energy Consumption and Value Added in Food Subsector (ISIC 3 Digit)

Subsectors	ISIC	Energy Consumption share (%)						Value Added Share (%)					
		80	90	97	00	10	15	80	90	97	00	10	15
Basic Food	**311**	46.4	53.8	52.4	55.0	72.9	77.9	30.1	34.7	36.8	45.4	63.8	67.1
Other Food	**312**	10.0	5.1	4.6	4.6	3.3	2.9	5.0	2.3	2.2	2.6	2.1	2.1
Beverage	**313**	5.5	5.6	4.7	4.7	5.1	3.3	4.7	4.6	4.3	5.9	6.9	3.2
Tobacco	**314**	38.1	35.5	38.3	35.7	18.8	15.9	60.2	58.3	56.7	46.1	27.2	27.6
AGGREGATE		100	100	100	100	100	100	100	100	100	100	100	100

The changes in the value-added share were also aligned with the changes in energy consumption share. Energy consumption share in Basic Food (311) increased from around 46.4% in 1980 to around 77.9% in 2015, while other subsectors experienced a decreasing trend of energy consumption share. The decrease in the share of energy consumption occurred in Tobacco (314), Other Food (312) and Beverages (313), where the shares of these subsectors decreased from 38.1%, 10.0% and 5.5% in 1980 to around 15.9%, 2.9% and 3.3% in 2015.

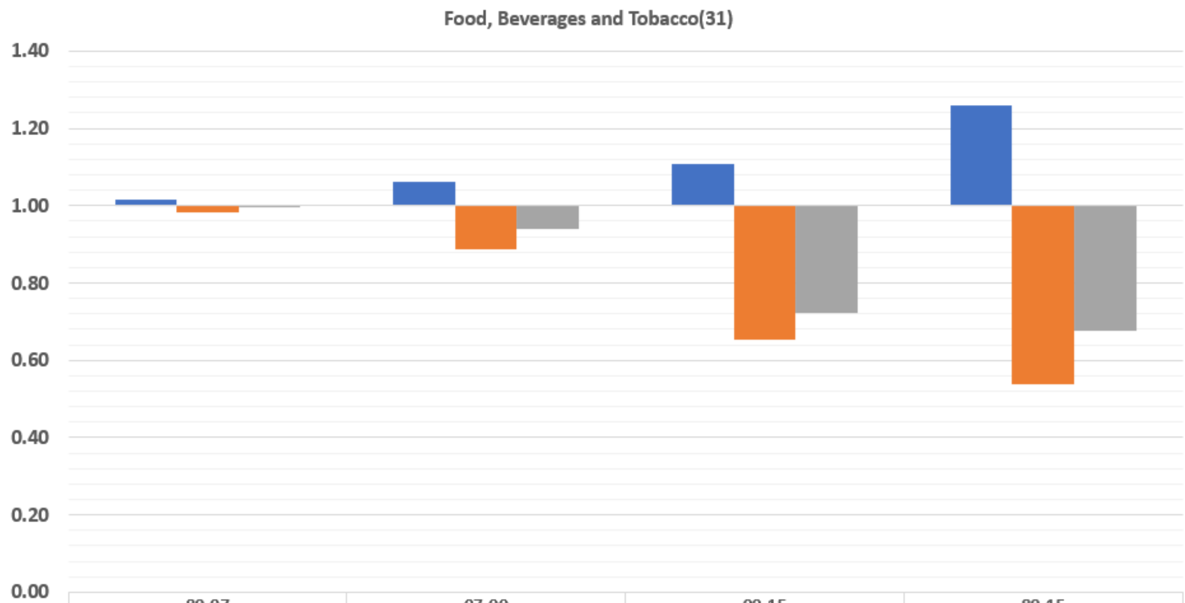
From 1980 to 2000, the aggregate energy intensity in the Food industry fell by 6.4% (see Table 4.6). The fall in energy intensity was driven by the decreasing energy intensity in the Basic Food, Other Food and Beverage industries, while the Tobacco industry increased its energy intensity for about 14.4%. The aggregate energy intensity in this industry fell even deeper for around 27.6% from 2000 to 2015. On the contrary, during the period of 2000 to 2015, the Tobacco industry experienced the highest reduction in its energy intensity for around -46.1%. Overall, from 1980 to 2015, the aggregate energy intensity of the food industries decreased by about 32.2%. In this period, energy intensity in Other Food subsectors decreased significantly for around 53%, followed by Basic Food, Beverage and Tobacco for approximately 49%, 39.8%, 38.3%, respectively. Compared to other sectors in the Manufacturing, the impact of the 1997 Financial Crisis in the Food sector was insignificant. During the crisis period of 1997 to 2000, the energy intensity in individual subsectors in the Food industries still experienced a decreasing trend, while most of the other manufacturing industries from other sectors had an increased energy intensity.

Table 4. 6. Energy Intensity of Food Subsector (ISIC 3 Digit)

Subsectors	ISIC	Energy Intensity (Tera Joule/ Million Rp 1980)						EI Changes (%)		
		1980	1990	1997	2000	2010	2015	80-00	00-15	80-15
Basic Food	**311**	0.027	0.025	0.024	0.020	0.017	0.014	–26.4	–30.7	-49.0
Other Food	**312**	0.034	0.036	0.036	0.029	0.023	0.016	–16.1	–43.9	-53.0
Beverage	**313**	0.020	0.020	0.019	0.013	0.011	0.012	–35.7	–6.4	-39.8
Tobacco	**314**	0.011	0.010	0.012	0.012	0.010	0.007	14.4	–46.1	-38.3
AGGREGATE		**0.017**	**0.016**	**0.017**	**0.016**	**0.015**	**0.012**	**-6.4**	**–27.6**	**–32.2**

From 1980 to 2015 (see Figure 4.3), the decomposition results in Food Sector (31) showed that the intensity effect (DINT) significantly contributed to reducing the aggregate energy intensity (DTOT) by around 56%, while the structural effect (DSTR) increased the aggregate energy intensity by around 26%. Overall, the aggregate energy intensity in the Food sector decreased by 32% compared to its base level in 1980.

Figure 4. 3. Decomposition on Energy Intensity in Food, Beverages and Tobacco Sector



	80-97	97-00	00-15	80-15
DSTR	1.01	1.06	1.11	1.26
DINT	0.98	0.89	0.65	0.54
DTOT	1.00	0.94	0.72	0.68

During the crisis period of 1997 to 2000, the aggregate energy intensity decreased by 6%, which was a result of decreasing intensity effect by around 11%. The role of intensity effect become more significant from 2000 to 2015, where this effect reduced the aggregate energy intensity for around 35% compared to its level in 2000. The decreasing in the intensity effect potentially relate to significant improvement in advancement in the Food industries technology. However, in the same period of 2000 to 2015, the role of the structural effect had increased the aggregate energy intensity by

11% compare to its level in 2000. This increase in structural showed a shift to more energy intensive activity in the Food industries. This evidence can be seen (Table 4.5) from the changes of the value-added contribution of Tobacco industry (with less energy intensity) to Basic Food industry (with more energy intensity).

4.8.2. Textile, Wearing Apparel and Leather (32)

The textile industry experienced a quite significant structural change during the study period (see Table 4.7). This can be seen from the changes in the individual value-added shares over the period. In 1980, the Textiles subsector (321) dominated the total shares for around 75.3%, followed by Wearing Apparel (322), Leather (323) and Footwear (324) for approximately 10.4%, 8.5% and 5.8%, respectively. However, in 2015, the shares of each subsector become spread more evenly, where the shares of Textiles and Footwear subsectors dropped to around 39.6% and 3%, respectively; followed by an increase in other subsectors share including Wearing Apparel and Leather to around 29.7% and 27.7%, respectively. During the crisis period, most of the textile subsectors had a decreasing value-added share, except Wearing Apparel. Similarly, to the value-added share, the trend of energy consumption share in Textile industries also changed significantly (Table 4.7). The Textiles industry was the highest energy-consuming subsector during the study period, followed by Wearing Apparel, Leather and Footwear.

Table 4. 7. Share of Energy Consumption and Value Added in Textile Subsector (ISIC 3 Digit)

Subsectors	ISIC	Energy Consumption share (%)						Value Added Share (%)					
		80	90	97	00	10	15	80	90	97	00	10	15
Textiles	**321**	80.9	76.2	67.0	63.8	53.0	46.5	75.3	71.4	59.5	55.9	45.2	39.6
Wearing apparel	**322**	10.2	12.7	15.3	19.1	29.7	28.9	10.4	11.7	16.1	23.4	34.0	29.7
leather and leather products	**323**	5.0	7.4	13.6	13.0	13.8	21.4	8.5	12.2	20.0	16.6	17.2	27.7
Footwear	**324**	3.9	3.7	4.2	4.0	3.5	3.2	5.8	4.7	4.4	4.0	3.6	3.0
AGGREGATE		100	100	100	100	100	100	100	100	100	100	100	100

From 1980 to 2015, all of the subsectors in the textile industries experienced a decreasing energy intensity of more than 50%, where the aggregate energy intensity decreased by 68.8% (see Table 4.8). Wearing Apparel had the greatest decrease in energy intensity by around 69%, followed by Textiles, Leather and Footwear by about 65.9%, 59% and 50.5%, respectively. From 1980 to 1997, all of the subsectors in the textile industries had a substantial improvement (decrease) in its energy intensity.

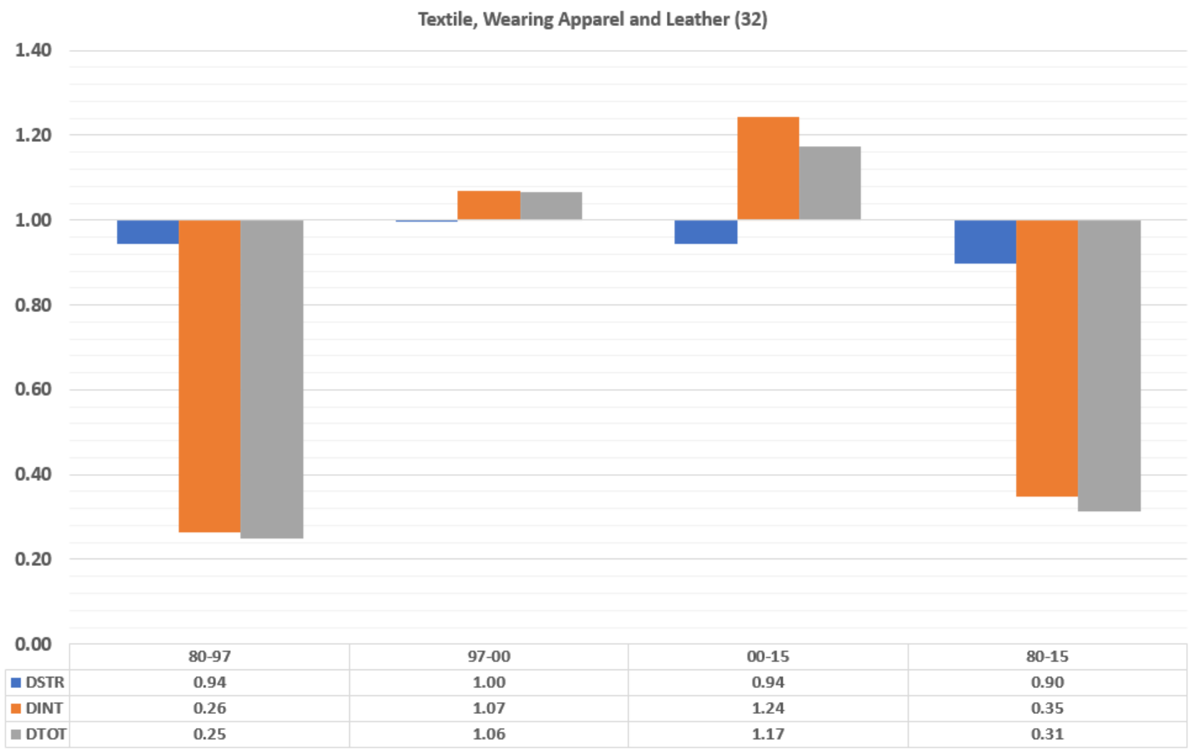
However, after 1997, most of these subsectors had a deterioration (increase) in energy intensity.

Table 4. 8. Energy Intensity of Textile Subsector (ISIC 3 Digit)

Subsectors	ISIC	Energy Intensity (Tera Joule/ Million Rp 1980)						EI Changes (%)		
		1980	1990	1997	2000	2010	2015	80–00	00–15	80-15
Textiles	**321**	0.068	0.028	0.018	0.019	0.022	0.023	–71.8	20.9	-65.9
Wearing apparel	**322**	0.062	0.028	0.015	0.014	0.017	0.019	–77.8	39.9	-69.0
leather and leather products	**323**	0.037	0.016	0.011	0.013	0.015	0.015	–64.6	15.8	-59.0
Footwear	**324**	0.043	0.021	0.015	0.017	0.019	0.021	–60.4	25.0	-50.5
AGGREGATE		0.063	0.026	0.016	0.017	0.019	0.020	–73.4	17.5	–68.8

The highest energy intensity falls in the textile industries occurred from 1980 to 2000 by around 73.4% while, from 2000 to 2015, energy intensity in this sector increased by about 17.5%. This trend showed that energy intensity in within Textile industries improved significantly before 2000 while after 2000 all of the subsectors in the Textile industry had a worsening in its energy intensity.

Figure 4. 4. Decomposition on Energy Intensity in Textile, Wearing Apparel and Leather Sector



The driving factors behind the changes in aggregate energy intensity in the Textiles industries can be observed from the results of energy intensity decomposition (see Figure 4.4). From 1980 to 2015, the aggregate energy intensity (DTOT) decreased by around 69% compared to its base level in 1980. This decrease was due to the decreasing intensity effect (DINT) and structural effect (DSTR) at around 65% and 10%, respectively, compared to the base level in 1980. There are two trends of the intensity effect, before 1997, the intensity effect had a decreasing impact while, after 1997, the intensity effect had an increasing impact. On the contrary, the structural effect showed a decreasing effect over the study period, which indicated a shift to a more energy-efficient industry. This shift can be seen from the changes in value-added shares that showing an increasing share of Wearing Apparel and Leather Subsectors over the study period.

4.8.3. Chemicals, Petroleum, Coal, Rubber and Plastic Products (35)

The three highest value-added contributors in the Chemicals industries are Industrial chemicals (351), Other Chemical Products (352) and Rubber Products (355). They accounted for more than 90% of total value-added shares in the Chemical industries (see Table 4.9). Industrial Chemicals (351) had a quite consistent value-added share during the study period at around one-third of total chemicals industries, although it fell to around 25.7% in 1990. The value-added share of Other Chemical Products (352) decreased from around 41% in 1980 to approximately 34.3% in 2015. The decrease of value-added share in Other Chemical Subsector was followed with an increase in the share of Rubber products (355) from around 25.2% in 1980 to 32.4% in 2015, while other subsectors had a negligible share in the Chemical industries.

Table 4. 9. Share of Energy Consumption and Value Added in Chemicals Subsector (ISIC 3 Digit)

Subsectors	ISIC	Energy Consumption share (%)						Value Added Share (%)					
		80	90	97	00	10	15	80	90	97	00	10	15
Industrial chemicals	**351**	21.0	20.1	23.4	24.6	31.2	24.6	29.6	25.7	27.6	28.1	31.9	29.9
Other chemical products	**352**	43.9	38.3	39.1	39.8	36.8	36.9	41.0	38.9	39.2	39.0	36.6	34.3
Petroleum refineries	**353**	0.0	1.3	1.4	1.5	1.0	0.8	0.0	0.5	0.6	0.5	0.4	0.4
Miscellaneous products of petroleum and coal	**354**	0.0	1.2	1.5	1.5	1.4	1.2	0.0	0.6	0.8	0.8	0.7	0.6
Rubber products	**355**	24.8	31.0	25.2	23.6	23.9	30.1	25.2	30.6	28.1	27.8	28.2	32.4
Plastic products	**356**	10.3	8.2	9.4	9.1	5.7	6.3	4.3	3.7	3.7	3.7	2.1	2.5
AGGREGATE		100	100	100	100	100	100	100	100	100	100	100	100

Similar to the value-added share, the three highest energy-consuming sectors in the chemical industries are Industrial Chemicals (351), Other Chemical (352) and Rubber Products (355).

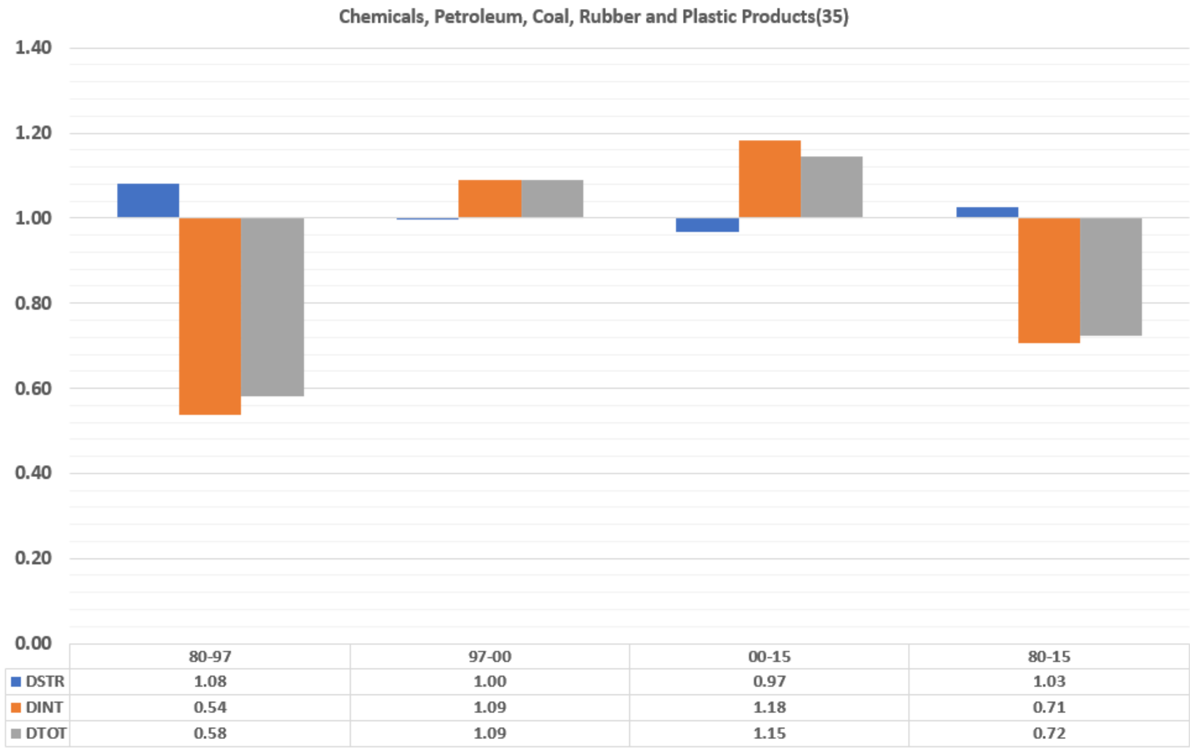
There are two obvious trends in the aggregate energy intensity in the Chemicals industry: (1) falling energy intensity from 1980 to 2000 and (2) increasing energy intensity from 2000 to 2015. In the first period (1980 to 2000), the aggregate energy intensity in the chemicals industry fell by around 36.8%, where the greatest decrease came from the Rubber products industry at around 45.5%. In the second period (2000 to 2015) in contrast, the aggregate energy intensity in this industry increased by around 14.6%. From this trend, it can be observed that the Chemicals industry experienced many improvements in the aggregate energy intensity from 1980 to 2000, while after 2000 to 2015, there was an increasing trend of energy intensity in the individual subsectors in the Chemicals industry.

Table 4. 10. Energy Intensity of Chemicals Subsector (ISIC 3 Digit)

Subsectors	ISIC	Energy Intensity (Tera Joule/ Million Rp 1980)						EI Changes (%)		
		1980	1990	1997	2000	2010	2015	80-00	00-15	80-15
Industrial chemicals	**351**	0.020	0.016	0.014	0.015	0.019	0.017	-22.3	8.0	-16.1
Other chemical products	**352**	0.030	0.021	0.016	0.018	0.020	0.022	-39.8	20.8	-27.2
Petroleum refineries	**353**	N/A	0.050	0.041	0.047	0.047	0.047	N/A	0.0	N/A
Miscellaneous products of petroleum and coal	**354**	N/A	0.038	0.029	0.031	0.038	0.041	N/A	33.2	N/A
Rubber products	**355**	0.027	0.021	0.014	0.015	0.017	0.019	-45.5	25.9	-31.4
Plastic products	**356**	0.067	0.047	0.040	0.043	0.053	0.050	-35.8	16.5	-25.2
AGGREGATE		**0.028**	**0.021**	**0.016**	**0.017**	**0.019**	**0.020**	**-36.8**	**14.6**	**-27.5**

Overall, during the study period of 1980 to 2015, the aggregate energy intensity in the Chemicals industries decreased by around 27.5% compared to its base level in 1980 (see Table 4.10). The Rubber Products subsector had the greatest decline in energy intensity at around 31.4%, followed by Other Chemicals, Plastic Products and Industrial chemicals Subsector by around, 27.2%, 25.2% and 16.1%, respectively; while the decrease in Petroleum refineries and Miscellaneous of Petrol Products had negligible change. The Petroleum Refineries (353), Miscellaneous products (354) and Plastic Products (356) subsectors are considered as having the most energy intensive industries in the Chemicals sector, which accounted for around 0.047, 0.041, and 0.050 tera joule/million in 2015, respectively. Large energy intensity improvements in the Chemical industries potentially reflect continuing of technology advancement, for instance the application of industrial robots and automation. In the worldwide, the chemical sector is one of the largest users of industrial robots after the vehicles industry, electronics manufacturing and metal industry, where this industry's enhance its energy productivity through automation (IEA 2017a; IFR 2016).

Figure 4. 5. Decomposition on Energy Intensity in Chemicals, Petroleum, Coal, Rubber and Plastic Products Sector



From 1980 to 2015, the aggregate energy intensity (DTOT) in chemicals industries decreased by around 28% compared to its base level in 1980, which is a result of the decreasing intensity effect (DINT) by around 29% and an increasing of structural effect (DSTR) by only 3% (see Figure 4.5). From the decomposition result, it can be seen that from 1980 to 1997 the intensity effect experienced a decreasing trend by around 56%, while from 2000 to 2015, the intensity effect increased by around 18%. Overall, most of the efficiency improvements in the Chemicals industries gained before the crisis period (1980 to 1997), while after the crisis period (1997 to 2015) the chemical industries become less efficient in terms of energy intensity.

4.8.4. Non-Metallic Mineral Products (36)

A substantial structural shift can also be observed in the Non-metallic Mineral industries (see Table 4.11). In 1980, the Cement and Lime subsector (363) dominated a significant value-added share for around 76.3%, while other Subsectors contributes insignificantly including, Glass (362), Pottery (361), Clay (364) and Other Non-Metal (369) for around 16.7%, 3.8%, 2.3%, 1%, respectively. However, from 1980 to 2015, there was a substantial change in the individual subsectors' output shares, where the shares in Cement and Lime subsector fell to around 46.1% in 2015. This significant drop in the Cement and Lime subsector was followed by an increasing share by other subsectors: Glass, Pottery, Clay and Other Non-Metal for approximately 31.7%, 6.1%, 2.5% and 13.6%, respectively.

Table 4. 11. Share of Energy Consumption and Value Added in Non-metallic Subsector (ISIC 3 Digit)

Subsectors	ISIC	Energy Consumption share (%)						Value Added Share (%)					
		80	90	97	00	10	15	80	90	97	00	10	15
Pottery, china and earthenware	361	1.9	2.0	2.4	2.8	2.8	2.8	3.8	4.0	4.6	5.6	6.0	6.1
Glass and glass products	362	6.5	8.3	11.1	12.8	13.0	13.2	16.7	21.2	30.6	35.0	29.8	31.7
Cement and Lime	363	90.6	88.6	85.4	83.1	77.6	77.2	76.3	71.5	61.4	55.8	49.9	46.1
Clay products	364	0.6	0.6	0.7	0.8	0.8	0.8	2.3	2.4	2.6	2.8	2.7	2.5
Other non-metallic products	369	0.4	0.4	0.5	0.5	5.8	6.1	1.0	0.9	0.8	0.9	11.6	13.6
AGGREGATE		100	100	100	100	100	100	100	100	100	100	100	100

Similarly, with the value-added share, Cement and Lime subsector dominated the energy consumption share throughout the study period, although its share experienced a decline from around 90.6% in 1980 to around 77.2% in 2015 (see Table 4.11). On the contrary, other subsectors increased their shares, that is, Glass, Pottery, Clay and Other Non-metal from around 6.5%, 1.9%, 0.6% and 0.4% in 1980 to around 13.2%, 2.8%, 0.8% and 6.1%, respectively.

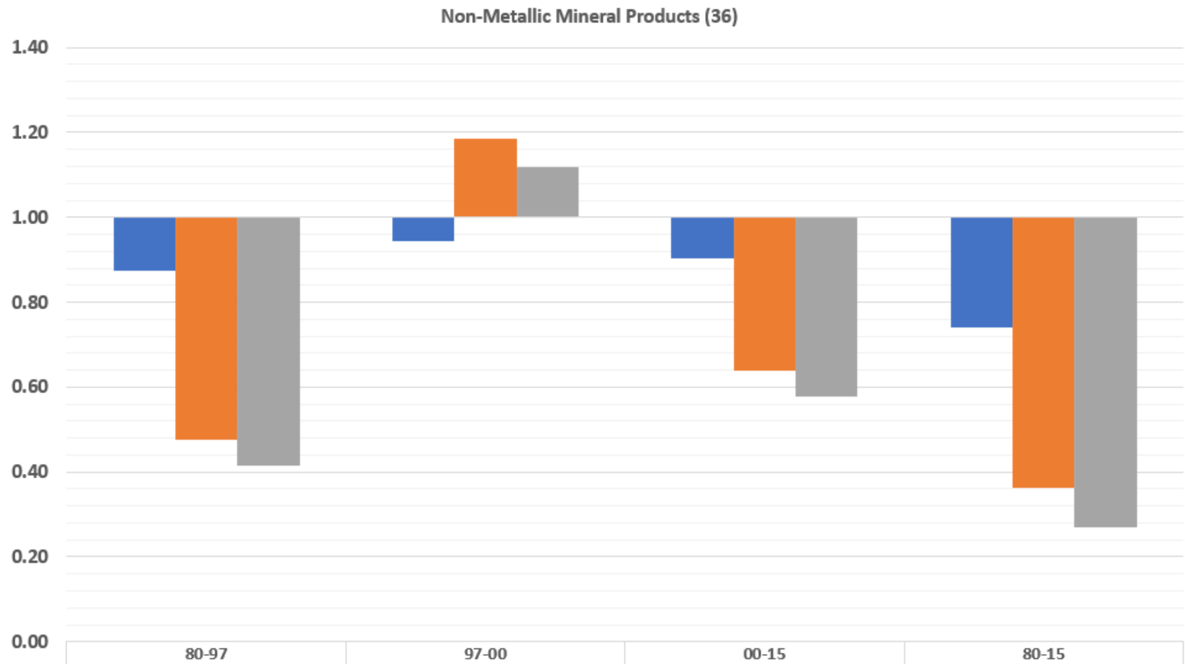
Table 4. 12. Energy Intensity of Non-metallic Subsector (ISIC 3 Digit)

Subsectors	ISIC	Energy Intensity (Tera Joule/ Million Rp 1980)						EI Changes (%)		
		1980	1990	1997	2000	2010	2015	80-00	00-15	80-15
Pottery, china and earthenware	361	0.185	0.169	0.079	0.085	0.056	0.044	-53.8	-48.4	-76.2
Glass and glass products	362	0.143	0.130	0.054	0.062	0.053	0.040	-56.8	-34.2	-71.6
Cement and Lime	363	0.431	0.412	0.210	0.251	0.189	0.163	-41.7	-35.0	-62.1
Clay products	364	0.093	0.085	0.040	0.048	0.036	0.031	-48.6	-35.9	-67.1
Other non-metallic products	369	0.132	0.158	0.088	0.103	0.061	0.044	-21.5	-57.6	-66.7
AGGREGATE		**0.363**	**0.332**	**0.151**	**0.169**	**0.121**	**0.097**	**-53.5**	**-42.2**	**-73.1**

Overall, from 1980 to 2015, Non-metal industry experienced a substantial decline in aggregate energy intensity for approximately 73.1% (see Table 4.12), where the greatest decrease occurred in the Pottery, China and earthenware subsectors by around 76.2%. All of the individual subsectors in the Non-metal industries contributed significantly to this energy intensity improvement (decrease), whereas Cement and Lime (363) contributed the most to this decrease; due to the energy consumption share from this industry was the highest among other industries in the Non-metal sector. During the period of study, the energy intensity in Cement and Lime Subsector declined from around 0.431 tera joule/million Rupiah in 1980 to around 0.163 tera joule/million Rupiah in 2015.

According to IEA (2017a), the decrease of energy intensity in many non-metal industries showed a substantial progress of energy efficiency which were generally boosted by the upgrade in technology use, closure of obsolete facilities, investing in new facilities and improving performance in existing facilities (IEA 2017a).

Figure 4. 6. Decomposition on Energy Intensity in Non-Metallic Mineral Products Sector



	80-97	97-00	00-15	80-15
DSTR	0.87	0.94	0.90	0.74
DINT	0.48	1.19	0.64	0.36
DTOT	0.42	1.12	0.58	0.27

Similarly, to other sectors in the Manufacturing (see Figure 4.6), the highest driving forces to decrease the aggregate energy intensity in the Non Metal industry is the Intensity Effect which contributes to around 64%. Besides the intensity effect, the structural effect also added a quite significant impact to reduce the aggregate energy intensity in the Non-metal industry by around 26%. Overall, from 1980 to 2015, the aggregate energy intensity in 2015 decreased by approximately 73% compared to its base level in 1980. The decrease in the structural effect indicates that the Non-metal industry has shifted to become a less energy-intensive industry, as this evidenced from the changes in the value-added shares. For instance, the decrease of Cement and Lime output shares followed by an increase of output shares in other less intensive Subsectors: Glass, Pottery, Clay and Other Non-metal Subsectors (see Table 4.11).

4.8.5. Basic Metal Industries (37)

Structural shifts also occurred in the Basic Metal industries (see Table 4.13). A quite substantial shift from industry based on Iron and steel (371) to Non-Ferrous Metal (372) can be seen from the changes in value-added shares during the period 1980 to 2015. In 1980, the Iron and Steel Basic industries dominated the value-added share for around 81.6%, but in 2015, its share decreased to around 50.5%. On the contrary, the Non-Ferrous Metal subsector increased its share from 18.4% in 1980 to approximately 49.1% in 2015. The changes in the energy consumption share also indicated a substantial shift in energy use, whereas the decreasing of the energy consumption share from Iron and Steel industries was followed by an increase of energy consumption share in the Non-ferrous industry.

Table 4. 13. Share of Energy Consumption and Value Added in Basic-metal Subsector (ISIC 3 Digit)

Subsectors	ISIC	Energy Consumption share (%)						Value Added Share (%)					
		80	90	97	00	10	15	80	90	97	00	10	15
Iron and steel basic industries	**371**	76.5	78.2	75.2	74.2	64.1	57.1	81.6	83.0	75.7	72.5	61.2	50.9
Non-ferrous metal basic industries	**372**	23.5	21.8	24.8	25.8	35.9	42.9	18.4	17.0	24.3	27.5	38.8	49.1
AGGREGATE		100	100	100	100	100	100	100	100	100	100	100	100

From 1980 to 2000, the aggregate energy intensity in the Basic Metal industry increased by around 24.8%. This increase was mostly driven by the increase of energy intensity in the Iron and Steel Basic industries at around 36.2%, while the Non-ferrous industry improved its energy intensity by around 8.1%. In contrast, from 2000 to 2015, aggregate energy intensity in this industry fell by approximately 35.9%. During this period, both energy intensity in the Iron and Non-ferrous industries significantly dropped by around 29.8% and 40.4%, respectively.

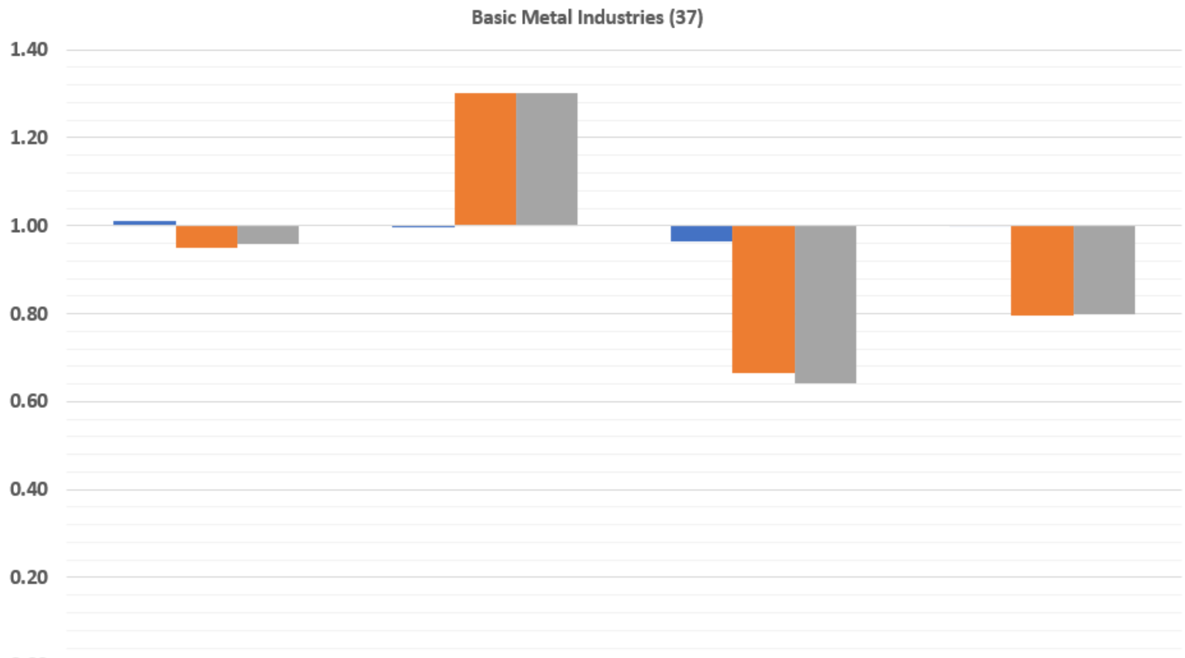
Overall, the aggregate energy intensity in the Basic Metal industry decreased by around 20.0% from 1980 to 2015 (see Table 4.14). Most of the decrease of aggregate energy intensity in the Basic Metal industry came from the Non-ferrous Metal subsector, which contributed around 45.2%. In addition, the Iron and Steel Basic industries also signified the overall decrease in energy intensity by around 4.4%. During the crisis period of 1997 to 2000, the Basic metal industry deteriorated in its aggregate energy intensity as it increased from 0.036 tera joule/million Rupiah in 1997 to around 0.047 tera joule/million Rupiah in 2000.

Table 4. 14. Energy Intensity of Basic-metal Subsector (ISIC 3 Digit)

Subsectors	ISIC	Energy Intensity (Tera Joule/ Million Rp 1980)						EI Changes (%)		
		1980	1990	1997	2000	2010	2015	80-00	00-15	80-15
Iron and steel basic industries	**371**	0.036	0.033	0.036	0.049	0.042	0.034	36.2	–29.8	-4.4
Non-ferrous metal basic industries	**372**	0.049	0.044	0.037	0.045	0.037	0.027	–8.1	–40.4	-45.2
AGGREGATE		**0.038**	**0.034**	**0.036**	**0.047**	**0.040**	**0.030**	**24.8**	**–35.9**	**–20.0**

The results of energy intensity decomposition in the Basic Metal industry indicated that, from 1980 to 2015, changes within industry energy intensity had reduced the aggregate energy intensity by around 20% compared to its base level in 1980 (see Figure 4.7). On the contrary, the structural effect had no impact on the overall changes in the aggregate energy intensity. According to IEA (2017a), many energy-intensive industries like, Basic Metal industries inclined to have a similar level of energy intensity, potentially due to the larger contribution of energy cost to total production costs, standardised production methods, competitive markets, caused producers to be more cost-efficient. Furthermore, the increasing use of automation is also apparent in this sector, which also improve this sector's energy productivity via greater automation of production (IFR 2016).

Figure 4. 7. Decomposition on Energy Intensity in Basic Metal Industries Sector



	80-97	97-00	00-15	80-15
DSTR	1.01	1.00	0.96	1.00
DINT	0.95	1.30	0.66	0.80
DTOT	0.96	1.30	0.64	0.80

From the decomposition results, most of the efficiency improvement (decreasing intensity effect) in the Basic Metal industry occurred during 2000 to 2015, where this period the intensity effect reduced the aggregate energy intensity by around 34% compared to its base level in 2000. This evidence implied that during this period, the Basic Metal industry had a significant technology advancement to improving its energy efficiency. But, during the crisis period of 1997 to 2000, there was a substantial increase in intensity effect. In this crisis period, the intensity effect increased the aggregate energy intensity by around 30% compared to the base level in 1997, whereas it indicated a deterioration in energy efficiency in the Basic Metal industry.

4.9. Discussion

The aggregate energy intensity of Indonesia's manufacturing sector averagely decreased during the period 1980 to 2015. The decrease of aggregate energy intensity was mainly due to the intensity effect/changes within industry energy intensity. The decrease of changes within industry implies an improvement in energy-efficient technology. That is, it is potentially caused by employing more advanced technologies, innovation, shifting to a more efficient energy mix and/or applying a more efficient technique, brought relevant support in minimizing aggregate manufacturing energy intensity. However, during the crisis period of 1997 to 2000, changes within industry had the greatest impact on the overall increase of aggregate energy intensity compared to the other periods. The deterioration of changes within industry was potentially related to Indonesia's financial crisis in 1997 which also deteriorated the instability of Indonesia's economy.

Beside the intensity effect, the changes in aggregate energy intensity were also affected by the changes in the structural effect. During the study period of 1980 to 2015, the role of structural effect signified the trend of improvement in aggregate energy intensity, although the magnitude of the structural effect was not as strong as the intensity effect. The decreasing influence of structural effect indicated the changes towards less energy-intensive industries in the manufacturing sector in Indonesia. Overall, both the structural effect and the intensity effect provide the counterbalance in reducing the aggregate energy intensity in the manufacturing sector.

Based on the result of sub sectoral decomposition in the manufacturing sector (ISIC 3), there are three major periods that can be observed (see Figure 4.3 to Figure 4.7) to analyse the potential improvement in energy intensity in the manufacturing sector: the period before the crisis (1980 to 1997), the period of crisis (1997 to 2000) and the period after the crisis (2000 to 2015).

Narrowing the period of observation to 1980 to 1997 showed that the changes within industry energy intensity was the main contributor in reducing the aggregate energy intensity in the manufacturing sector, signalling the existence of efficiency improvements. There are at least three subsectors that have a substantial decrease in the intensity effect in this period: Textile at around 74% (see Figure 4.4), Non-metal at around 52% (see Figure 4.6) and Chemicals at around 46% (see Figure 4.5). Indeed, the structural effect also showed a decrease in Textile and Non-metal for around 6% and 13%, respectively. On the contrary, the Chemicals subsector experienced an increase in the structural effect by around 8%, which indicated a shift to be more energy-intensive industry.

Even though changes within industry energy intensity had a substantial improvement in the period of 1980 to 1997, the trend of changes within industry reversed during the crisis period of 1997 to 2000. In this period, most of the subsectors in the manufacturing sector experienced a worsening (increase) in the intensity effect, which contributed to the increase in aggregate energy intensity during this period. The highest deterioration (increase) in the intensity effect occurred in the Basic Metal industry at around 30% compared to its base level in 1997 (see Figure 4.7). However, in this period, the Food industry experienced a decrease in its intensity effect for around 11% compared to the base level of 1997 (see Figure 4.3).

In the period after the crisis, from 2000 to 2015, the role of intensity effect to change the aggregate energy intensity in the manufacturing sector more varied. For instance, in the Food industries, Non-metal and Basic Metal, the within industry changes reduced the individual Subsector energy intensity for around 35%, 36% and 34% compared to the base level in 2000 (see Figure 4.3, Figure 4.6, Figure 4.7). On the contrary, the intensity effect in the Textile and Chemicals industries had an increasing effect for around 24% and 18% (see Figure 4.4 and Figure 4.5). Moreover, the role of structural effect also indicated a decrease in most of these sectors, except for the Food sector, which showed an increase for around 11%.

The Asian financial crisis in 1997 brought a devastating impact on the Indonesian economy. Notwithstanding that the economic crisis commenced in mid of 1997, the impact of the crisis was dramatically exposed in 1998 and the deteriorating impact still felt until 2000; as economic growth decreased, and the manufacturing industry contracted. However, after the 1997/98 Asian financial crisis, Indonesia had recovered and developed its economy by opening and removing barriers on investment, production and trade.

During the period of 1980 to 1997, Indonesia's manufacturing sector had an increasing energy consumption whereas, in this period, energy price was highly subsidized. The low energy prices directly affected to the substantial growth of energy consumption in the manufacturing sector. Indeed, the low prices potentially contribute to the expansion of energy-intensive industries and indirectly assist in the structural shift from light industries to energy-intensive industries.

Nevertheless, the aggregate energy intensity of the manufacturing sector was deteriorated (increased) during the period of crisis of 1997 to 2000. The increase in aggregate energy intensity may not essentially signify that energy efficiency of particular sectors has worsened. Several production processes may involve more energy usage (or more energy-intensive) than others, where the aggregate energy intensity will increase as a result of decreased activity in the sector. For instance, during the crisis period, the aggregate value-added activity in every energy-intensive subsector was decreasing. This decreased value added had severely impacted the increase of aggregate energy intensity in many manufacturing industries.

However, after the crisis period from 2000 to 2015, Indonesia's economic condition had gradually improved. The manufacturing's value-added had been better off, which also improved (decreased) the aggregate energy intensity in the manufacturing sector. This study argues that one of the factors to the declining of aggregate energy intensity was a result of substantial improvement in energy efficiency policy in Indonesia, including enforcement of energy efficiency measures[10] and gradual alleviation of energy subsidy that significantly increased the energy prices specifically for the manufacturing sector. The increasing energy prices might have been one of the driving forces influencing the changes in energy intensity. Soaring energy prices urge manufacturers to find strategies to lower expenses, enhance competitiveness and minimize energy intensity, including investing in new and efficient technologies to enhance energy productivity[11] and improving to production lines.

In addition to the energy price reform, the Indonesian government has also improved its energy conservation policies by amending several regulations. Since 2006, the government enacted the Presidential Regulation No. 5/2006 that introduced several changes in its energy policy. Further, the government also stipulated the Government Regulation No. 70 of 2009 which aims to enforce energy management for energy users greater than 6000 ToE and regulates the responsibility of potential manufacturing sectors (Peraturan Pemerintah 2009). Several potential energy-intensive industries are targeted under this regulation including Textiles, Chemicals, Non-metals and Basic metals. Related pilot practises and policy measures have been conducted even further ahead.

[10] Chapter 7 provides further discussions of energy efficiency policy in Indonesia.
[11] Minimize energy consumption per unit of output.

These policy measures centralize on energy-intensive sectors and the aims are to determine and to reduce the usage of obsolete technologies and to optimize the industrial production structure and production capacity. The evidence of these policies effectiveness can be distinguished in the significant improvement of energy intensity in many energy-intensive industries during the period of analysis.

4.10. Conclusion

The main objective of this study was to investigate the energy efficiency performances in the manufacturing sector by examining the past changes in energy consumption and energy intensity in Indonesia's manufacturing sector from 1980 to 2015.

A rapid industrialisation process took place in the manufacturing sector which has experienced quite significant structural changes over the period of study. Manufacturing sectors output grew significantly from 1980 to 1997, even though, during the economic crisis from 1997 to 2000, the growth rate of all industries slowed down. Hill (1990) concludes that the key factor of industrial transformation in Indonesia between the period of the 1970s to 1990s was due to its fast diversification. Additionally, Rodrik (2006) also claimed that the major dimension to economic development is product diversification. Ultimately, the structural shifts in Indonesia's manufacturing sector indicate the change from light industries with labour intensive to heavy industries with more capital and technology-intensive (Widodo 2014).

The rapid industrialisation process in Indonesia is accompanied with a significant structural shift across subsectors within the manufacturing industry. Indonesia’s manufacturing sector has increased its economic output substantially between 1980 and 2015. During this period, the proportional contribution to overall GDP of food (31), textile (32), wood (33) and Non-metal (36) industries decreased, while Paper (34), Chemicals (35), Basic metal (37) and fabricated metal (38) industries increased their share to total output. Food and Fabricated metal sectors are the two largest contributor sectors to overall value-added over the study period, whereas both sectors also have the smallest energy intensity compared to other manufacturing industries. During the study period, the value-added contribution from the food manufacturing sector has slightly decreased, whilst the value-added contribution from fabricated metal industries increased significantly.

By contrast with the national picture (see Chapter 3), the period from 1980 to 2015 has seen a strong and fairly continuous decrease in the aggregate energy intensity of Indonesia's manufacturing sectors, with a reduction of 65% over 35 years, reinforced by some limited change in industry structure towards lower intensity. Over the period as a whole, this overall reduction was dominated by increases in energy efficiency within industries, as indicated by a 62% fall in the within-industry intensive index. On the contrary, the effect of moving to a less intensive industry structure was much less important with 9% decreases in the structural index. The decomposition results show that the main driving force to reduce the aggregate energy intensity in manufacture sector is the intensity effect/ within industry changes, while the structure effect only plays a small role to reduce the overall energy intensity in Indonesia's manufacturing sector during the study period of 1980 to 2015.

Between 1980 to 1997, the intensity effect and structural effect decreased the aggregate energy intensity significantly, which suggested efficiency improvements in energy use, particularly in the Textile, Non-metal and Chemicals sectors, where a large fall in energy intensity effect occurred. Signals of the structural effect improvements (decreasing) also occurred in most of these industries, except for the Chemicals subsector which experienced an increase in the structural effect which indicated a shift to more energy-intensive industry.

However, following Indonesia's economic crisis from 1997 to 2000, which dropped the aggregate economic growth and exchange rate, the contribution of these effects differed compared to the previous period. The shock of the Financial Crisis saw an unexpected reaction when value-added fell by 13% but energy use remained largely unchanged, implying a rise in energy intensity. The intensity effects in most subsectors increased and dominated the changes in aggregate energy intensity. The greatest increase in the intensity effect occurred in the Basic Metal industry. However, in this period, the Food industry experienced a decrease in its intensity effect. The increase of changes within industry energy intensity led to an increase in aggregate energy intensity, while the role of structural effect was found smaller compared to within industry changes.

After the crisis period, changes within industry energy intensity again reduced the aggregate energy intensity, and the structural effect also increased the magnitude of the reduction of aggregate energy intensity. Over 2000 to 2015 the earlier trends resumed, but at a more subdued pace. The aggregate energy intensity in the manufacturing sector had a decreasing trend and improved quite significantly. Over this period aggregate intensity fell by 23%, driven by a 19% fall in intensity within industry and a 5% change in the structural effect.

For instance, the intensity effect in the Food industries, Non-metal and Basic Metal experienced a substantial decrease to aggregate subsectors energy intensity, although changes within industry energy intensity in the Textile and Chemicals industries had an increasing effect. Indeed, the role of structural effect also indicated a decrease in most of these sectors, except for the Food sector, which showed an increase.

In terms of the two-digit industries, it is notable that all showed a substantial reduction in energy intensity over the period, ranging from 20% for basic metal industries to 73.2% for non-metallic mineral products. To throw further light on the changes, this study has examined at a more detailed of five highest industries which accounted for about 86% of manufacturing energy use in 2015, including Food, Beverages and Tobacco (31), Textile, Wearing Apparel and Leather (32), Chemicals, Petroleum, Coal, Rubber and Plastic Products (35), Non-Metallic Mineral Products (36), and Basic Metal Industries (37).

Indonesia's economy had gradually improved after the crisis period from 2000 to 2015, which also ameliorated the aggregate energy intensity in the manufacturing sector. This improvement in the manufacturing's energy intensity potentially a result of the enforcement of energy efficiency policy in Indonesia, specifically the government regulation No. 70 of 2009 that regulates all the energy users greater than 6,000 ToE. Additionally, the Indonesian government had also reformed its energy subsidy which significantly increased the energy prices specifically for the manufacturing sector. IEA (2017a) highlights the tendency of higher energy prices to foster industry efficiency. Indeed, all of these policy measures had encouraged manufacturers to enhance its competitiveness and minimize its energy intensity, including investing in new and efficient technologies to enhance its energy productivity.

The analysis also revealed that the greatest energy intensity sector is the Non-metal sector (particularly the cement and lime sector). In 1980, the Non-metal industry consumed around 43.3% of energy use but only 6.3% of value-added in Indonesian manufacturing, implying a very high energy intensity from this sub-sector.This sector consumed more energy per value-added and involves a large share of Indonesia's manufacturing energy use compared to other sectors. Furthermore, the decomposition results reveal that the intensity effect reduction in the manufacturing sector changed through different periods of time. The trend helps to understand the consequences of economic incidents which could limit the growth of some industries from the point of view of structural change and energy use. However, besides these driving forces explained in this chapter, some other factors might also have influenced to the overall trends of energy intensity in the Manufacture sector in Indonesia and it is hard to offer a single explanation.

Chapter 5
Decomposition Analysis of Energy Intensity in Indonesia's Passenger and Freight Transport Sector

5.1. Introduction

Indonesia's transportation energy consumption is rapidly increasing, primarily due to rising economic activity and population growth. As an emerging economy and the fourth most populous country in the world (WorldBank 2014a), Indonesia's economic growth has had around 6% growth every year since 2010, leading to an increase in the mobility of the middle class (Deendarlianto et al. 2017). Indonesia's transportation sector has gone through rapid development, causing a significant use of fossil fuel energy consumption. This sector uses more than 60% of Indonesian's total oil use, approximately 70% of which consumed in road transportation (Deendarlianto et al. 2017).

Based on the *International Energy Outlook 2017* report (EIA 2017), the transportation sector is predicted to consume around 55% of the total share of liquid fuels usage worldwide by 2040. In line with the EIA study, *Southeast Asia Energy Outlook 2017* (IEA 2017b) also stated that the most rapid energy demand in Southeast Asia comes from the transport sector, that increased by almost two-fold from 2000 to 2016. Furthermore, the International Energy Agency (IEA 2017a) report also shows that the highest increase in energy consumption from 2000 to 2015 in Indonesia came from the transportation sector. Therefore, this sector has progressively become an important component of Indonesia's economic structure.

Like many governments of developing countries, the Indonesian government faces hard choices between energy prices and energy efficiency. In their attempts to support affordable energy prices and to maintain socially well-balanced economic growth, the Indonesian government frequently intervenes in the energy market by means of varying kinds of policies (Resosudarmo and Tanujaya 2002), including by overseeing the energy prices; specifically, the fuel price and electricity rates. These lead to unsustainable energy subsidies, where Indonesia's energy subsidies are mostly used to enhance economic development and reduce energy poverty by allowing access to low-cost energy services.

In the last decade, Indonesia had experienced several increases in fuel prices[12] (see table 5.1). Subsidies for fossil fuels were increasing as a portion of the national budget, although the recent price increase was the lowest in the world, particularly for a net importing country (IEA 2015a). Starting from 2005, the Indonesian Government had cut subsidies for energy and increased fossil fuel prices more than threefold. The purpose of this energy price reform was not only to limit the difference between international and domestic prices but also to bring decrease the burden on the state budget; as the budget for fuel subsidies accounted a substantial percentage in the national state budget (Howes & Davies 2014).

Table 5. 1. Fossil Fuel Subsidy Reforms since 2005

Year	Fuel Type	Fuel price policy reform
2005	Diesel and gasoline	Manufacturing industries are no longer able to get subsidized diesel. In March, the price increased by 29% and further increased in October by 114%.
2006	LPG	LPG price increase targeted to manufacturing industries
2007	Kerosene and LPG	In order to encourage LPG use, the government introduce the kerosene to LPG conversion program
2009	Diesel and gasoline	In January, Diesel and gasoline decreased by 7% and 11%, respectively.
2013	Diesel and gasoline	Both diesel and gasoline are increased by around 40%
2013	Electricity	Electricity base tariff increased by 15%
2014	Diesel and gasoline	Both Diesel and gasoline are increased by 36% and 31%, respectively
2015	Diesel and gasoline	Gasoline subsidies are removed, and diesel subsidies are reduced by Rp 1,000/ litre.

Rp = Rupiah, Kg = kilogram, LPG = liquefied petroleum gas.

Source: ADB (2015); Beaton and Lontoh (2010).

Yusuf, Patunru and Resosudarmo (2017), Chen et al. (2016) and He et al. (2016) show that an increase in energy price can significantly improve energy efficiency. Therefore, the energy price instrument is one of the essential tools for energy reform and subsidies for energy is a key determinant of energy prices. The most common definition of an energy subsidy is a payment from government to consumer or producer in order to control energy prices (IEA 1999; OECD 1998). In Indonesia, energy subsidies are mainly used by the government to control the energy price lower rather than the economic production cost.

In the international context, there is much research conducted to find out the decomposition analysis of energy intensity in the transportation sector including Achour and Belloumi (2016), Fan and Lei (2016), Lipscy and Schipper (2013), Zhang, M et al.

[12] Thus far, the energy prices including electricity, natural gas and fossil fuel have been fully regulated by the government. The Indonesian government oversees the price of fossil fuel products with adjusting periodically following a formula in which the international price plays an important variable.

(2011), and Timilsina and Shrestha (2009). However, to the best of author's knowledge, there have been no studies conducted to decompose the energy intensity in Indonesia's transportation sector. Thus, this study provides a preliminary attempt applying the LMDI method to examine the driving factors in influencing Indonesia's transportation sector energy intensity over the period of 2000 to 2016. In addition, this study also attempts to evaluate the influence of fuel prices increases to the energy usage and energy efficiency performance in the transportation sector, by looking at the changes of energy intensity changes in passenger and freight transport.

Up to now, there has been less interest in the growth of energy intensity and its driving factors in the Indonesian case — the transportation sector. Removing the energy subsidy is not intended to substantially decrease the level of energy intensity. In other words, increasing the energy prices (i.e. by reducing the amount of energy subsidy in the state budget) might not directly lead to a decrease in energy intensity. There are some other factors that drive the changes in the energy intensity, which have to be accurately analysed. Indeed, identifying the underlying driving forces associated with the changes in energy intensity in Indonesia is essential in order to formulate sound policy measures that can reduce the level of energy intensity, particularly in the transport sector.

Since the transportation sector in Indonesia is very complex and the statistical energy data in the transportation sector is limited, this study only investigates Indonesia's transportation for a limited period. This study examines all four modes of the transportation system in Indonesia: road, rail, water and air. Those modes of transport are used for both freight and passenger transportation. This study is crucial for Indonesia's government in order to develop policies to improve energy efficiency, as well as to investigate the driving factors that affect the changes in transportation energy usage.

5.2. Literature Review

The decomposition indices method has been extensively employed in measuring the driving factors behind the changes in energy used in transport. Schipper et al. (1992) investigate the changes in the structure of passenger transport energy consumption in eight OECD countries from 1970 to 1987 by employing Laspeyres Divisia Indices. They observed that shifting to more energy intensive transport mode and increasing passenger-kilometres has become the main reason for the increase in energy use. By using a similar method as Schipper et al. (1992), Scholl, Schipper and Kiang (1996) who analysed factors affecting energy consumption and emissions in freight transport for ten countries from 1973 to 1992, they found energy consumption for freight and emissions increased because of increasing freight activity, mode shifting towards trucks and less energy saving. Lipscy and Schipper (2013) examined energy efficiency in the Japanese transportation sector from 1970 to 2010 by employing the Laspeyres Decomposition method. They compared the policy and trend of energy transportation-related issues of Japan and the United States. Their results reveal that the Japanese transportation sector has a low activity level and modal structure compared to energy intensity, where the road transport mode energy intensity showing a little improvement over the last forty years.

Zhang, M et al. (2011) investigated the factors affecting energy use in the Chinese transportation system from 1980 to 2006 by applying the LMDI method. They found that the activity effect in the transport sector was the main contributor to increasing total energy use while the energy intensity effect has a major role in decreasing the total energy consumption. Employing a similar LMDI method, Chung, Zhou and Yeung (2013) probed transportation energy efficiency in 30 provinces of China from 2003 to 2009. They discovered a consistent result with Zhang, M et al. (2011) showing that the activity effect contributes to increasing the overall energy consumption.

As the economic theory forecasts that a higher price will affect in decreasing consumption. Thus, an increase in fuel price is considered in this chapter as one factor affecting the changes in energy intensity. Keppler and Birol (2000) and Hang and Tu (2007) argued that reducing energy price will decrease energy intensity and lead to an improvement in energy efficiency. Additionally, by employing firm level data, Fisher-Vanden et al. (2004) demonstrated that a rise in different type of energy products ameliorate energy efficiency. Furthermore, Lin, Boqiang and Moubarak (2014) also revealed strong evidence of energy saving resulting from a higher energy price in China's paper industry. Increases in the energy price results in decreasing energy intensity by means of efficient usage and structural adjustment (Farajzadeh & Nematollahi 2018; Song & Zheng 2012).

Nevertheless, there are contrasting points of view regarding the influence of price on energy intensity. By employing provincial level data, Song and Zheng (2012), suggested that energy price had a lesser effect on energy efficiency. Further, Yang et al. (2016) investigated at China's provincial level and revealed that the role of energy price to energy intensity is weak compared to other factors. Yusuf, Patunru and Resosudarmo (2017) analysed the impact of energy subsidies reduction to Indonesia's economy across provincial level and found that the impact varies across sectors and regions. Their results showed that without a budget recycling mechanism, the energy subsidy provide a good impact for industrial and rural development.

Other research also reveals some drawbacks of high subsidies that lead to inefficiency and failure in providing an affordable energy price for the poor (Resosudarmo, Alisjahbana and Nurdianto 2012). Dube (2003), Gangopadhyay, Ramaswami and Wadhwa (2005) and Kebede (2006) observed that the high subsidized energy prices are more benefitting the non-poor households rather than the poor. Further, Chattopadhyay (2004) argued the needs of reducing the cross-subsidies of electricity rates in India that less are optimal for several consumer groups. With regard to the high subsidies of energy in Indonesia in the previous few decades, the influence of energy subsidy to the overall trend of energy intensity in the transport sector is essential as one of the factors that will be measured in this study.

5.3. Methodology

This study investigates the driving forces of, and examines the transportation energy consumption trend for, Indonesia by applying the LMDI method for period 2000 to 2016 (see the formula of LMDI-II Multiplicative in Chapter 2 – Literature Review). The transportation energy consumption is divided into passenger and freight transportation, covering the four modes: road, water, rail and air.

Energy intensity for freight and passenger transport in this study was computed separately to compare the energy efficiency improvement in each type of transport mode. Structural effect and intensity effect are two driving forces that are attributed for the changes in aggregate energy in transportation. Energy intensity effect is a ratio that relates to energy consumption and turnover, which represents the energy efficiency of transportation activity. This effect is predicted to decrease over time owing to the development of more energy efficient technologies. In addition, the structural effect captures the change of turnover for each transport mode. This effect measures the changes of energy use in due to the changes in modes of transports share of the economy. All things being equal, the changes in the level of transportation turnover modal shares directly affect the level of transportation energy consumption modal share.

5.4. Data

Since the lack of energy statistical data in the transportation sector in Indonesia, this study only takes into account the four modes of transport: road, water, rail and air. The data for this study comes from a peer-reviewed database of transport data: the Transport Databank (Zhang, X & Emmerson 2016). This data is a collaboration of the Asian Development Bank (ADB), the Clean Air Asia's Transport Research Laboratory (TRL), University of California Davis' Institute of Transportation Studies and the

Partnership of Sustainable, Low Carbon Transport (SLoCaT). The collaboration published a database on transport with a focus on Asia and the Pacific. The historical data was constructed from national surveys, and international statistics (Zhang, X & Emmerson 2016).

Table 5. 2. Variables in the Transport Sector

Subsector	Mode of transport	Structural factors	Intensity factors
Passenger	Road	Share of total passenger kilometre	Energy per passenger kilometre[13]
	Rail		
	Water		
	Air		
Freight	Road	Share of total tonne kilometre	Energy per tonne kilometre[14]
	Rail		
	Water		
	Air		

The transport sector has two tasks: moving passengers and moving freight. To measure activity (or turnover), in this study, this is estimated by passenger-kilometre (PKM) and tonne-kilometre (TKM). PKM measures the efficiency of passenger transport by calculating how much energy is needed to move one passenger per kilometre, while TKM is employed to measure the efficiency of freight transport by determining how much energy is consumed to move one tonne of goods per kilometre. The energy consumption for both passenger and freight transports are measured in Kilo Ton of Oil Equivalent (KTOE). Changes in energy consumption are decomposed in terms of the structural effect and intensity effect using the relative contribution of the passenger and freight transport tasks. This study separates the analysis of passenger and freight sectors differently as the underlying economic factors shaping for both sectors differed (Lipscy & Schipper 2013).

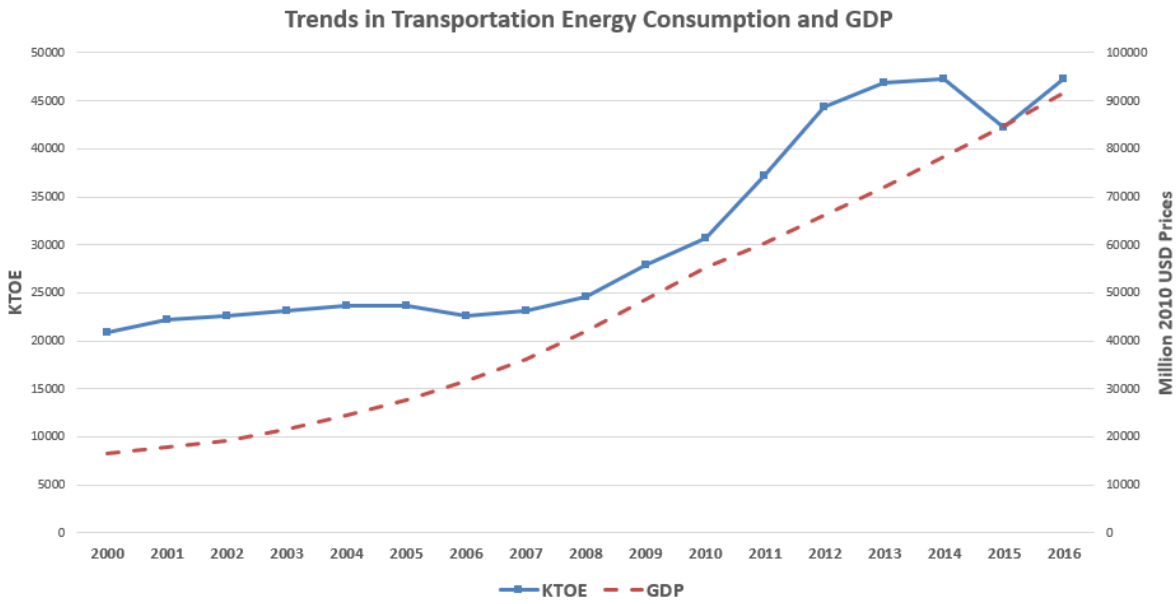
5.5. Analysis of energy consumption in the transportation sector

As increasing energy consumption aligns with economic growth, which is defined as GDP per capita (Masih & Masih 1996), it is worth comparing transport energy use and GDP. Figure 5.1 reveals the increasing trend both in GDP and transport energy consumption in Indonesia from 2000 to 2016. Thus, in general, as GDP and energy use increase, it can be assumed that it will be aligned with increasing mobility and improved standard of living. Turnover in the passenger transport is influenced by several factors, for instance, population growth, urbanization and changes in income, where these

[13] A passenger kilometre is defined as one passenger being moved one kilometre.
[14] Tonne-kilometre is one tonne of freight being moved one kilometre – for freight transportation.

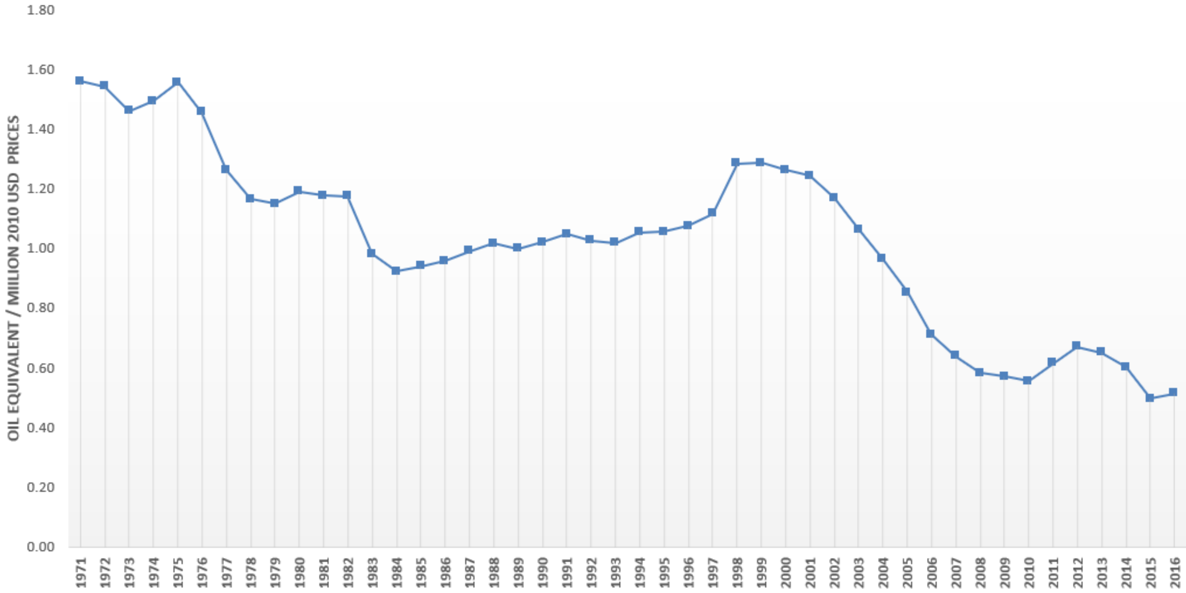
factors are expected to change the level of energy consumption in the transport sector (Chai et al. 2016; Tiwari & Gulati 2013). While, for the freight transport, economic growth is one of the major factors that affects the transport of commodities (Tiwari & Gulati 2013).

Figure 5. 1. Trends in Transportation Energy Consumption and GDP



As can be seen in Figure 5.2, since 1971 to 1984 and 2000 to 2016 the aggregate energy intensity in the transportation sector has been declining, except for the period from 1984 to 1998. The energy intensity of Indonesia measured as energy consumption per unit of GDP, demonstrated a significant improvement (declining trend) by approximately half over the period 2000 to 2016. However, there was a slight increase in the transport energy intensity from 2010 to 2012. Based on the US$ prices of 2010, the energy intensity dropped from around 1.26 (in 2000) to approximately 0.56 (in 2016) of oil equivalent/million 2010 US$.

Figure 5. 2. Transportation Energy Intensity in Indonesia from 1971 to 2016



While value added data are available for total transport, these data are not available for road freight and passenger transport separately. Given that these components are so important (each providing about half of energy use in transport by 2015) but also so distinctive, this study analyse them separately, using different dominators for the energy intensity measures (freight tonnes and passenger kilometres), for the period 2000 to 2016. Many factors have contributed to the decreasing trend of energy intensity, whereas this study attempts to investigate: the changes in the transport modes contribution ("modal shift") and the improvements of energy efficiency.

5.5.1. Passenger Transport

In passenger transport, the aggregate turnover and aggregate energy consumption have grown approximately four-fold from 2000 to 2016, generated substantially by an increase in the distance travelled per passenger (IEA 2017a). Passenger transport turnover increased from 710 billion PKM in 2000 to 3,286 billion PKM in 2016, with an average annual growth rate of 10.1%. For the same period, total energy consumption in passenger transport increased from 12,957 KTOE in 2000 to 54,384 KTOE in 2016 with an average annual growth rate of 9.4%. It is apparent that the increasing energy consumption growth and its turnover tracked each other very closely, with average yearly growth rates of 9.38% and 10.05%, respectively. This growth illustrates that Indonesia's transportation sector experienced increasing energy usage and steady development driven by many forces including economic growth and improved standard of living.

Table 5. 3. Share and Growth of Turnover (Passenger Transport — PKM)

Sectors	Annual Growth Rate of Passenger Turnover (%)					Share of Total (%)				
	00-05	05-08	08-14	14-16	00-16	00	05	08	14	16
Road	11.6	21.6	5.4	4.8	10.1	94.6	95.4	96.4	95.7	95.6
Rail	-5.7	7.7	-0.3	1.1	-0.4	2.7	1.2	0.8	0.6	0.5
Water	0.5	8.3	8.1	5.8	5.4	0.5	0.3	0.2	0.2	0.3
Air	19.5	13.1	11.2	5.4	13.3	2.2	3.2	2.6	3.5	3.6
Aggregate	11.4	21.2	5.5	4.8	10.1					

The largest turnover share in the passenger transportation sector came from road transport with approximately around 95.6% of the aggregate turnover in the passenger transportation sector in 2016 (see table 5.3). Following road transport, air, rail and water transport accounted for around 3.6%, 0.5%, and 0.3%, respectively. It is not surprising that road transport has the largest share given the vast development of Indonesia's highway networks over the last decade.

Road transport has quite a steady turnover share from around 94.6% in 2000 to about 95.6% in 2016. The turnover share of rail and water modes decreased quite significantly during the study period from around 2.7% and 0.5% in 2000 to 0.5% and 0.3% in 2016, respectively. The turnover in air transport increased from around 2.2% in 2000 to about 3.6% in 2016. The change in air travel activity suggests travellers are increasingly choosing to fly than using other modes of transport. Domestic aviation was the fastest growing mode of passenger transport, increasing by around 19% per year from 2000 to 2005 and approximately 13% annually from 2000 to 2016. Activity in other modes of passenger transport also expanded, except for rail transport mode that had the lowest growth over the period. Indeed, rail transport significantly slowed its growth during the study period.

Table 5. 4. Share and Growth of Energy Consumption

Sectors	Annual Growth Rate of Passenger Energy Consumption (%)					Share of Total (%)				
	00-05	05-08	08-14	14-16	00-16	00	05	08	14	16
Road	10.3	19.2	4.9	4.7	9.1	91.8	89.7	91.1	88.1	88.0
Rail	-6.3	7.0	0.0	2.4	-0.5	0.9	0.4	0.3	0.2	0.2
Water	-0.9	8.4	8.3	9.3	5.4	0.9	0.5	0.4	0.5	0.5
Air	19. 5	13.3	11.1	5.4	13.3	6.4	9.4	8.2	11.2	11.4
Aggregate	10.8	18.6	5.5	4.8	9.4					

For a closer look at the structural proportion of energy consumption in passenger transport, Table 5.4 illustrates the energy consumption of passenger transportation from 2000 to 2016. Road transport was the highest energy-consuming sector, responsible for around 91.8% of that consumed by total passenger transport in 2000 but decreasing to around 88% in 2016. The share of water transport and railway energy consumption decreased from 0.9% in 2000 to 0.5% and 0.2% in 2016, respectively. While the share of civil aviation almost doubled from approximately 6.4% in 2000 to 11.4% in 2016.

The primary reason for the changes in the transport sector energy consumption and turnover is the shift in use of different modes of transport. This shift occurred as changes from less intensive energy consumption mode, for instance, railway transport, to more intensive energy consumption modes: road and air transport.

Table 5. 5. Energy Intensity in Passenger Transport sector

Sectors	**Passenger Energy Intensity (KTOE/ Billion Passenger Kilometre)**					**Energy Intensity Changes** (%)
	00	**05**	**08**	**14**	16	00 - 16
Road	17.7	16.7	15.7	15.2	15.2	-14.0
Rail	6.0	5.9	5.7	5.8	6.0	-1.0
Water	31.9	29.6	29.7	30.0	31.9	-0.2
Air	52.9	52.9	53.1	52.9	52.9	-0.1
Aggregate	18.2	17.7	16.6	16.5	16.6	-9.3

Table 5.5 shows the energy intensity of each transport mode in 2000, 2005, 2008, 2014 and 2016. From 2000 to 2016, aggregate energy intensity in the passenger transport sector decreased by around 9.3%. The declining trend in this period was mainly driven by the declining trend of energy intensity in the road transport for about 14%, followed by rail, water and air transport sector for approximately 1%, 0.2% and 0.1%, respectively.

Overall, the energy intensity of the passenger transport sector declined steadily over the decade from 2000 to 2016. In Table 5.5, it can be seen that the least efficient transport mode or the highest energy intensity in the passenger transport is civil aviation, followed by water transport with road and rail transport in the third and fourth place. The aviation sector is the least efficient mode, as it requires around 53 KTOE per billion passenger kilometres, accounting to nearly three times more than that by road transport and almost nine times as much as by railway. The most efficient transport mode in passenger transport is railway, which only requires around six KTOE per billion passenger kilometres.

5.5.2. Freight Transport

Table 5.6 and 5.7 present the total energy consumption of freight transport and turnover from 2000 to 2016. Freight transport turnover increased from 498 billion tonne-kilometre in 2000 to 1749 billion tonne-kilometre in 2016, with an average annual growth rate of 8.2%. For the same period, total energy consumption in freight transport also increased from 12,422 KTOE in 2000 to 56,868 KTOE in 2016 with an average annual growth rate of 10.0%. This shows the growth of energy consumption is higher than the growth of its turnover.

Table 5. 6. Share and Growth of Turnover (Freight transport —TKM)

Sectors	Annual Growth Rate of Freight Turnover (%)					Share of Total (%)				
	00-05	05-08	08-14	14-16	00-16	00	05	08	14	16
Road	11.0	15.7	5.2	5.7	9.0	36.6	45.1	46.6	41.1	41.1
Rail	-2.5	-1.6	-0.3	3.6	-0.8	0.7	0.4	0.3	0.2	0.2
Water	3.4	13.4	7.9	5.9	7.3	61.7	53.3	52.0	53.6	53.7
Air	9.0	12.5	38.1	4.7	19.2	1.1	1.2	1.1	5.1	5.0
Aggregate	6.5	14.4	7.4	5.7	8.2					

Turnover activity in freight transport increased quite significantly from 2000 to 2016 (see Table 5.6). Differing from passenger transport, the highest turnover share in freight transport came from water transport. In 2016, water transport accounted for around 53.7% of the aggregate activity in the freight transport sector. Following water transport, road transport also accounted for a significant share for around 41.1%. Air and rail transport were only responsible for around 5% and 0.2%, respectively. The share of aviation in freight transport almost quadrupled over the last decade. Aviation transport had the highest growth rate turnover during the study period. Freight tasks carried out by shipping fell quite significantly, with the market share of shipping declining from around 61.7 per cent to approximately 53.7 per cent from 2000 to 2016.

Table 5. 7. Share and Growth of Energy Consumption (Freight Transport)

Sectors	Annual Growth Rate of Freight Energy Consumption (%)					Share of Total (%)				
	00-05	05-08	08-14	14-16	00-16	00	05	08	14	16
Road	10.1	14.9	4.5	5.0	8.2	83.2	86.3	86.7	74.1	74.0
Rail	–3.1	–1.6	–0.8	3.7	–1.1	0.2	0.1	0.1	0.0	0.0
Water	1.2	15. 5	8.3	7.8	7.3	8.2	5.6	5.7	5.2	5.5
Air	8.2	12.4	38.9	4.9	19.2	8.4	8.0	7.5	20.7	20.5
Aggregate	9.3	14.7	9.9	5.1	10.0					

Table 5.7 details energy consumption in freight transport from 2000 to 2016. Similarly, to passenger transport, road transport is the largest energy-consuming sector in the freight transport sector. This sector consumed approximately 83.2% of that used by total freight transport in 2000 which decreased quite significantly to around 74% in 2016. Trucks are the main energy consumers in the road freight transport. The reduction of road transport followed with the increase of energy consumption in other modes, particularly in aviation. The energy consumption by aviation increased from around 8.4% in 2000 to around 20.5% in 2016. The significant changes of energy consumption also occurred in the rail and water transportation, where the share of these modes decreased from 0.2% and 8.2% in 2000 to 0.04% and 5.5% in 2016, respectively. Overall, the aggregate energy consumption in the freight transport sector rose by around 10 per cent a year over the period from 2000 to 2016. This increase was largely attributable to the increase in aviation. On the contrary, energy consumption in rail transport fell substantially during the period of this study.

Table 5. 8. Energy Intensity in the Freight Transport sector

Sectors	Freight Energy Intensity (KTOE/ Billion Ton Kilometre)					Energy Intensity Changes (%)
	00	05	08	14	16	00-16
Road	56.8	54.6	53.4	51.3	50.6	–10.9
Rail	7.1	6.9	6.9	6.7	6.7	–5.7
Water	3.3	3.0	3.1	3.2	3.3	–0.7
Air	199.5	192.0	191.6	198.5	199.5	0.0
Aggregate	25.0	28.5	28.7	32.9	32.5	30.3

Table 5.8 shows the energy intensity of each transport mode for freight transport for the periods 2000, 2005, 2008, 2014 and 2016. The energy intensity of the freight transport sector increased significantly to about 30.3% over the study period. During this

period, the road transport sector experienced the most significant improvement in energy intensity, decreasing to around 10.9%, followed by rail and Water to approximately 5.7% and 0.7%, respectively; while air transport had negligible changes in its energy intensity. In spite of individual freight transport sector experienced a declining trend in energy intensity, the aggregate energy intensity in the freight transport showed an increasing trend. This contradictory trend of aggregate energy intensity and sectoral energy intensity (see Table 5.6 and Table 5.7) was due to the growth rate of annual turnover (8.2%) which was lower than the growth rate of annual energy consumption rate (10%).

As with passenger transport, the highest energy intensity in the freight transport also came from air transport. The second highest energy intensity came from road transport, followed by rail and water transport, respectively. The water transport mode proved to be the most efficient in the freight transport sector, as it only required around 3 KTOE per billion tonne kilometres, accounting to around sixty times less than that by air transport. The high energy intensity in the freight transport was primarily attributable to the high energy intensity of the air freight transport mode.

5.6. Decomposition Analysis

Final energy use in both passenger and freight transport sector rose during the study period. As can be observed, the trend of the energy intensities of passenger and freight transport is contradictory. From 2000 to 2016, energy intensity in passenger transport declined from approximately 18.2 KTOE/billion tonne PKM in 2000 to 16.5 KTOE/billion PKM in 2016 (decreasing around 9.3%). On the other hand, energy intensity in freight transport climbed rapidly from around 25 KTOE/billion tonne-PKM in 2000 to 32.5 KTOE/ billion tonne-PKM (approximately a 30.3% increase).

By employing the LMDI method, this study estimates the driving forces of passenger and freight transport-related energy consumption in Indonesia, including the structural effect (DSTR) and intensity effect (DINT). As the energy source for the transportation sector mainly comes from oil and oil products, the decomposition analysis is divided into several sub-periods following the rising of the oil price in Indonesia. During the study period, the fuel price had been increased periodically. Diesel price was increased twofold in 2005, while in 2008 both diesel and petrol were raised[15] by one-third (Howes & Davies 2014). In 2013, the Indonesian government further increased diesel and petrol prices by 22% and 44%, respectively. Further, in November 2014, petrol and diesel were again increased by 31% and 36%, respectively.

[15] In 2005, premium gasoline has been raised from Rp 1800 to Rp 4500 /litre, and kerosene from Rp 700 to Rp 2000 /litre. Further, in 2008, premium gasoline has been raised from Rp 4500 to Rp 6000 /litre, and kerosene from Rp 2000 to 2500 /litre.

The results of the decomposition for passenger transport and freight transport in Indonesia from 2000 to 2016 are graphed in Figure 5.3 and 5.4.

Figure 5. 3. Decomposition Result of Passenger Transport

	00-05	05-08	08-14	14-16	00-16
DSTR	1.03	0.99	1.02	1.00	1.04
DINT	0.95	0.95	0.97	1.00	0.87
DTOT	0.97	0.94	1.00	1.00	0.91

The decomposition results in passenger transport in Figure 5.3 show that the transportation energy intensity effect (DINT) significantly contributed directly to reduce the aggregate energy intensity (DTOT), while the role of the structure effect (DSTR) is found to be relatively small in most sub-periods. The energy intensity effect contributes strongly in decreasing total energy intensity in passenger transport. From 2000 to 2016, this effect induced a decrease in passenger transport energy intensity at around 13%, while the structural effect increased the energy intensity to only 4%. The structural effect has had a negative effect on energy intensity in the passenger transport sector over this period. Overall, between 2000 to 2016, the aggregate energy intensity (DTOT) in passenger transport decreased by around 9% compare to its base level in 2000.

From 2005 to 2008, the structural effect contributed a 1% reduction in energy intensity, while the intensity effect decreased energy intensity by around 5%. Overall, aggregate energy intensity in the passenger transport decreased by around 6% during this period. In the period of 2008 to 2014, the aggregate energy intensity in the passenger transport was stable, due to the increase in structural effect that was offset by the intensity effect.

The graph reveals that energy efficiency in the passenger transport improved over the period from 2000 to 2016. This means that improving the transport intensity effect can significantly influence energy saving. This effect may relate to policy measures that have been enacted in Indonesia such as developing new green vehicle technology, improvement in fuel quality, advances in the transportation system and promoting energy alternatives. While, on the other hand, the increases in the structural effect potentially due to modal shifting, from less energy intensive mode, like rail transport, to more energy intensive modes such as air and road transport. As noted earlier, the road transport sector has been a prominent transportation mode.

Figure 5. 4. Decomposition Result of Freight Transport

	00-05	05-08	08-14	14-16	00-16
DSTR	1.19	1.02	1.17	0.99	1.42
DINT	0.96	0.98	0.98	0.99	0.92
DTOT	1.14	1.01	1.15	0.99	1.30

The aggregate energy intensity in freight transport rose by 30% from 2000 to 2016. Most of the increase in energy intensity was attributable to the structural effect — around 42%, which was partly offset by the decreases in the intensity effects — around 8%. Without the intensity effect, energy intensity in the freight transport would have increased over this period. From 2005 to 2008, the freight transport aggregate energy intensity increased by 1% compared to its base level in 2005. The increase in aggregate energy intensity was attributable to the structural effect that increased the energy intensity by 2%, but this increase was offset by the intensity effect. From 2008 to 2014, the aggregate energy intensity in the freight transport increased by 15% compared to its base level in 2008. In this period, the structural effect contributed a 17% increase in aggregate energy intensity, while the intensity effect only decreased by around 2%.

The finding from this study is similar with a recent report from IEA (2017a) that argued structural effect in the freight transport in Indonesia is increasing due to structural shift in the freight transport, particularly the shift to road transport mode such as trucks.

According to IEA (2017a), light commercial vehicles are typically the most energy-intensive out of the freight movement modes. The intensity effect in the freight transport was found less significant (smaller) compared to passenger transport, this potentially due to limited policy efforts in improving fuel efficiency particularly in the heavy-duty vehicles (IEA 2017a). Further, the absence of fuel efficiency policies also deteriorates energy efficiency efforts. The increasing trend in energy intensity is consistent with the movement to more energy intensive transport mode. The rate of increasing energy intensity in the freight transport is relatively larger compared with passenger transport.

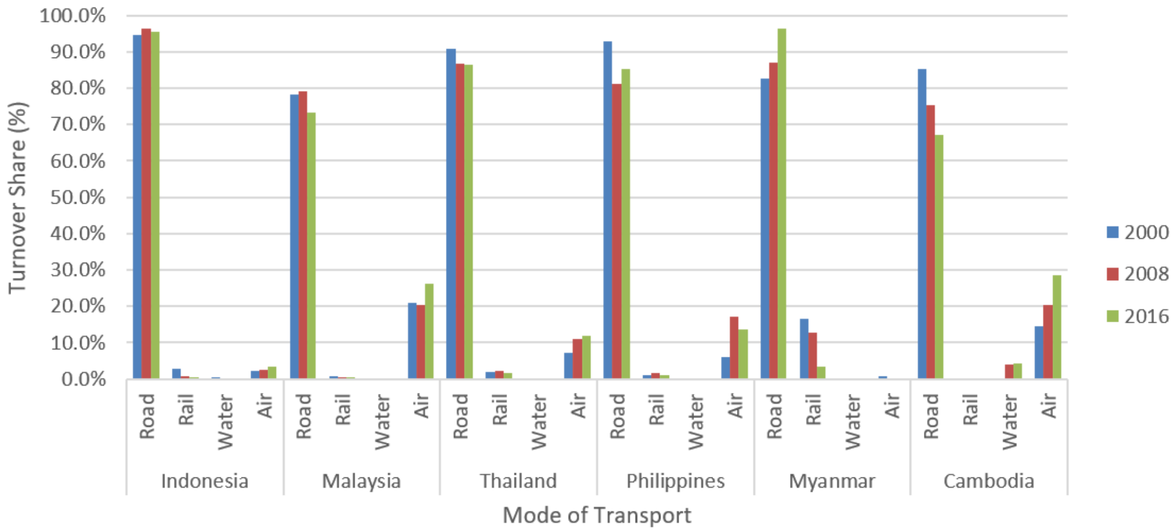
Similar with the decomposition result in the Passenger Transport (Figure 5.3), the decomposition result in the freight transport (Figure 5.4) revealed that the transportation structure effect significantly increases the aggregate energy intensity in the freight transport sector, while the intensity effect is less significant in magnitude compare to the structural effect. The energy savings from Intensity effects (efficiency improvements) in the freight transport sector (8%) is smaller compared to the passenger transport sector (13%). In terms of structural effect, the freight transport sector experienced a more substantial structural change (42%) compared to passenger transport (4%). The increased structural effect in both freight and passenger transport indicated that the transport sector in Indonesia has shifted to more energy intensive transport mode over the period of 2000 to 2016.

5.7. Indonesia and other ASEAN Countries

Up to now, the majority of ASEAN countries have developed some energy savings targets, like a medium-term target to reduce its energy intensity (ACE 2015b). Thus, it is important to discuss their achievement as a benchmark for Indonesia. This chapter provides an analysis of Indonesia's energy use compared to other selected ASEAN countries from 2000 to 2016. Due to a limit in the available data, the group of six ASEAN countries in this chapter is different from the ASEAN-6 countries in the Chapter 3. The selected ASEAN countries for analysis in this chapter only includes Indonesia, Malaysia, the Philippines, Thailand, Cambodia and Myanmar.

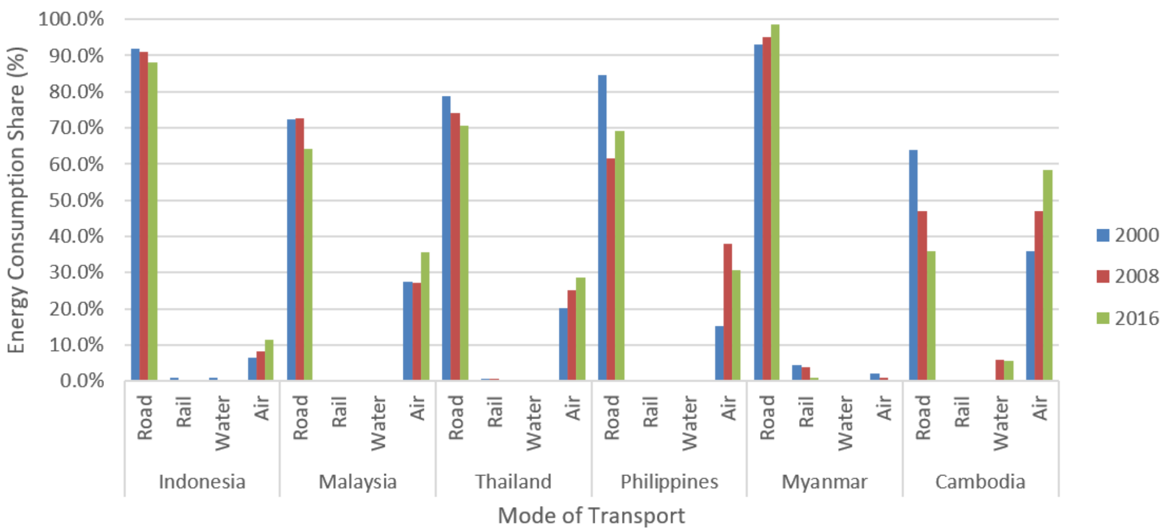
Figure 5.5 illustrates the passenger turnover share for the six selected ASEAN countries. Road transport has the largest share in the passenger transportation in all of the six selected ASEAN countries over the study period. This mode of transport contributes for more than 70% of the share for Malaysia, Thailand, the Philippines, Myanmar and Cambodia, where in Indonesia this mode contributed more than 90% from 2000 to 2016. The second highest turnover contributor came from the air transport. In Cambodia, air transport almost doubled from 14.7% in 2000 to around 28.6% in 2016, where the increase of aviation was followed with a decrease of road transport. Another significant increase in air transport can also be seen in Malaysia, where this sector contributed for around 26.3% in 2016. Rail transport has quite significant share in Myanmar for around 16.5% in 2000 but fell to around 3.4% in 2016. Water transport in the total turnover was found the lowest in all of the six ASEAN countries for less than 1%, although in Cambodia it increased to around 4.4% in 2016.

Figure 5. 5. Passenger Turnover Share in ASEAN Countries



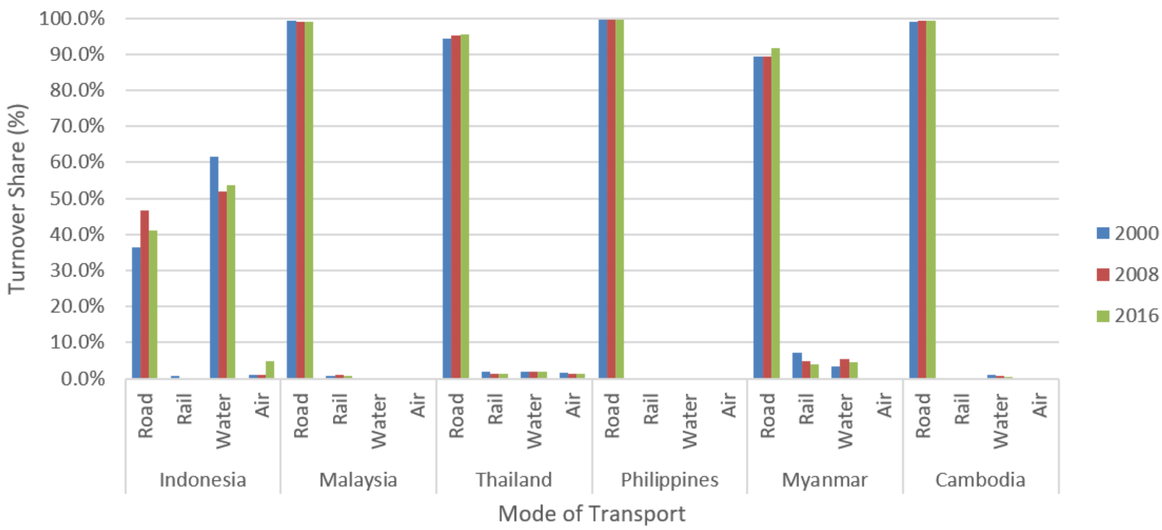
Similarly, to the share of turnover, energy consumption in the road transport mode also played a key role in the overall energy consumption in passenger transport from 2000 to 2016 (Figure 5.6). This mode of transport consumed more than 70% in all of the six ASEAN countries, except Cambodia, where its energy consumption share decreasing almost a half from 63.9% in 2000 to 35.9% in 2016. The share of energy consumption in air transport increased quite significantly in Malaysia, Thailand, Philippines, Cambodia and Indonesia which increased from 27.4%, 20.3%, 15.1%, 36.1%, 6.4% to around 35.7%, 28.7%, 30.6%, 58.4%, 11.4%, respectively. Similar to the share of turnover, the share of energy consumption in railways and waterways were found to be insignificant in all of the six ASEAN countries, which only covered less than 6% during the study period.

Figure 5. 6. Passenger Energy Consumption Share in ASEAN Countries



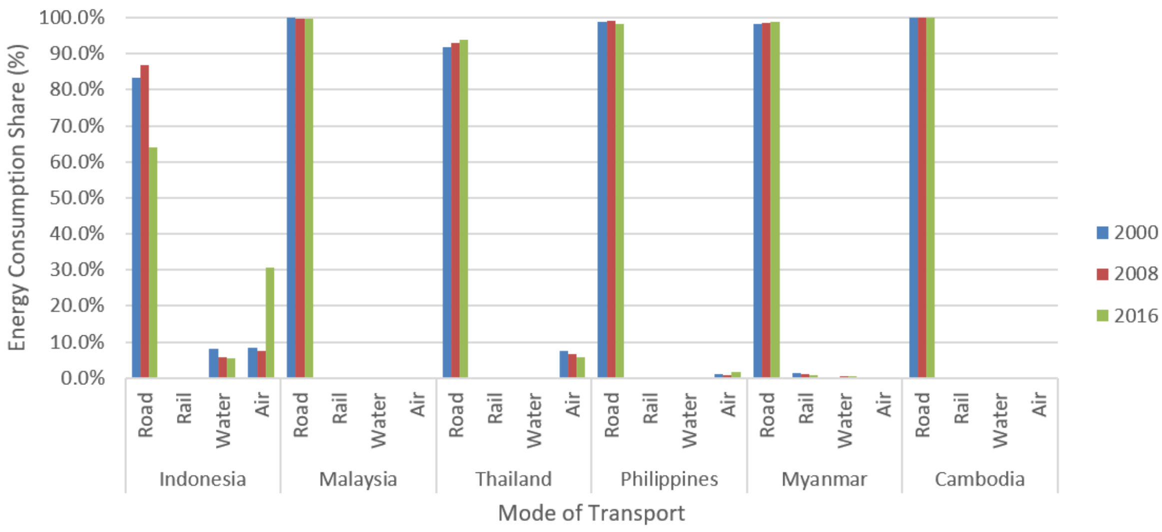
From Figure 5.7, the total share of turnover in freight transport in the six ASEAN countries was dominated by the road transport mode for more than 90% of the study period, except for Indonesia. In Indonesia, the water transport had the largest turnover, for more than a half of the total turnover, where the other half of the turnover came from road (around 30% to 40%), air (around 1% to 5%) and rail (less than 1%) from 2000 to 2016. Compared to Indonesia, all of the other six ASEAN countries had a negligible amount of turnover from rail, water and air, although Myanmar had a small contribution from rail and water, at around 10% during the study period.

Figure 5. 7. Freight Turnover Share in ASEAN Countries



Similarly, with the turnover share, the energy consumption in the freight transport also depict a comparable share (Figure 5.8). The road transport sector is the highest energy consuming sector in all of the six ASEAN countries which accounted for more than 90% of the total energy consumption share in Freight.

Figure 5. 8. Freight Energy Consumption Share in ASEAN Countries



For Indonesia, particularly, even though the turnover share of the water transport was the largest, the energy consumption shares from this mode was not as large as its energy use. Water transport only consumed around 5% to 8% of the total energy consumption from 2000 to 2016 (Figure 5.8). On the contrary, road transport consumed around 60% to 80%, although this mode only contributed around 30% to 40% of the total turnover share during period of study. The air transport sector increased its total share of turnover and energy consumption.

5.8. Discussion

In regard to turnover and energy use, both freight and passenger transport in Indonesia have experienced a positive growth. The main factors affecting this trend were the changes in energy intensity, transport choices and turnover growth. For passenger transport, the major transport mode for passenger transport in Indonesia was road transport mode, while for freight transport it was waterways. The highest energy consuming transport mode in Indonesia for both freight and passenger were road transport. In spite of being a country with many archipelagos, road transport contributed the largest turnover in passenger transport, whereas air, waterways and rail transport did not play a significant role in passenger transportation in Indonesia. Over the study period of 2000 to 2016, road transport accounted for the largest share, with more than 90% of the share in terms of passenger-kilometres travelled.

Geographically, Indonesia used water transport majorly for freight transport; because of Indonesia is an archipelagic country. This large share of waterways for transport is potentially due to Indonesia's effort on developing an integrated water transport system. Railway transport has a relatively negligible share either in passenger or freight transport in Indonesia. As rail transport has a very small role in passenger and freight transport in Indonesia, the energy consumption by rail transport is also negligible. Air transport has increased its share both in passenger and freight transport in Indonesia over the study period. The shift towards air travel in both passenger and freight transport showed a change towards a more energy inefficient mode of transport.

In passenger transport, the structural effect (DSTR) had an increasing impact on the aggregate energy intensity in most years, although its magnitude was insignificant compared to the decreasing intensity effect. The increasing structural effect was associated with the modal shifting, from less intensive energy modes, like railway, to more energy consumption modes, like road and aviation. In passenger transport (see Table 5.3), the share of railways to total turnover dropped from 2.7% in 2000 to 0.5% in 2016; Air transport increased from 2.2% in 2000 to 3.6% in 2016; while road transport only increased slightly by around 1% in 2016 compared to the base year. Based on IEA (2017a), the increasing demand of air transport services in Indonesia recently has been encouraged by the substantial development of airways transport infrastructure in Indonesia, specifically airports and the growing of low-cost airlines. Between 2015 and 2016, the total number of airline passengers grew 10.5%, to 95.2 million (IEA 2017a). In line with the increasing turnover share in the aviation, the ratio of air transport energy consumption to other modes also increased from around 6.4% in 2000 to approximately 11.4% in 2016. Moreover, the energy consumption in the road transport decreased from 91.8% in 2000 to 88% in 2016; while rail and water transport also had a slight decrease in energy consumption (see table 5.4). Road transport has been the prominent transportation mode, which explains more than 90% of total turnover and total energy consumption during the study period.

Compared to passenger transport, the structural change in freight transport has been more obvious as it accounted for 30% of total energy intensity change (DTOT) in absolute value (see Figure 5.4). It is clear that there has been a shift from water transport towards road and civil aviation. The share of water transport decreased quite significantly from 61.7% in 2000 to 53.7% in 2016 (see Table 5.6), while road and air transport increased its share to around 36.6% and 1.1% in 2000 to around 41.1% and 5.0% in 2016. On the other hand, the energy consumption share of road transport has declined from 83.2% in 2000 to 74% in 2016, while air transport substantially increased from around 8.4% in 2000 to 20.5% in 2016 (see Table 5.7). The energy consumption shares of navigation and rail transport have also gone down but only slightly compared to the other modes.

Over the period 2000 to 2016, the energy intensity of the passenger transport sector declined steadily, while in the freight transport energy intensity increased quite significantly. In passenger transport, the decreasing aggregate energy intensity was attributable to the intensity effect that lowered the overall energy intensity in the passenger transport to around 9% from 2000 to 2016. On the contrary, the structural effect led to an increase of 4% in aggregate energy intensity, although this increase was largely offset by the decreasing intensity effect by around 13%. For the same period in freight transport, the intensity effect decreased the aggregate energy intensity at around 8%, while the structural effect increased the aggregate energy intensity at around 42%. Thus, aggregate energy intensity in the freight increased by around 30% from 2000 to 2016.

Overall, the aggregate energy intensity in the passenger transport decreased considerably, while aggregate energy intensity in freight transport increased quite significantly from 2000 to 2016. Further, the findings also indicate that the transportation energy intensity effect had a greater contribution in reducing overall energy intensity in both passenger and freight transport, while the role of the structural effect increased the aggregate energy intensity in both passenger and freight. The role of intensity effect in Freight was found lesser in magnitude to reduce the aggregate energy intensity compared to the passenger transport over the study period, while the role of structural effect in freight was found more substantial to increase the aggregate energy intensity compared to the passenger transport. The reduction of the intensity effect can be associated with better and more effective policy measures, for instance encouraging the use of cleaner fuels, upgrading traffic equipment and supporting the development of new technology. In addition, since the fuel price reform, Indonesia's energy prices have increased substantially, although it is lower than international fuel prices. Therefore, energy price changes potentially have had a small impact on overall energy intensity changes in the transport sector.

5.9. Policy Implications

Several features of Indonesia’s transport system are distinctive in an international context. Almost all passenger kilometres are travelled on roads (95.6% in 2016), with virtually no rail (0.5%) or water (0.3%) passenger travel, but with a small but rising share of air travel (3.6% in 2016). Rail is also absent in freight movement in Indonesia, accounting for only 0.2% of total tonne-kilometre movements in 2016, which are mainly divided between road (41.1%) and water (53.6%) in 2016, although air freight is rising rapidly, reaching 5.0% in 2016. The absence of rail in either passenger or freight movements and the high, if declining, the share of freight movements are both quite distinctive.

A good transportation system is one of the main components for strong economic growth (Pradhan & Bagchi 2013). However, energy consumption in this sector has grown continuously over the last decade and will potentially continue to increase in the future. Attempts to reduce energy use in the transportation sector require significant attention, where clear and coherent government policy needs to be established to conduct a suitable energy policy in this sector. Therefore, the findings in this study are aimed to establish a scientific evidence for developing policy on energy efficiency measures in the transportation sector.

The structural effect of the passenger and freight transport indicated a negative influence (that is, increasing) aggregate energy intensity over the period of the study. This seemingly indicates contradictory efforts in reducing overall energy intensity. Based on the observation of energy usage performance across transportation modes in the study period, the breakdown of road and air transport turnover for both passenger and freight have increased substantially, employing more energy per unit of turnover compared to other modes of transport. Therefore, to lower the level of energy use in the transport sector, one of the key policy measures required is to promote different modes of transport besides road (for passenger) and air transport (for freight), such as railways, waterways transport, and other modes of transport that consume less energy.

The road transportation system is a crucial sector that not only moves people and goods but is also essential for industry and local trade. Therefore, the key strategy to further reduce the energy intensity growth in the transport sector is to lower the growth of energy consumption. Enacting green energy policies, such as shifting to cleaner energy fuels (Schipper & Ng 2004) and encouraging the use of public transport (ADB 2006), including rail and water transportation would help obtain this goal. Regulatory measures, including vehicle efficiency and occupancy standards (An & Sauer 2004) are needed to reduce energy intensity in the transport sector. Moreover, fiscal measures, such as providing tax incentives and subsidies for the development of public transportation (ADB 2006), cleaner fuels or development of green technology could be considered as an effective way to encourage awareness of the people to use energy more efficient that lead towards a modal shifting of more energy efficient transport mode.

Overall, Indonesia’s transport structure needs to be focused on the waterway and railway transports that have lower energy use and greater transport capacity. The Indonesian Government needs to enact various policy measures to escalate investment in the waterways and railways. Improving the development of inland waterways and railways network can be done gradually by providing more effort in optimizing networks across different transport modes and enhancing the road infrastructure to make all other transport modes closely connected (Wang, Yuanfeng, Li & Xu 2014). These efforts are expected to gain an efficient transport system, where railways and waterways become more dominant in the Indonesia's transport system.

5.10. Conclusion

In recent years the Indonesian economy has grown rapidly, and the transportation sector provided a substantial contribution to standard of living and economic growth. This study investigates the growth of the transport sector energy intensity and the potential factors influencing the energy intensity in passenger transport and freight transport from 2000 to 2016.

Energy use in the transportation sector grew more slowly than overall energy use in Indonesia for a period of about 30 years after 1971, falling from 58% of the total in 1971 to only 38% in 2000, but has since surged back to 51% by 2016 (see Chapter 3). Final energy consumption in both passenger and freight transport sector rose during the study period. Over 2000 to 2016, total final energy consumption in transport has grown by 10% per annum, so that transport now provides a large and rapidly growing component of total energy use.

More than two-thirds of energy consumption in the transport sector is for passenger transport, mainly road but also increasingly in air transport. Both passenger and freight transport experienced a significant growth in energy consumption during the study period, increasing by around 9% a year over the study period. In line with this increase, activity also saw a similar increase for both passenger and freight transport, although activity in passenger transport grew more rapidly than freight transport over the study period.

Road transport has been the main consumer of oil in passenger and freight transport and this mode is one of the fastest growing energy users in the transportation sector in Indonesia over the last decade. Road transport accounts for around 75% of total energy consumption in both passenger and freight transportation. The second largest share of energy consuming sector in this sector is air transport with 21%, followed by water and rail transport at approximately 3% and 0.1%, respectively. In terms of passenger kilometre turnover, road is the main mode of passenger transport in Indonesia, followed by air, rail and water transport. On the other hand, in freight transport, in terms of tonne-kilometre turnover, water leads, followed by road, air and rail transport mode.

The decomposition result concludes a different magnitude of structural effect and intensity effect to the overall changes of aggregate energy intensity in both passenger and freight transport. In passenger transport, the improvement of intensity effect was found to have significantly reduced the overall aggregate energy intensity, while the change in structural effect was found to have a relatively small reduction in the aggregate energy intensity. Overall, the decline in energy intensity in passenger transport is attributed to the intensity effect. On the other hand, in freight transport, the structural effect contributed directly to an increase in aggregate energy intensity, while the role of intensity effect was found to be insignificant in regard to the decline of aggregate energy intensity. The increase of structural effect in freight transport is mainly due to the structural changes from the less intensive transport sector to more intensive sectors. This result demonstrates that the use of the water and rail transport shrank, while road and air transports expanded. Road and water transport's share of energy consumption showed a stronger decline across other modes during the study period. In contrast, air transport showed an expanding trend compared to other modes.

Energy prices potentially become one of the most essential factors influencing energy intensity in the transportation sector. During the study period, there have been several increases in fuel price in Indonesia, which occurred in 2005, 2008, 2013 and 2014. These fuel price increases may promote the improvement of energy efficiency specifically in the road transport sector. Often, higher energy prices can induce improvements in energy efficiency, thereby lowering energy intensity (IEA 2017a). This study showed a period of declining energy intensity in both passenger and freight transport sector was associated with a period of high energy prices from 2005 to 2008, 2008 to 2014 and 2014 to 2016.

However, it is difficult to attribute the cause of energy price hikes only to the decline in energy intensity, particularly in the road transport sector. The changes in the intensity effect or energy efficiency improvements seems a more plausible explanation. Energy efficiency improvements for passenger transport may come from more efficient vehicles rather than just from fuel price hikes. One reason behind this is that the fuel price elasticity that flows on to highway transport in Indonesia is potentially low (Burke, Batsuuri & Yudhistira 2017). The price of fuel in Indonesia has been relatively cheap, thus an increase in the price might generate a small response. As fuel price is only one factor that drives expense, an increase in fuel prices might have quite a small impact on the decision of whether or not to drive. Various other costs that also influence this decision include the cost of vehicle maintenance and insurance; traffic congestion; tolls;

vehicle depreciation; time; stress of driving, and fatigue (Burke, Batsuuri & Yudhistira 2017). This suggests other factors such as technologies play an important role in reducing energy intensity in this sector.

Besides improvements in energy efficiency, the changes in the structure of transport is another key factor that can further reduce energy intensity in the transport sector. Lack of better alternatives of transport potentially become the reason behind the shift to more energy intensive transport. In terms of passenger-kilometre turnover, there has been a slight shift from rail mode towards road and air transport during the study period. This shift can be seen from the increase in the reliance on road and air transport passengers, while the use of rail transport mode has decreased considerably. Similarly, to passenger transport, the share of road and aviation in freight transport has also increased over the study period. While the share of water and rail in freight transport decreased considerably. Air transport has gained quite a significant share of freight transport, largely at the expense of water transport. These shifts towards less efficient transport in both passenger and freight transport showed a change towards a more inefficient form of transport.

As this study is conducted at the aggregate level, a caveat needs to be incorporated with the findings. There are several other factors which occur at the micro level, for instance differences in climate, topography and other variables related to the changes of energy consumption in transport that also have substantial influence on overall transport energy intensity that not yet been examined. Despite that this might looks as a limitation, the aim of this study is to discover and capture the factors affecting aggregate changes in both passenger and freight transport energy intensities, for which the setting and method employed in this study sufficed.

Chapter 6
Disparities of Energy Usage in Indonesia: An Empirical Analysis

6.1. Introduction

Indonesia is a vast country with many archipelagos and unevenly distributed natural and human resources, which leads to a significant economic disparity amongst regions (Akita & Lukman 1995; Hill, Resosudarmo & Vidyattama 2008; Tadjoeddin, Suharyo & Mishra 2001). Energy efficiency is closely associated with the level of a region's development where diverse developmental states establish different obstacles to energy conservation. Several countries have enacted policy measures to improve energy efficiency and energy intensity. According to Mishra and Smyth (2014), if there is a rapid energy convergence and relatively modest GDP growth rates, restraining energy use is achievable. Moreover, according to Mishra and Smyth (2014) decreases in disparities of energy use per capita amongst regions i.e. countries or provinces could be an evidence of effective policies. Thus, examining energy usage convergence and its relation to energy consumption changes to GDP growth are essential, as they are associated with sustainability in energy consumption and efficiency (Mishra & Smyth 2014).

Quantifying disparities in energy intensity is a method that employed in several studies to examine the energy intensity distribution across regions. Sun (2002) measured disparities in energy intensity across OECD countries by employing the mean deviation. Ezcurra (2007), examined the energy intensity convergence from 1971 to 2001 across 98 countries and concluded a convergence of energy intensity. Further, Alcantara and Duro (2004) investigated the inequality of energy intensity amongst OECD countries by applying the Theil index. Also employing the Theil index, Duro and Padilla (2011) examined the worldwide energy intensity inequality. At the country level, energy intensity is generally measured by decomposing the changes in energy intensity by employing the IDA method that decomposes the changes in the economic structure and the changes in the energy efficiency (Ang 2015).

Several studies have examined the relations of energy intensity convergence amongst countries. For instance, Liddle (2010) and Markandya, Pedroso-Galinato and

Streimikiene (2006); and across individual sectors amongst different countries, for example Miketa and Mulder (2005), and Mulder and de Groot (2007, 2012). The findings from these researches, overall contribute to the convergence concept such as the underdeveloped countries and sectors with poor energy intensity tend to follow the prominent countries with a better energy intensity level. Furthermore, by dividing his research into different cohorts of countries, Liddle (2010) found that energy intensity convergence occurred from 1971 to 2006 in sub-Saharan African countries, although the energy intensity for the other set of regions including Latin America, Middle East, the Caribbean and North African were not converging. Ultimately, according to Duro, Alcántara and Padilla (2010), in general, the evolution of a reduction in energy intensity disparities amongst regions represents a convergence to greater energy efficiency and conservation. Based on these studies, it is essential to rigorously examine the disparities across provinces in Indonesia with regard to the energy efficiency and to investigate the level, driving forces and trends of provincial disparities in energy usage. This research is expected to present the basis of provinces energy-saving potential and formulating a better energy-saving policy.

Understanding the distribution of energy usage in Indonesia also involves understanding the issues of inter-regional economic inequality in Indonesia. Since the reform era and decentralization process started in the 2000s, the western region (including Java-Bali and Sumatera) of Indonesia has been wealthier than the central (including Kalimantan and Sulawesi) and eastern regions (including Maluku, Nusa Tenggara and Papua). The economy of the western region of Indonesia grew faster through the 1990s, which also worsened the economic disparities across the western and eastern regions of Indonesia. Nevertheless, these illustrations of disparities in Indonesia have varied over time. Research into regional inequality in Indonesia have merged into a common model that inter-regional disparities in GDP remained constant during the 1980s, widened in the 1990s and began to converge in the period of the early 2000s. Many government policies lately have corroborated to expand and revitalize the eastern region of Indonesia (Bappenas 2017) to minimize income disparities. The early outcomes suggest that these discretions have stabilized, if not reduced, income disparities across these regions.

Some research has been conducted to measure income inequality in Indonesia (Akita 2002; Akita & Lukman 1995; Hill, Resosudarmo & Vidyattama 2008). However, no study has been done to measure energy usage inequality in the Indonesian case, specifically at the provincial level. It is expected that this study will contribute to the literature by measuring whether Indonesia's provinces energy usage disparities mirror those of economic inequality. It is clear that income inequality exists at the provincial level in Indonesia and it is assumed that there is a similar pattern of energy intensity disparities exists in Indonesia which wealthier provinces consuming more energy at the provincial level in Indonesia.

This study proposes to analyse the disparities of energy usage levels specifically in energy intensity amongst those provinces. The decrease in energy intensity disparities could correspond to the large decrease of Indonesia's energy intensity over time; this means there is a convergence to more efficient in energy usage (Duro, Alcántara & Padilla 2010). The relationship of Gross Regional Domestic Product (GRDP) and energy intensity is examined to explain the disparities amongst Indonesian provinces where the differences in energy intensity amongst relatively wealthy and poor provinces will be analysed further.

To bring down energy intensity efficiently, it is essential to recognize differences across regions in Indonesia's energy intensity. This study analysed Indonesia's 33 provinces and investigated the driving factors of energy intensity in 2010 and 2015. This study aims to examine the driving factors behind Indonesia’s energy intensity changes and the regional differences of socio-economic factors. By investigating the variations across provincial energy intensity distribution and measuring the driving factors, this study provides descriptions of the energy intensity difference of various provinces. There are obvious differences amongst regions in terms of structure, economy, technology and economic development. Thus, it is essential to observe the drivers that affect the energy intensity changes across provinces and the relative performance of energy efficiency among different provinces in order to develop a sound energy efficiency policy with differing local conditions.

This study will add to the literature in several ways. First, to the author’s knowledge, no other study has utilized the energy consumption inequality approach that is usually employed on an international cross-country level to the national cross-provincial scale; particularly in Indonesia’s case. Whereas a clear pattern relating to energy consumption to GDP can be viewed on the international scale, this study will see if the same relationship can be seen on a provincial level. Likewise, many prior studies of income inequality in Indonesia have not taken into account the environmental measure of development.

At the same time, there are many studies that investigate the factors affecting Indonesian energy consumption compared to economic measures. However, to the best of author’s knowledge, no studies have investigated energy usage disparities at the provincial level in Indonesia. Thus, this study adds to the literature by investigating whether income inequality patterns in provincial level are similar to energy usage disparities across the provincial level in Indonesia. This study begins this analysis with the following research questions: What is the extent of the disparity in energy use in provinces across Indonesia? Is energy usage greater in the wealthier provinces of Indonesia? Does the evidence show a convergence[16] of energy usage across provinces in Indonesia?

Disparities across regions in Indonesia is potentially a result of natural resources diversity, geographical condition, human resources, cultural and ethnicities, etc. This diversity may provide advantages on the one hand, but on the other hand, it may potentially become a source of social and political instability (Tadjoeddin, Suharyo & Mishra 2001). Therefore, providing comprehensive views of disparities issues across the provincial level in Indonesia is essential in order to formulate sound development planning and policies to reduce disparities problems across regions.

6.2. Literature Review

Many studies have measured the evidence of convergence amongst developed and developing countries. In the economics, the term of convergence is defined as a decrease of the large living standards gaps amongst countries over period of time, whereas the developing countries have improved their welfare and standards of living to catch-up with the developed countries (Maza & Villaverde 2008). One of the popular measures for economic welfare is per capita GDP, whereas many studies have examined the level of per capita income convergence amongst regions and countries, such as, Guetat and Serranito (2007); Reza and Zahra (2008); and Ranjbar et al. (2014).

In terms of economic studies in energy, the term of convergence is defined by measuring the energy intensity or energy productivity measured across countries and regions or across sectors within a country and region. Amongst the first to conduct a study of convergence in energy intensity were Mielnik and Goldemberg (2000). This study investigated a sample of 41 developing and developed countries from 1971 to 1992 and found an energy intensity convergence across the sample of countries. A further study on energy intensity convergence applied a different approach with employing the economic convergence growth studies. For instance, by employing an economic growth convergence approach during the period of 1992 to 2002, a study from Markandya, Pedroso-Galinato and Streimikiene (2006) concluded that several countries in the Eastern Europe converged to the levels of European Union average. Moreover, by

[16] The concept of convergence relates to the decrease of a development indicator dispersion, for instance, distribution of per-capita income across regions, whereas in this study is represented as per-capita energy consumption, total energy consumption and energy intensity distribution across provinces.

studying 98 countries and using a nonparametric distribution approach from 1971 to 2001, Ezcurra (2007) found an energy intensity convergence within the sample of the group of countries.

As several studies have investigated aggregate energy intensity/ productivity or across the economy wide, Miketa and Mulder (2005) examined the ISIC 2-digit level of ten manufacturing sectors in 56 developing and developed countries and concluded there was a decline in cross country differences, specifically in the less energy intensive industries. Besides Miketa and Mulder (2005), some studies focused on disaggregating the manufacturing sectors within the OECD countries. For instance, by employing the ISIC two-digit level data of 14 manufacturing sectors, Mulder and de Groot (2007), concluded that there was a converging trend between technological leader’s countries with lagging countries in terms of energy productivity. Furthermore, using the ISIC one-digit level of electricity intensity of OECD countries, Liddle (2009) found that electricity intensity in the industrial sector was converging to a bimodal, while the electricity intensity in the commercial sector converged to a bell-shaped distribution. Further, by applying two large data sets of 134 countries from 1990 to 2006 and 111 countries from 1971 to 2006, Liddle (2010) improved the Ezcurra's study by updating the data up to include 2006 to investigate regional differences. This study discovered that the sub-Saharan African countries converged between themselves, similar to the Eurasian countries and OECD that also showed a converging pattern; although the Middle East and North African and Latin America and the Caribbean countries were not converging. Furthermore, by employing Pesaran’s method, Le Pen and Sévi (2010) observed an energy intensity convergence across 97 countries from 1971 to 2003 and found the signs of convergence in OECD and Middle East countries but not in the full sample of 97 countries. Employing a similar technique to Liddle and Ezcurra, Herrerias (2012) employed transition matrix and the weighted distribution method to examine the pattern of convergence across developing countries. Moreover, employing electricity and energy consumption, Mohammadi and Ram (2012) concluded a more powerful worldwide electricity convergence than energy consumption convergence.

By examining 18 OECD countries’ data with 23 service sectors from 1980 to 2005, Mulder, de Groot and Pfeiffer (2014) discovered a shift to the service sector bringing a decrease in aggregate energy intensities, although the energy productivity level in the service sector was not similar with the manufacturing sector. A further study from Mishra and Smyth (2014) concluded energy consumption per capita converged in the ASEAN, which become an indication of club convergence over ASEAN regions. Similar techniques were also employed by Kim (2015), and Apergis and Christou (2015), who showed evidence of electricity intensity convergence, such as club convergence in electricity consumption per capita. (Wang, Yiming et al. 2014) identified three clubs of carbon emissions convergence within China. Similarly, Zhang, D and Broadstock (2016) also found three clubs of convergence in China in regard to energy intensity appearances. Both papers cautioned that there was a possibility of potentially misleading evidence that employs regional groupings (for example, dividing Chinese provinces into central, eastern and western) in describing energy intensity. Another study from Zhu, Y et al. (2016) investigated the Chinese energy markets; and found diesel and electricity markets were not integrated, but gasoline and coal markets had a pattern of integration.

The dynamics of energy intensity of GDP can vary greatly across countries and periods of time (Alcantara & Duro 2004). Some research has been done to examine the inequalities of energy usage evolution and economic indicators differences (Duro, Alcántara & Padilla 2010; Grossi & Mussini 2017; Lawrence, Liu & Yakovenko 2013; Pires Manso 2018; Sun 2002). Those studies showed that the dynamics of energy intensity potentially reflect the differences in the economic structure and technologies level in a country. Another method by Esteban (2000) analysed European regional productivity, whereas he developed a shift-share method. This method provides three separate variables i.e. the efficiency factor, linked to the specific energy consumption of a country in each sector; the structural carriable associated with the specific productive composition of a country and the allocative factor that associated with the extent of which a country is specialised in the sectors that employs more energy per unit of output than the average of all countries. This method has also been applied in Duro et al (2010) to explain energy intensity disparities across 16 OECD countries during 1995 to 2005.

Using OECD countries as a sample, Sun (2002) examined the differences in energy intensities from 1971 to 1998. By employing mean deviation, he found that the degree of difference of energy intensities amongst OECD countries decreasing over the study period. Similarly, by employing OECD countries data from 1980 to 2006, Duro, Alcántara and Padilla (2010) built a methodology to decompose inequality in per capita energy consumption into explanatory components, namely energy intensity, affluence and interaction. They concluded that the decrease of energy intensity differences amongst countries appeared the most significant role in the decrease of inequality in per capita energy consumption, while the affluence factor (differences in GDP level per capita) serves as the main factor causing the high inequalities in energy consumption.

A recent study of energy usage disparity was conducted by Grossi and Mussini (2017). They investigated the inequality of energy intensity amongst EU-28 countries from 2007 to 2012 using the Zenga index. To determine the unequal components of the energy intensity from the bottom to the top of distributions, their research broke down the inequality of energy intensity into three effects: final energy intensity, energy transformation and their interactions in energy intensity inequality. They concluded that the final energy intensity performs a major role in explaining energy intensity inequality distribution. Another study was conducted by Pires Manso (2018), where they analyzed energy consumption inequality in European Union countries (EU-15) from 2005 to 2014 employing the Gini Coefficient, Atkinson Inequality Index, Generalized Entropy Indices and Lorenz Curve. By grouping the EU-15 into four clusters: Mediterranean, Nordic, Continental and Anglo-Saxon, they found that there was an inwardly small shift in the Lorenz Curves and the Gini Index has decreased around 2% from 2005 to 2014; indicating a decrease in inequality. A similar finding of a decrease in energy consumption inequality also concluded by Lawrence, Liu and Yakovenko (2013) for world energy consumption per capita from 1980 to 2010. By employing the U.S. Energy Information Administration (EIA) data, they discovered an upward shift in Lorenz curves and the Gini Index decreased significantly during this period.

Against the background of those above research into inequality measures to energy usage, this study primarily adds to the existing literature in providing measurements of the variances of energy usage across regions. Instead of investigating the disparities of energy usage at a worldwide level, this study focuses its investigation on a national level across 33 provinces in Indonesia. Thus, the nation-state level analysis in this study will be more applicable, as the investigations are constructed on the characteristic of the specific region, whereas it is expected to shed light on the particular issues induced by the changes of economic structure and the changes within industry in various provinces.

6.3. Methodology

Tools for measuring income inequality to environmental and energy indicators have been discussed in recent studies. They show that the Atkinson and Theil indices (Duro 2012), the Gini index (Duro 2013; Mussini & Grossi 2015) and the Lorenz curve (Groot 2010) can be employed to analyse inequality in the distribution of environmental and energy indicators. Moreover, many researchers have employed traditional inequality measures to investigate the distributions of energy economic indicators (Duro, Alcántara & Padilla 2010; Ezcurra 2007; Grossi & Mussini 2017; Lawrence, Liu & Yakovenko 2013; Sun 2002). One of the primary features of these indexes is that every measure set different weights to the variable distribution thus, in some cases, the yield may potentially differ over time (Duro 2012). Thus, in order to provide a more robust analysis and prevent biased conclusions, this study employs several indicators that are distinct in their observations. Amongst the indicators employed in this study include the Gini Coefficient (Ceriani & Verme 2012), Theil Index (Raj & Koerts 1992), Atkinson Index (Atkinson 1970), and the coefficient of variation (Abdi 2010; Brown 1998). The purpose of employing various measures of inequality indices is to gain firm conclusions about the disparities results. As comprehensive assessments of convergence cannot be drawn from specific instruments but rather a range of measurements.

6.3.1. Gini Index (G)

The Gini Index (Gini, 1912) is an important tool to comprehensively analyze disparities in the distribution of income. This index weights further changes in the observations located around the mean. It is generally used with the Lorenz Curve when measuring the level of income distribution equitableness, where the coefficient is generally applied to estimated gaps of income across regions and individual, for instance, the level of inequality. A Gini Index is measured between 0 to 1 (or 100%), where zero coefficient asserts no disparities and coefficient of 1 denotes high disparities.

In this study, the Gini Index is used to investigate the disparities of the distribution of energy usage that includes total energy Consumption per province, energy consumption per capita per province, and energy intensity per province. The Gini Index in this study is employed to compare energy usage distribution from 2010 to 2015; thus, it is feasible to observe if disparities are decreasing or increasing.

Following the aforementioned principles, the formula of Gini Index to analyze regional energy usage disparities can be expressed as:

$$G = \frac{1}{2\mu} \sum_{i=1}^{n} \sum_{j=1}^{n} p_i p_j \left| e_i - e_j \right| \qquad (1)$$

where:

e_i and e_j denote the energy usage[17] of provinces *i* and *j*, respectively, p_i, p_j and denote the relative weights of provinces *i* and *j*, respectively, *n* represents the number of provinces and μ denotes the average energy usage of all provinces.

6.3.2. Theil Index (T)

Similarly, to the Gini Index, the Theil index (Theil, 1967) is also applied to analyse energy usage disparities across provinces in Indonesia between 2010 and 2015. This index ranges from 0 (no disparities) to 1 (maximum disparities). The Theil family of inequality indexes gives different measures precisely in the way observations are treated, from the most "progressive" measures—that is the ones which are more sensitive to changes in the lower part of the distribution (such as T (0) — to the less sensitive.

$$T(\beta) = \frac{1}{\beta(\beta-1)} \sum_{j=1}^{n} p_i \left[\left(\frac{e_i}{\mu} \right)^{\beta} - 1 \right] \quad (2)$$

The β parameter measures the sensitivity of the distributional changes, where the smaller β value indicates the more sensitive the index to the bottom ranking of observations.

6.3.3. Atkinson Index (A)

The Atkinson index (Atkinson, 1970) quantifies disparities in energy usage with ranging from 0 (no aversion to disparities) to infinite (high aversion to disparities).

$$A(\varepsilon) = 1 - \left[\sum_{i=1}^{n} p_i \left(\frac{e_i}{\mu} \right)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}} \qquad \varepsilon \neq 1 \quad (3)$$

where:

[17] In this study, Energy Usage is defined as Total Energy Consumption per Province, Energy Consumption per capita per province, and Energy Intensity per Province.

ε denotes as the degree of social inequality aversion, where $\varepsilon = 0$ means there is no aversion to inequality and $\varepsilon = \infty$ means the index only captures the poorest observation.

6.3.4. Coefficient of Variation (CV)

Coefficient of Variation is a ratio between standard deviation to the mean, which is generally denoted as a percentage. Distributions of energy usage from 2000 to 2015 is also measured using Coefficient of Variance, whereas CV > 1 (more than 1) is assessed as high-variance (high disparities); and CV < 1 (less than 1) is regarded as low-variance (low disparities). This index associated with a statistical conceptualization of inequality, is neutral in this regard, and treats the different observations uniformly, regardless of their location on the distribution.

$$CV_\omega = \frac{\sigma_\omega}{\mu} \tag{4}$$

σ_ω is the weighted standard deviation.

6.3.5. Log Mean Divisia Index

In addition to the previous energy usage inequality indices, this study also provides its analysis by examining the driving forces of provincial energy intensity trend by employing the LMDI method during period 2010 and 2015 (discussion of the formula of LMDI-II Multiplicative is provided in Chapter 2).

6.4. Dataset

This study compiles energy and economic data for 33 Indonesia provinces. The study compares different types of energy usage data, including energy consumption, energy consumption per capita and energy intensity. Final energy consumption, population and GDP at a provincial level will be derived from Indonesia's statistics bureau (BPS), Ministry of Energy and Mineral Resources (MEMR), National Gas Company (PGN) and National Fuel Company (PERTAMINA).

The Data in the study was calculated by BAPPENAS (Indonesia’s National Development Planning Agency) and consolidated with other line ministries and related stakeholders. Energy Use Data contains the following data: 1) Sales of petroleum fuel, electricity, natural gas, LPG, coal briquettes, and amount of electricity customers; 2) Activity data; 3) Intensity of energy use in household, commercial, industrial, and transportation sectors; 4) Balance sheet between energy use and energy supply. Energy use data includes energy use calculation in household, industrial, commercial, transportation and other sectors.

Table 6. 1. Dataset used in this Research and its Source

No.	Data (Yearly)	National	Provincial	Source
1.	Indonesian Statistics	√	√	BPS
2.	Provincial Statistics		√	BPS
3.	Energy Statistics of Indonesia	√		ESDM
4.	Electricity Statistics	√	√	ESDM
5.	National Economic Survey (SUSENAS)	√	√	BPS
6.	Industrial Survey Statistics	√	√	BPS
7.	GRDP Province based on Sector	√	√	BPS
8.	Data of Fuel and Gasoline Sales by PERTAMINA		√	PERTAMINA

6.5. Analysis

As an archipelagic country Indonesia has geographically around 13,000 islands. According to Hill, Resosudarmo and Vidyattama (2008), the diversity of Indonesia's population, location of economic activities and natural resources, has placed Indonesia as one of the most geographically diverse countries. In 2018, Indonesia was comprised of 34 provinces and around 514 districts and cities (Kabupaten/ Kota). The large variations of Indonesia's geography are not only in its geographical conditions and natural reserves but also in its energy consumption patterns and population density. In addition, there is an obvious difference in economic development amongst Indonesia's rural and urban areas, leading to discrepancies in energy consumption and economic production. As a result, a different structure has been established in consuming energy resources in Indonesia, where most of the energy is used in the cities.

6.5.1. Descriptive analysis

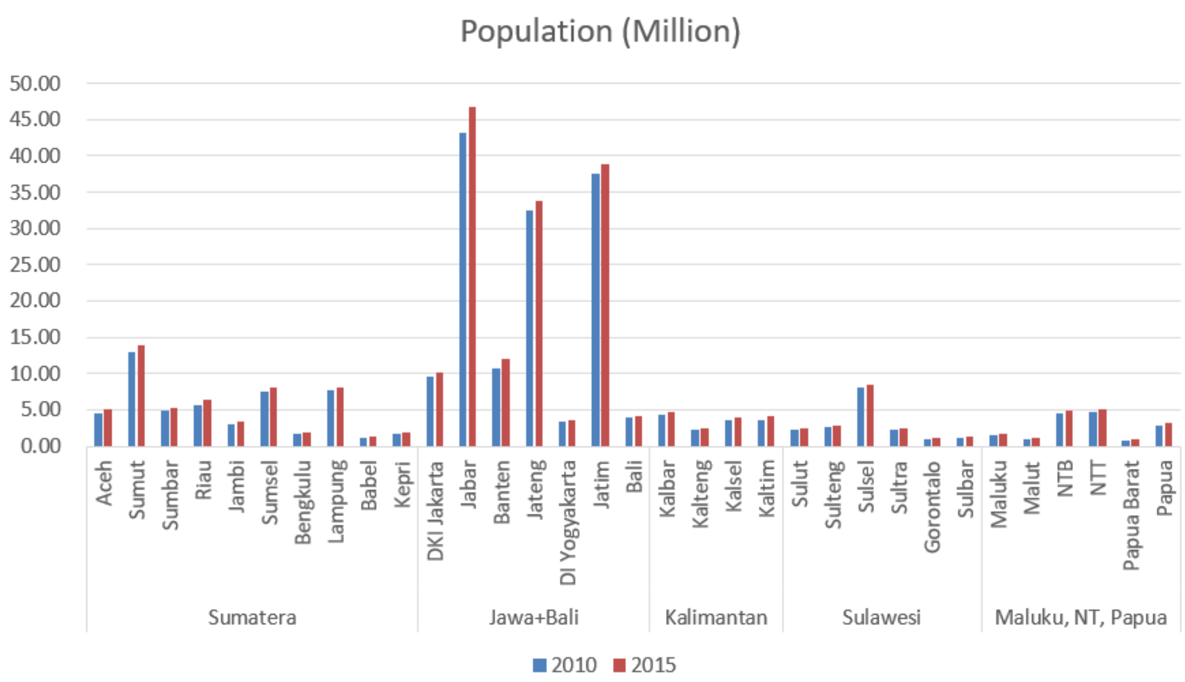
Several variables analyzed in this study are population, GRDP, GRDP per capita, energy consumption, energy consumption per capita, and energy intensity. Following Hill (1990), this study classified provinces in Indonesia into five major regions/ islands:

1. Java+Bali region includes seven provinces: DKI Jakarta, Jabar, Banten, Jateng, DI Yogyakarta, Jatim and Bali;
2. Sumatera region includes ten provinces: Aceh, Sumut, Sumbar, Riau, Jambi, Sumsel, Bengkulu, Lampung, Babel and Kepri;
3. Kalimantan region includes four provinces: Kalbar, Kalteng, Kalsel and Kaltim;
4. Sulawesi region includes six provinces: Sulut, Sulteng, Sulsel, Sultra, Gorontalo and Sulbar;
5. Maluku, NT and Papua region include six provinces: Maluku, Malut, NTB, NTT, Papua Barat and Papua.

6.5.1.1. Population

Based Figure 6.1, it can be seen that Indonesia's population are mostly concentrated on the western Region, including Java+Bali and the Sumatra islands (accounting for around 80% of total Indonesia's population), while the eastern region including Kalimantan, Sulawesi, Maluku, Nusa Tenggara and Papua only accounted for around 20 per cent of the total population. The highest population is in Jabar (around 43 million in 2010 and 47 million in 2015) followed by Jatim and Jateng. These three provinces of Jabar, Jatim and Jateng cover almost a half of the total of Indonesian population in 2015 at around 119 million, whereas the total population of Indonesia in 2015 was approximately 255 million.

Figure 6. 1. Indonesia Population by Provinces and Islands



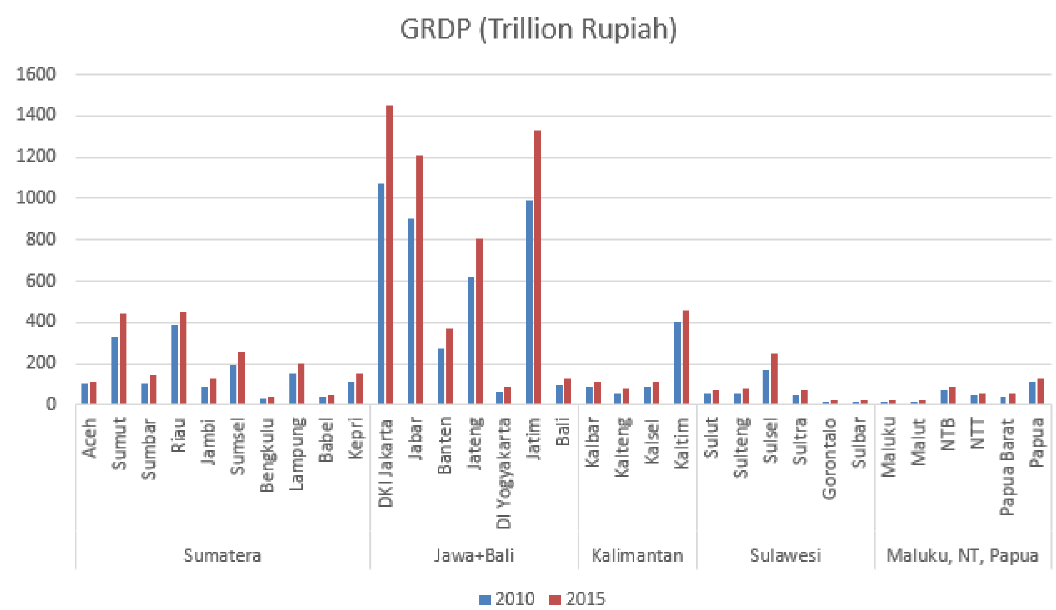
On the contrary, the smallest number of populations is residing in Papua Barat, which only covered for less than 1 million in 2015. Based on Kuncoro, M (2013), the high-density population in Java and Sumatera have contributed positively to more than 90 per cent of all Indonesia's manufacturing employment, whereas other regions only played a minor role.

6.5.1.2. Gross Regional Domestic Product (GRDP)

This study employs Gross Regional Domestic Product (GRDP) as a parameter to represent regional income, where GRDP describes as the total value added generated by the entire economy per province for the whole year.

From Figure 6.2, it can be seen that the GRDP distribution across provinces in 2010 and 2015 shows a high level of inequality, whereas the largest share of GRDP is concentrated in Jawa+Bali and Sumatera Regions. The GRDP share from these regions in 2010 and 2015 reached approximately 81% of the national economy, where around 58% contributed by Jawa+Bali and approximately 23% came from Sumatera. Eastern Region (including Sulawesi, Nusa Tenggara, Maluku and Papua) which only contributes around 20% of the national income. DKI Jakarta contributes the highest GRDP share, followed by Jatim and Jabar, whilst both Malut and Gorontalo contribute the smallest share. Since 2000, Indonesia's economic activities have been centralized in Java and Sumatera Island, where the predominant role is heavily driven by the industrial sector (Kuncoro, A 2009).

Figure 6. 2. Indonesia GDRP by Province and Island



The rapid economic development emerges that economic activities, particularly establishment of manufacturing industry tend to concentrate in specific regions, like around the capital city of Jakarta and other large capital provinces like Jabar, Jatim, Jateng, Sumsel and Sumut. The tendency to centralize the development of industry manufactures close to major capital province is a common process, since these cities provide access to economic resources, markets, bureaucracy and become the centre of economic growth (Widodo 2014). The more advanced infrastructure and adequate facilities attract the manufacturers to locate their firms near to these major capital provinces. Thus, the benefits of advanced industrial developments are still enjoyed by certain regions.

6.5.1.3. GRDP Per Capita

To measure a region's prosperity, this study employs GRDP province per capita which divides total GRDP per province to the province's population. The higher the GRDP per capita, the higher the region's wealth. In other words, the value of GRDP per capita represents the province's wealth level. Income might affect energy intensity by means of several channels. For instance, increasing income can persuade people to conduct more energy-consuming behavior and thus lower the energy intensity level. However, it could also make people more conscious to the limited resources of the environment and employ energy-saving technology.

Figure 6. 3. Indonesia GDRP per Capita by Province and Island

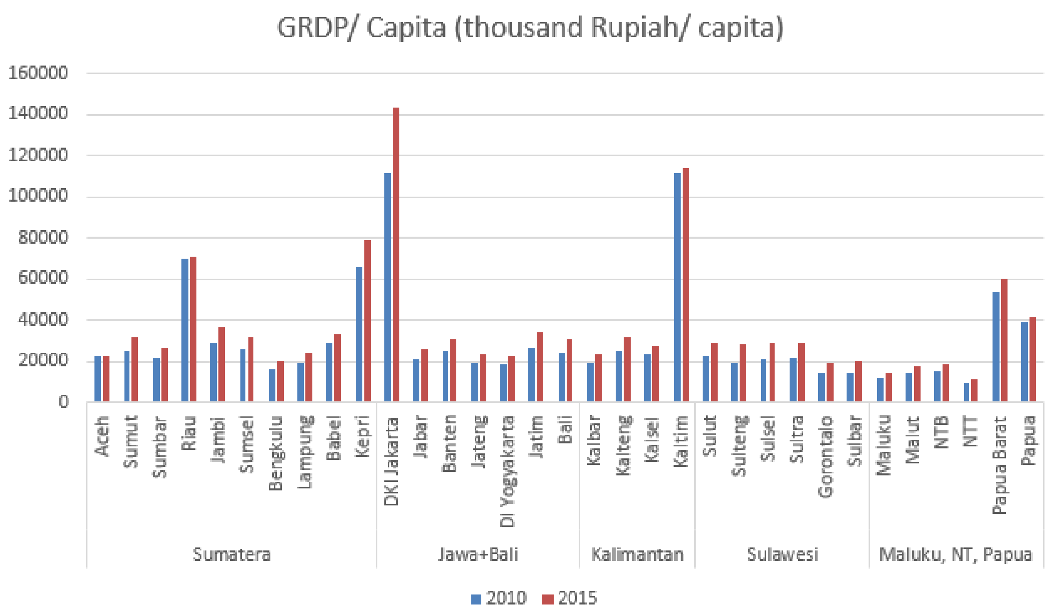


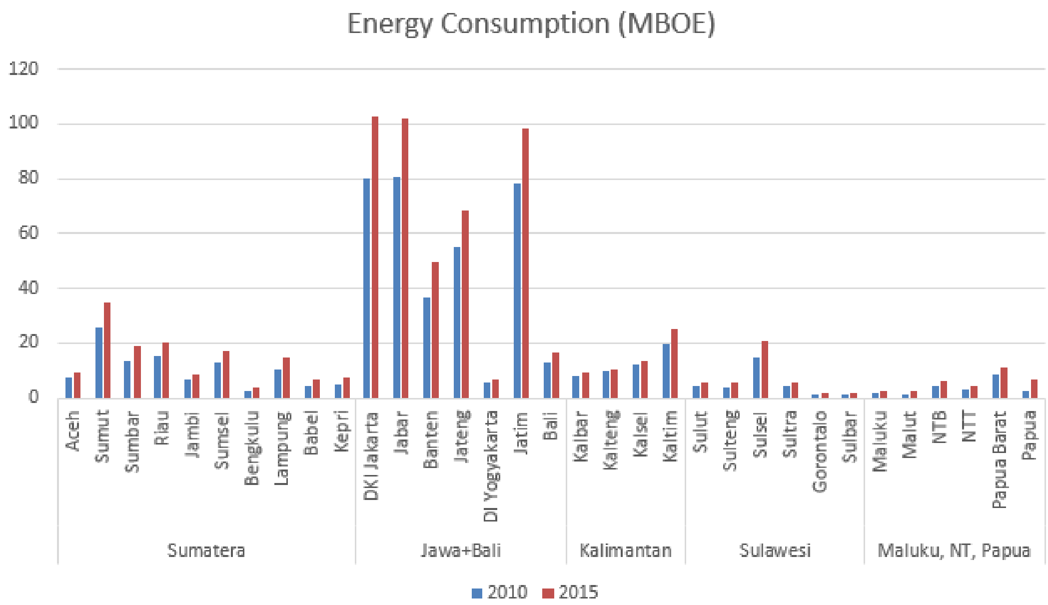
Figure 6.3 shows that the economic disparities across provinces are quite high because some provinces have GRDP per capita much larger than the national average. The highest GRDP per Capita in 2015 was DKI Jakarta, followed with Kaltim, Riau and Kepulauan Riau (Kepri), while the lowest GRDP was in NTT and Maluku. DKI Jakarta has the highest GRDP per capita since it is the capital city of Indonesia and is the centre of industry, services and trade. Additionally, the abundance of natural resources, such as oil and gas, mining materials, and forests provides Kaltim with the second largest GRDP per capita across all provinces in Indonesia. Following Kaltim, the Riau and Kepri also have a quite high GRDP per capita due to the existence of Batam city as a centre of industrial activity and international trade. On the other hand, some provinces have a lack of either natural resources or human resources that made their GRDP per capita much below the national average, for instance, NTT and Maluku.

The level of economic activity in Jawa+Bali and Sumatera regions are more advanced than other regions, it can be seen from the level of income per provinces in these regions. Economic development in Jawa+Bali and Sumatera are mostly dominated by the secondary and tertiary sector such as processing industries, manufacturing and services. On the other hand, the economic activity development of the outside Jawa+Bali and Sumatra concentrate more on the primary sector, that is agriculture and mining, whereas the growth of the secondary and tertiary sector is relatively slow.

6.5.1.4. Energy Consumption

The distribution of inter-provincial energy consumption in Indonesia also shows high disparities. Based on Figure 6.4, the total energy consumption per provinces from 2010 to 2015 indicates that energy consumption mostly concentrates in Jawa+Bali and Sumatera Regions. The highest energy consumption is in DKI Jakarta, followed by Jabar and Jatim. In 2015, the energy consumption in Jawa+Bali regions consumed almost one-third of total energy consumption in Indonesia at around 61.74%, whereas DKI Jakarta, Jabar and Jatim consumed 14.26%, 14.2% and 13.7%, respectively. While on the other hand, in the same period, the lowest energy consumption lies in the three provinces of Gorontalo, Sulbar and Maluku which only consumed for less than 1% of total energy consumption in Indonesia at approximately 0.22%, 0.29% and 0.38%, respectively.

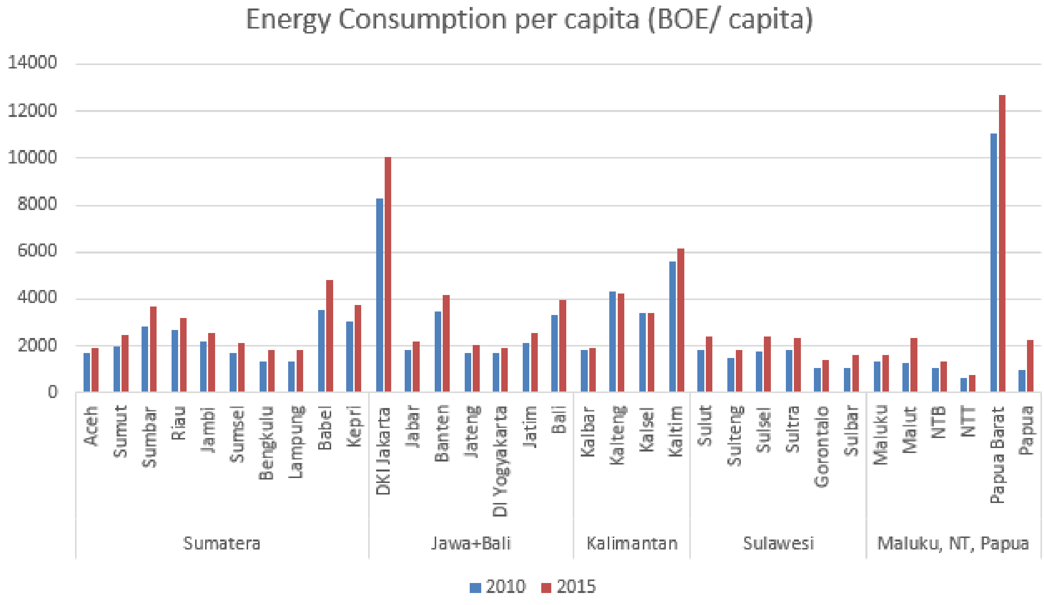
Figure 6. 4. Energy Consumption (MBOE) by Province and Island



6.5.1.5. Energy Consumption per Capita

Disparities in energy use between regions can also be illustrated by province energy consumption per capita. Figure 6.5 shows that the disparities of per capita energy consumption across provinces in Indonesia are quite high due to some provinces having more energy consumption compared to the national average. Employing data for 2010 and 2015 in 33 provinces, the largest energy consumption per capita is in DKI Jakarta and followed by Papua Barat, while the least energy consumption per capita is in NTT and Maluku.

Figure 6. 5. Energy Consumption per Capita



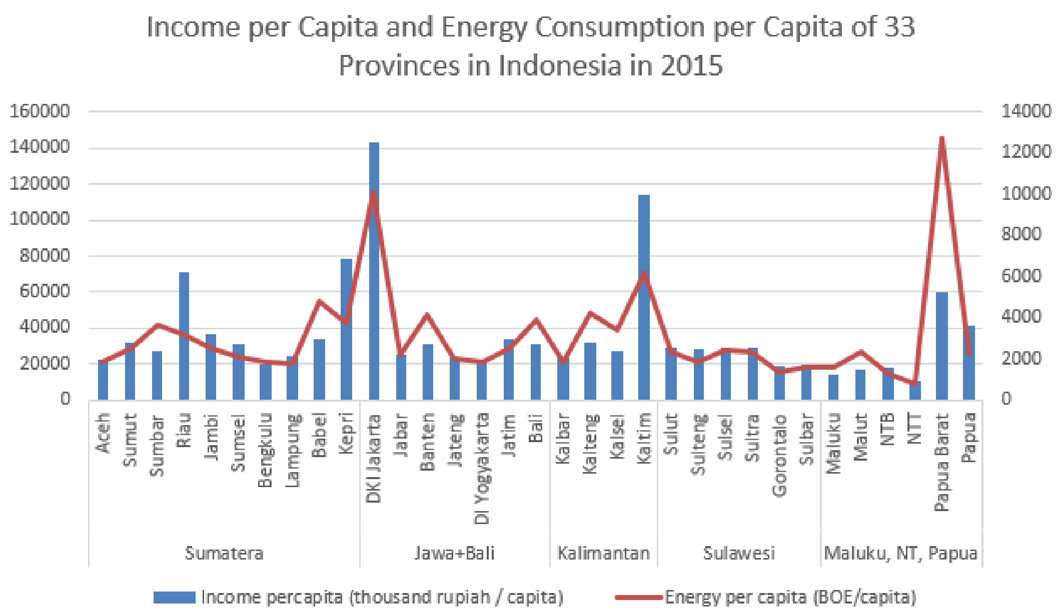
The high energy consumption per capita in DKI Jakarta potentially due to DKI Jakarta being the capital city and having many industries and establishments operating their businesses there. This boosts its energy consumption per capita. Indeed, Papua Barat is a resource-rich province, which is known as a major oil producer and having nature-based tourism activities (for example, the Raja Ampat Islands). Despite Papua Barat's wealth of natural resources, it has a sparse population. This situation potentially be the reason that makes the energy consumption per capita in Papua Barat disproportionately large. There are several mining companies located in Papua Barat, for instance PT Freeport Indonesia. This mining company is one of the largest mining companies in Indonesia mine gold and copper. This company contributes more than 50% of Papua's economy. In addition, British Petroleum contributes around 42 per cent of West Papua's GRDP (via the LPG project in Bintuni).

One of the essential problems related to energy in Indonesia is unequal energy consumption and distribution across the country (Alami et al. 2017). The geographical location of energy resources that is far from the users is one of the barriers in distributing energy equally across regions (Nugroho 2015). Thus, adequate infrastructure is essential to utilize energy sources efficiently and effectively. For instance, the difficulty of linking power grids from Java to the outer islands, or the far distant of gas pipelines from Sumatera to Java or from East Kalimantan to Java. Inadequate of energy infrastructures led to lower energy consumption per capita in several provinces in eastern Indonesia like NTT.

6.5.1.6. The Income per Capita and Energy Consumption per Capita

Figure 6.6 shows the amount of energy consumption per capita in Jawa+Bali and Sumatra region are consistent with the level of economic activity in these regions (western Indonesia) which is far more economically advanced than those outside of Jawa+Bali and Sumatera (especially eastern Indonesia). The high income per capita in DKI Jakarta was also followed with the high energy consumption per capita. As with DKI Jakarta, several other provinces also showed a similar trend. However, in Papua Barat, the high income per capita was followed with a far higher energy consumption per capita compared to other provinces.

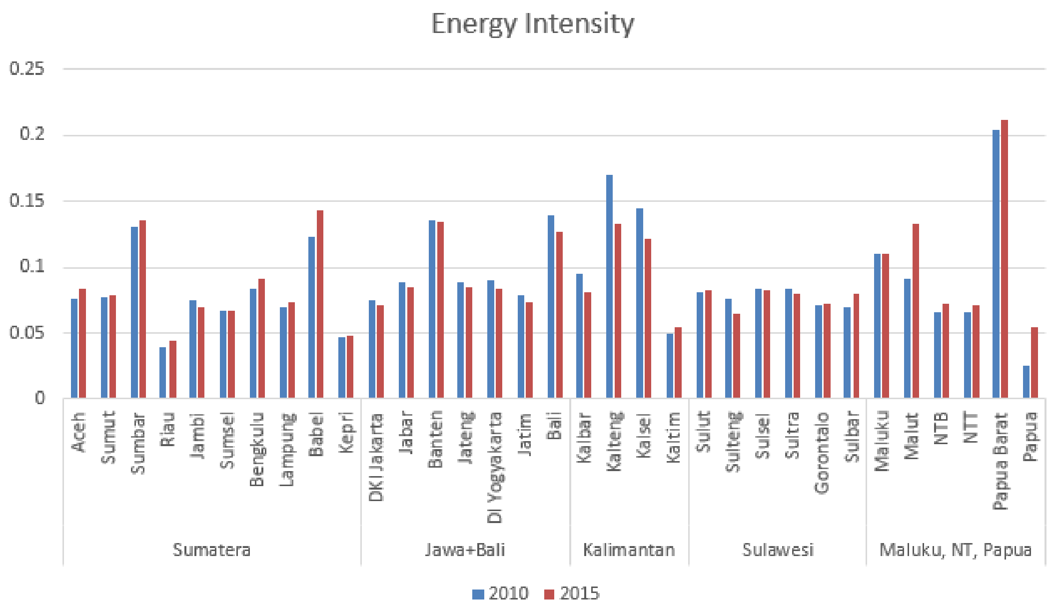
Figure 6. 6. The Income per Capita and Energy Consumption per Capita by Province in 2015



6.5.1.7. Energy Intensity

In order to measure the level of energy efficiency by regions, this study proposes to use the energy intensity ratio. This ratio measures the level of provincial energy intensity by dividing total energy consumption per province to total GRDP per province. The disparity and improvement of energy intensity by province can be seen from Figure 6.7. The lower the value of energy intensity by province overtime represents that the province has improved (decreased) its energy efficiency. While, on the other hand, the increasing energy intensity by province indicates a deterioration (increase) in energy efficiency level.

Figure 6. 7. Indonesia Energy Intensity by Province and Island



Energy intensity across provinces in Indonesia are diverse. The gap between provinces with low energy intensity and high energy intensity is quite substantial. From 2010 to 2015, the five lowest energy intensity provinces were Papua, Riau, Kepri, Kaltim and Sulteng. On the other hand, the five provinces with the highest energy intensity are Papua Barat, Kalteng, Babel, Kalsel and Sumbar.

Table 6.2 demonstrates the level of energy intensity changes across 33 provinces between 2010 to 2015, where the ratio tends to be varied across provinces. It can be seen that there some provinces improved (decreased) their energy intensity over time, such as DKI Jakarta, Jabar, Jateng, DI Yogyakarta, Jatim, Bali, etc., while some other provinces have worsened (increased) its energy intensity on this period, including Papua regions and most of the eastern Indonesia's region.

Table 6. 2. Provincial Energy Intensity Changes from 2010 to 2015

Regions	Provinces	Energy intensity change (%)	Regions	Provinces	Energy intensity change (%)
Sumatera	Aceh	11.3	**Jawa+Bali**	DKI Jakarta	–5.2
	Sumut	2.5		Jabar	–4.6
	Sumbar	4.4		Banten	–0.7
	Riau	15.3		Jateng	–4.4
	Jambi	–7.5		DI Yogyakarta	–7.4
	Sumsel	1.2		Jatim	–6.6
	Bengkulu	10.0		Bali	–9.5
	Lampung	6.5	**Kalimantan**	Kalbar	–14.2
	Babel	16.0		Kalteng	–21.2
	Kepri	2.4		Kalsel	–15.3
Sulawesi	Sulut	1.3		Kaltim	8.9
	Sulteng	–16.2	**Maluku, NT, Papua**	Maluku	0.1
	Sulsel	–1.5		Malut	46.9
	Sultra	–4.6		NTB	9.1
	Gorontalo	3.3		NTT	8.7
	Sulbar	15.1		Papua Barat	3.6
Aggregate EI changes		**16.3**		Papua	0.1

From 2010 to 2015, the aggregate energy intensity across provinces in Indonesia increased by around 16.3% (see Table 6.2). For the accumulative rate of decline of provincial energy intensity from 2010 to 2015, the three greatest decreases in provincial energy intensity occurred in Kalteng, Kalsel, and Kalbar at around –21.2%, –15.3%, and –14.2%, respectively. On the contrary, the three greatest increases in provincial energy intensity occurred in Malut, Babel and Riau at approximately 46.9%, 16.0% and 15.3%, respectively. During this period, all of the provinces in Java-Bali region experienced a decrease in energy intensity, although the level of energy intensity decrease was not as substantial as Kalbar, Kalteng and Kalsel. While most of the provinces in Sumatera region and Maluku, NT, Papua region had an increase in its provincial energy intensity.

6.5.2. Indices

Many studies have measured the possible existence of convergence in cross-country energy intensity levels (Ezcurra 2007; Goldemberg 1996; Markandya, Pedroso-Galinato & Streimikiene 2006; Mielnik & Goldemberg 2000; Nilsson 1993). However, there are limited number of studies that examine a cross-province convergence within a country. Hence, this study contributes to the literature by examining disparities across 33 provinces in Indonesia over the period 2010 and 2015.

To comprehensively analyze regions' disparities in energy usage, this study began the analysis of energy usage disparities by examining the disparities of energy usage across the 33 provinces. Thus, it calculates different types of inequality measures as follows.

Table 6. 3. Indices Result

Measure	Year	Total Energy Consumption per Province	Energy Consumption per capita per Province	Energy Intensity per Province
Gini	**2010**	0.59	0.36	0.21
	2015	0.58	0.33	0.19
Theil	**2010**	0.65	0.24	0.08
	2015	0.61	0.21	0.06
Atkinson	**2010**	0.29	0.11	0.04
	2015	0.27	0.09	0.03
Coefficient Variance	**2010**	1.34	0.82	0.41
	2015	1.31	0.76	0.38

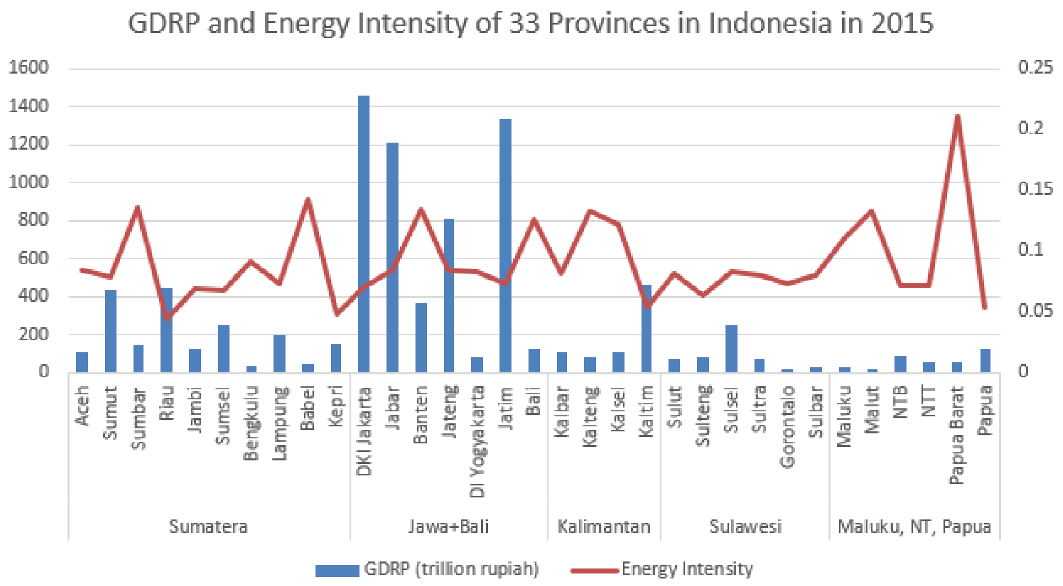
Table 6.3 shows the four different inequality measures: Gini Coefficient, Theil Index, Atkinson Index and Coefficient of Variance from 2010 to 2015 across 33 provinces in Indonesia. All the inequality measures in this table show that disparities in energy usage decreased from 2010 to 2015. For instance, between 2010 and 2015, the level of disparity in energy intensity per province decreased in all of indices of Gini Coefficient, Theil index, Atkinson index and Coefficient of Variance, which decreased from approximately 0.21; 0.08; 0.04; 0.41 to around 0.19; 0.06; 0.03; 0.38, respectively. Besides the decrease of disparity index in energy intensity, the other energy usage disparity indices (including energy consumption and energy consumption per capita) also showed similar results. Thus, in spite of the different measurement methods, the results of these indices represented good consistency and mutually verified of the validity of the methods computed. But, the choice of selecting one measure over another is not a key point in the discussion of energy usage distribution in this paper.

One of the driving factors behind the decreasing trend of energy usage disparities in Indonesia is the implementation of energy conservation law. The Indonesian Government enacted the energy conservation law in 2007 (Undang-Undang 2007) and the related regulations were also enacted since then. The enforcement of the energy conservation act has potentially increased public awareness for preserving energy usage over the whole nation and setback the rising trend in the regional disparities. Beside this Law, the Indonesian government has also introduced several other policies, for instance, since 2005, the Indonesian Government has reduced the fossil fuel subsidies allocation in the state budget gradually (ADB 2015). Furthermore, since 2011 the government has also vigorously addressed the issue of Climate Change by implementing the National Action Plan for Greenhouse Gas Emissions Reduction. These policies have been enforced at the regional level, which necessarily encouraged energy efficiency efforts in each province in Indonesia. Therefore, those measures have become the potential reasons behind the continual decrease of energy intensity in Indonesia, which also potentially narrowed the disparities of provincial energy intensity across provinces in Indonesia.

6.5.3. Spatial and Temporal Changes of Energy Usage of 33 Provinces

Based on Figure 6.8, in 2015, the top nine provinces with the most intensive energy intensity were Papua Barat, Kalteng, Babel, Malut, Maluku, Kalsel, Bali, Sumbar and Banten. On the contrary, the five provinces with the least energy intensity were Papua, Kepri, Riau, Kaltim, DKI Jakarta and Sumsel. The industrial structure potentially become the main factor behind the big difference in energy intensity amongst these provinces in Indonesia. The underdeveloped provinces concentrate on the highly energy intensive industries such as the manufacturing industry or mining industry, which employs more energy but relatively less in supporting its economic output. On the other hand, the developed provinces are more concentrated on the less energy-intensive industries like high-tech or services industry that utilize less energy but relatively contribute more to economic output.

Figure 6. 8. The Total of Indonesia GRDP and Energy Intensity by Provinces in 2015



6.5.3.1. Energy Intensity and GRDP

In order to provide a further description of energy intensity and value-added performance of the 33 provinces, this section provides an illustration of the changes of energy intensity and GRDP performance for every province in Indonesia from 2010 to 2015. From Figure 6.9a[18] and 6.9b,[19] there is an obvious spatial difference in the relationship between GRDP and energy intensity across 33 provinces in Indonesia. In this diagram, the red circle represents the total population in 2010, while the blue circle represents the total population in 2015. In this diagram, it can be found that Banten, Sulsel, Jateng, Jabar and Sumbar are in the Quadrant I with high energy intensity level and high GRDP compared to other provinces averagely, where these provinces indicated a slight reduction in energy intensity during 2010 and 2015. While, on the other hand, DKI Jakarta (the capital city), Jatim, Kaltim, Riau, Sumut, Lampung, Sumsel, Kepri and Papua are in Quadrant II. This quadrant represents the most ideal quadrant since it indicates a lower energy intensity and high economic output (GRDP) compare to the other average provinces. The worst quadrant is in quadrant IV, where this quadrant shows a high energy intensity and low economic output. Some of the provinces that are in this quadrant are Papua Barat, Kalteng, Kalsel, Maluku, Malut and Babel. The rest of the provinces are in Quadrant III with low energy intensity and low economic output:

[18] Description of energy intensity and value added of 33 provinces during 2010 to 2015.
[19] A clearer picture of energy intensity and value added of 33 provinces during 2010 to 2015.

Sultra, Sulut, Sulteng, NTT, NTB, Jambi, Papua, Bengkulu, Gorontalo and Aceh. Most of the provinces located in Quadrant III are considered less developed areas, where the economic development and energy consumption are still at relatively low levels.

The Sumatera and Java islands are more developed compared to other regions in eastern Indonesia. Many developments in Indonesia have been started and centralized in Java where the industrial production mostly focused on this island. Therefore, this island serves various benefits, particularly the presence of various production factors and better infrastructure.

The high level of energy intensity in Java potentially due to its vast development in industrial base. Java is one of the most prominent industrial bases in Indonesia and is one of the country's biggest trade and ports. From the 1980s, Java, specifically Jabar, Banten, Jatim and Jateng, have undertaken a significant structural adjustment process aiming at strengthening pillar industry, specifically promoting the manufacturing and tertiary industries. In the beginning of twentieth century, the other areas' industries were also developed very significantly including Sumut, Riau, Lampung, Sulsel, Sulteng, Sulut, Kalsel, Kaltim, Malut and Papua Barat.

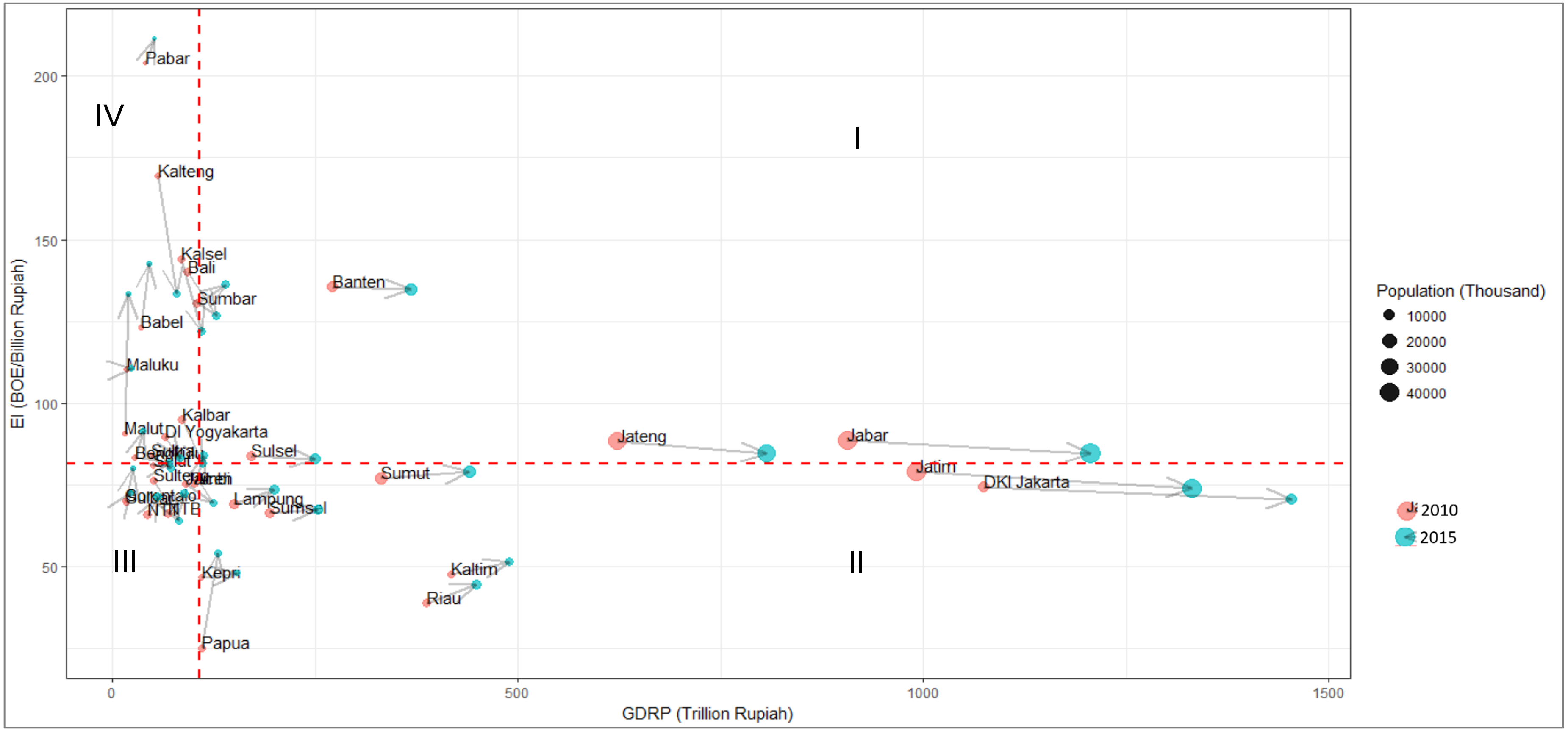
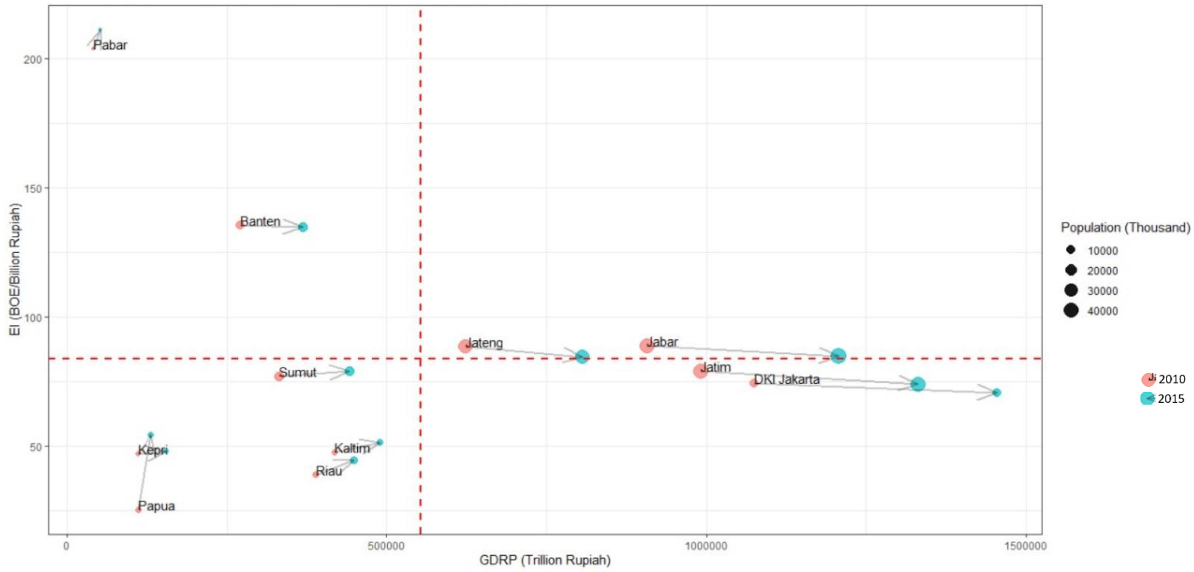
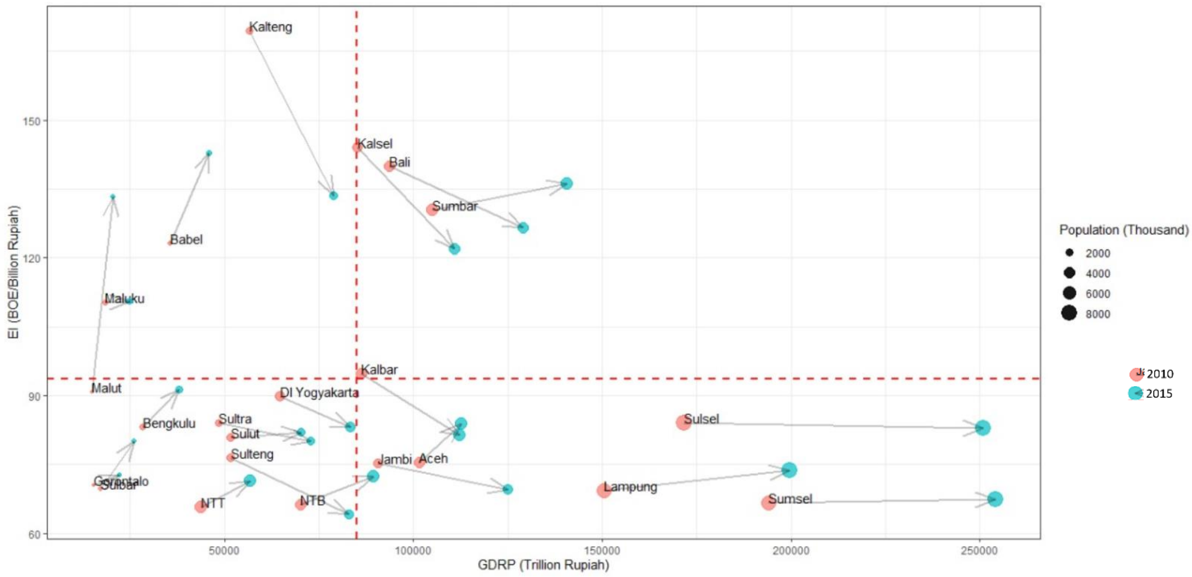


Figure 6. 9a. The changing of energy intensity and GRDP during 2010 and 2015

Figure 6.9b. The changing of energy intensity and GRDP during 2010 and 2015





6.5.4. Provincial Decomposition Analysis from 2010 to 2015

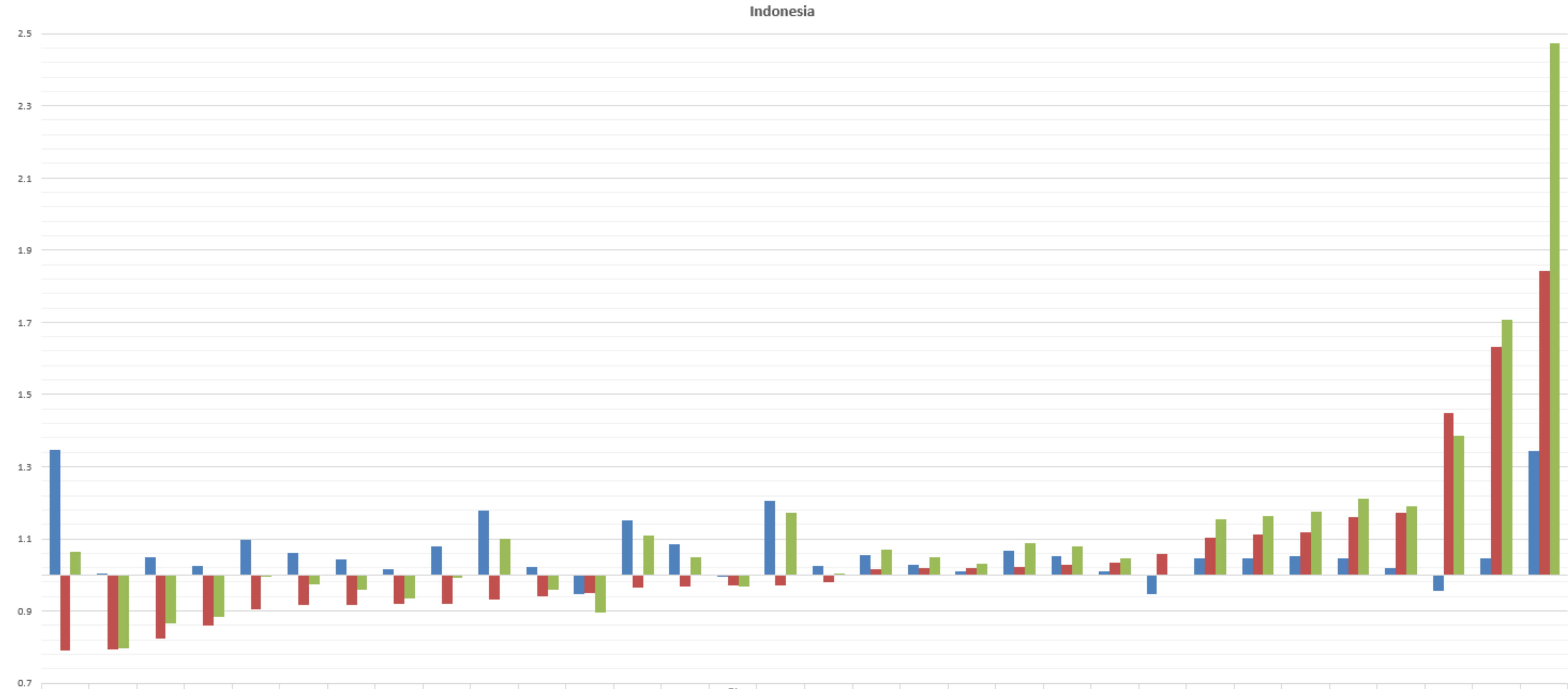
The temporal decomposition results are presented in Figure 6.10, this study determines the better-performed provinces on every single effect by comparing the energy intensity changes by each effect compared with the base year of 2010 value across 33 provinces. Referring to the LMDI-II multiplicative approach, the interpretation of value of an effect <1 (less than 1) means that this effect contributes to a decrease in the provincial energy intensity; vice versa, when the value is >1 (more than 1) means that this contributes to an increase in the provincial energy intensity.

The intensity effect contributed a significant role in the change of provincial energy intensity, where this effect had different magnitude on different provinces. During the study period, the intensity effect in 17 provinces was less than 1, including Sulsel, Riau, DI Yogyakarta, Sumsel, Lampung, Bali, Kaltim, DKI Jakarta, Jambi, Jatim, Jabar, Jateng, Kalbar, Kalsel, Kalteng and Papua Barat. In these provinces, the intensity effect decreased energy intensity at around 2% to 21% compared to its base level in 2010. For example, the intensity effect in Kalteng and Papua Barat contributed to the decreases in provincial energy intensity up to 21% compared to its base level in 2010.

On the other hand, there were 16 provinces that had an intensity effect more than 1: Papua, Malut, Sulbar, Aceh, Babel, Bengkulu, NTT, NTB, Sultra, Kepri, Sulut, Maluku, Gorontalo, Banten, Sumut and Sumbar. In these provinces, the role of intensity effect brought an increase to the provincial energy intensity for approximately 1% to 84% compare to its base level in 2010. For example, in Papua, the intensity effect contributed to the increases in provincial energy intensity, that brought up the provincial energy intensity up to 84%. Intensity effect (efficiency improvement) plays a more important role in the change of energy intensity, which was in accordance with numerous studies (Greening et al. 1997; Howarth et al. 1991; Liao, Fan & Wei 2007; Liu, N & Ang 2007; Ma & Stern 2008b; Metcalf 2008; Unander 2007).

From 2010 to 2015, the impact of the structural effect on provincial energy intensity differed considerably across provinces. The structural effect only had a minor influence on the decreasing provincial energy intensity in Sulbar, Sulteng and Sultra, at around 5%. The structural effect had a substantial impact on the increase of energy intensity in Papua Barat and Papua, with values at around 35%. In the remaining provinces, the structural effect contributed to an increase in its province energy intensity, with values of up to 21%. The structure effect indicates a shift in the shares of different economic activities that denotes total energy consumption.

Half of the provinces in Indonesia experienced efficiency improvement (17 provinces), while the other half of the provinces became more energy intensive or remained unchanged (16 provinces). Papua Barat and Papua had the highest structural effect with more than 35% compared to its level in 2010. Following these provinces, Lampung, Sumbar, Gorontalo and Sumsel had also an increase in structural index with more than 5%. These increases in the structural effect potentially indicates the fact that several heavy manufacturers were slowly immigrating from more developed areas to less developed eastern regions, and not only centralized in the western part of Indonesia like Jawa-Bali but also to other parts of Indonesia, specifically in the eastern part. Notwithstanding the fact that some wealthy provinces also encountered a greater increase in the structural effect, including Riau, Kaltim, Jateng, DKI Jakarta and Jabar. In terms of energy intensity improvement, most of the provinces in Kalimantan experienced a greater intensity effect (energy efficiency improvement) with a reduction of more than 10% compared to its level in 2010, including Kalteng, Kalsel and Kalbar; where Kalteng had the highest intensity effect improvement with 21% compared to the base year. Following these provinces, some rich provinces in Jawa+Bali also showed a moderate improvement in energy intensity.



	PAPUA BARAT	KALTENG	KALSEL	KALBAR	JATENG	JABAR	JATIM	JAMBI	DKI JAKARTA	KALTIM	BALI	SULTENG	LAMPUN G	SUMSEL	DI YOGYAKA RTA	RIAU
DSTR	1.35	1.01	1.05	1.03	1.10	1.06	1.04	1.02	1.08	1.18	1.02	0.95	1.15	1.09	1.00	1.21
DINT	0.79	0.79	0.82	0.86	0.91	0.92	0.92	0.92	0.92	0.93	0.94	0.95	0.97	0.97	0.97	0.97
DTOT	1.06	0.80	0.86	0.88	1.00	0.97	0.96	0.93	0.99	1.10	0.96	0.90	1.11	1.05	0.97	1.17

	SULSEL	SUMBAR	SUMUT	BANTEN	GORONTA LO	SULUT	KEPRI	SULTRA	NTB	NTT	BENGKUL U	BABEL	ACEH	SULBAR	MALUT	PAPUA
DSTR	1.02	1.06	1.03	1.01	1.07	1.05	1.01	0.95	1.05	1.05	1.05	1.05	1.02	0.96	1.05	1.34
DINT	0.98	1.01	1.02	1.02	1.02	1.03	1.03	1.06	1.10	1.11	1.12	1.16	1.17	1.45	1.63	1.84
DTOT	1.00	1.07	1.05	1.03	1.09	1.08	1.04	1.00	1.16	1.16	1.17	1.21	1.19	1.39	1.71	2.47

DSTR DINT DTOT

Figure 6. 10. Decomposition Results of 33 Provinces in Indonesia during 2010 and 2015

6.6. Policy Implications

Significant policy measures are required to reduce the level of energy intensity, particularly in those provinces with high degree of energy intensity, such as Papua, Sulbar, Malut, Aceh and Babel. As these emerging provinces develop their economy, the increase of energy consumption is inevitable. Thus, these provinces should do more to reduce their energy intensity by providing energy-saving measures, such as introducing energy efficient technologies. On the other hand, the more developed provinces, including DKI Jakarta, Riau, Kaltim, Sumut and Jabar, that have a lower level of energy intensity could provide technical and financial support to those provinces with less efficient energy intensity.

A coherent policy targeting to set reasonable energy structure across provinces should be conducted. In many provinces, the energy structure is anti-environmental, where the usage of fossil fuels become the main source of energy. Therefore, a sound policy to increase the usage of new and renewable energy such as solar energy, bio energy and geothermal energy should be further promoted by providing facilities and incentives to increase clean energy investment. Implementation of low-carbon development policies across provinces should be enhanced to provide balance between environmental protection and economic development. In most of the provinces, the role of the intensity effect was dominant in reducing provincial energy intensity, thus removing obsolete production capacities and enhancing efficiency in energy use are required.

The implementation of energy efficiency policies in the industrial sector, particularly in those provinces with relatively inadequate in terms of energy intensity, is indispensable. Based on the findings, the intensity effect is a key factor in reducing the provincial energy intensity, where it can be improved by employing energy-saving technology. Hence, the role of government is essential to promote and develop energy-saving technologies. Due to the heterogeneity across provinces' energy intensity, each province should also consider their capacities including existing technologies levels and natural resources, in advocating advanced energy-efficient technology and promoting research and development. For instance, as a result of significant industrialization and high energy intensity, those coal-dependent provinces, like Papua and Riau, might strongly increase their energy consumption in the long run. Thus, improvement of coal products' quality and efficiency is essential which can be enhanced by technological and scientific innovation in the coal industry. As the energy intensity of more developed provinces has improved to a large extent, the less-developed provinces should also promote and apply energy-saving technologies to their provinces in order to reduce the energy intensity disparities across provinces; which finally can improve the aggregate energy intensity.

6.7. Conclusion

The results of all the inequality measures computed in this study (including Gini Coefficient, Theil Index, Atkinson Index and Coefficient of Variance) agree that disparities in energy usage decreased from 2010 to 2015. Based on those results, this study concludes that energy usage disparities in Indonesia have decreased over the study period. This result is aligned with the study of Duro, Alcántara and Padilla (2010) who hypothesized that the evolution of a reduction in energy intensity disparities amongst regions represent a convergence. However, this study also extends a caution when considering the work of Duro, Alcántara and Padilla (2010) that the convergence of energy intensity disparities across regions does not directly describe the more efficient in energy usage. The decreases in the energy intensity disparities in Indonesia occurred as a result of the wealthy provinces (including most of the provinces in Java) reducing its energy intensity, while the poor provinces like Malut had increased its energy intensity.

In addition to the inequality measures, the multiplicative LMDI-II was also applied to explore the driving forces of the energy intensity in 33 provinces in Indonesia from 2010 to 2015. The main findings are presented as follows. The structural effect was the main factor resulting in the increase in energy intensity in most provinces, except in Sulbar, Sulteng and Sultra. On the other hand, the role of the intensity effect has differed in different provinces. In some provinces such as Papua, the intensity effect increased the provincial energy intensity while in others such as Papua Barat, the intensity effect decreased the province’s energy intensity.

This study identifies the main provinces that have the largest resources that become the source of disparities amongst other provinces, including DKI Jakarta, Kaltim, Riau, Aceh, Banten, Jabar, Jatim, Sumut and Papua. These provinces share one characteristic — a strong resource-based economy. DKI Jakarta is the capital city of Indonesia which is the centre of industry, services and trade. Papua Barat and Papua are both wealthy from gas mining and non-oil mining, including copper and gold. Aceh and Kaltim’s economy is dominated by forestry products, gas and oil. Riau has diverse activities — not only natural resources but is also a centre of export manufacturing with strong connections to Singapore. While other provinces like Banten, Jabar, Jatim, and Sumut grew faster than other provinces due to having a high-density population and advanced airports and seaports.

Overall, the results of the provincial decomposition analysis in Indonesia shows that more than a half of Indonesia's provinces have improved their intensity effect. The change in Indonesia's energy intensity has been generated from the intensity effect (energy efficiency improvement), while the role of structural effect was lower during the period of study. Indeed, during the study period, more than half of Indonesian provinces showed their mix of economic activity became more energy intensive, whereas Indonesia also experienced rapid industrialization. The government needs to develop substantial policy, in order to further reduce disparities in energy intensity across provinces, so that the aggregate energy intensity will continue to decrease in the future.

There are some factors that influence economic disparities across provinces in Indonesia. First, the most classic problem is the disparity between resources amongst provinces. Those regions that have abundant natural resources, will not face problems to extend their economic activities and become the centre of growth. While those regions that have a lack of resources fall behind compared to the regions with more resources. Second, the influence of different stages of infrastructure development amongst provinces. Advanced infrastructure will encourage economic activity through a smoother production process and better services. The level of development can be seen from the geographic characteristics. Most provinces located in western Indonesia (including provinces in Jawa+Bali and Sumatera) having a more developed infrastructure. While, on the other hand, some other provinces located in eastern Indonesia (including Kalimantan, Sulawesi, Nusa Tenggara and Papua) have more moderate development. Different infrastructure development also occurs between rural and urban areas; the centre of growth and hinterland and border areas; and Java and outside Java Island. Third, different financial capacities. Wealthier provinces have better financial capacity that can leverage their economic activities.

The factors listed above not only affect Indonesia's economic disparities but also potentially influences the disparity in its energy consumption. Based on the previous preliminary data analysis of 33 provinces from 2010 to 2015, there are similar characteristics of regions and provinces that have the highest income (GRDP) and will be followed with highest energy consumption, such as DKI Jakarta. Whilst those having the smallest income will also have the smallest energy consumption, for instance, Nusa Tenggara. In addition, further investigation shows that those provinces having the largest income per capita will have the largest energy consumption per capita, and vice versa.

Chapter 7
Conclusion and Policy Implications

7.1. Introduction

As income level rises, there is a tendency to a greater desire for higher levels of material comfort and higher demand for personal mobility. This usually leads to greater demand for energy. In this context, as a response to greater demand for energy, Indonesia's government has introduced several policy measures to improve energy efficiency-related issues. One of the policy initiatives has been to reformulate its National Energy Policy, aiming to enhance energy security and rebalance energy mix towards indigenous energy supplies. Related to energy security and diversification, one key focus is to reduce reliance on oil consumption by increasing gas consumption and production, escalate the usage of coal and new renewable energy sources (i.e. coal bed methane, nuclear and oil shale).

In order to maintain sufficient future energy supply, the government has enacted the Presidential Regulation Number 22 of 2017 about National Energy Policy, that establishes goals, policies and measures for energy use (Peraturan Presiden 2017). This regulation stipulates two targets: attaining energy elasticity of less than 1 by 2025, and creating an optimal energy mix by 2025 by reducing the share of oil consumption and escalating the share of gas, coal and new renewable energy in domestic consumption.[20]. Besides this regulation, the government also enacted Law Number 30 of 2007 concerning Energy that stipulates the direction of energy security and enhances the reliance on new and renewable energy by allowing incentives for its development (Undang-Undang 2007).

Enforcing and executing sound energy efficiency policy instruments is expected to minimize energy usage. More recently, in 2014, the Indonesian Government strengthened its National Energy Policy (Kebijakan Energi Nasional/KEN) and further outlined in 2017 measures under the National Energy Plan (Rencana Umum Energi Nasional/ RUEN). These actions have set Indonesia's objective to reduce its energy intensity by 1% per year up to 2025, by enforcing its energy efficiency policy measures

[20] Oil share shall below than 25% in 2025 and below 20% in 2050; gas share at a minimum of 22% in 2025 and 24% in 2050; coal share at a minimum of 30% in 2025 and 25% in 2050; biofuel, geothermal, other "new energy" and renewable energy, including wind power, solar power, hydropower, nuclear and biomass at a minimum of 23% in 2025 and 31% in 2050 of the total energy mix.

(Peraturan Pemerintah 2014). Moreover, the government also aims to reduce the total final energy consumption (TFC) by 17% by 2025 (Peraturan Presiden 2017).

Indonesia’s energy consumption is expected to grow aligned with its economic development; thus, efficiency is important to prevent unnecessary expenditure and energy usage (IEA 2017a). Indonesia’s energy usage accounted for approximately 36% of South East Asia’s energy demand and considered as the largest energy consumer in ASEAN (IEA 2017a), 2017). Moreover, according to International Energy Agency (IEA 2017a), Indonesia would be able to lower its total final energy consumption by at least 2% below the targeted of 17% in the Indonesian National Energy Plan in 2025 by enforcing the current energy efficiency policies effectively. Furthermore, the IEA also forecasted that, if Indonesia's government improved the current policy instruments and implemented all proposed policies, Indonesia could further lower its total final energy consumption by 4.5% compared to the targeted in the National Energy Plan (IEA 2017a). IEA also predicted that a 4.1 Gigawatt of electricity's generation would be required annually up to 2025. Thus, enforcing sound energy efficiency measures is critical for Indonesia to achieve greater energy saving.

In light of the previous chapters, this chapter presents an overview of energy efficiency policy in Indonesia, challenges and opportunities, and policy implications, specifically in the manufacturing and transportation sectors.

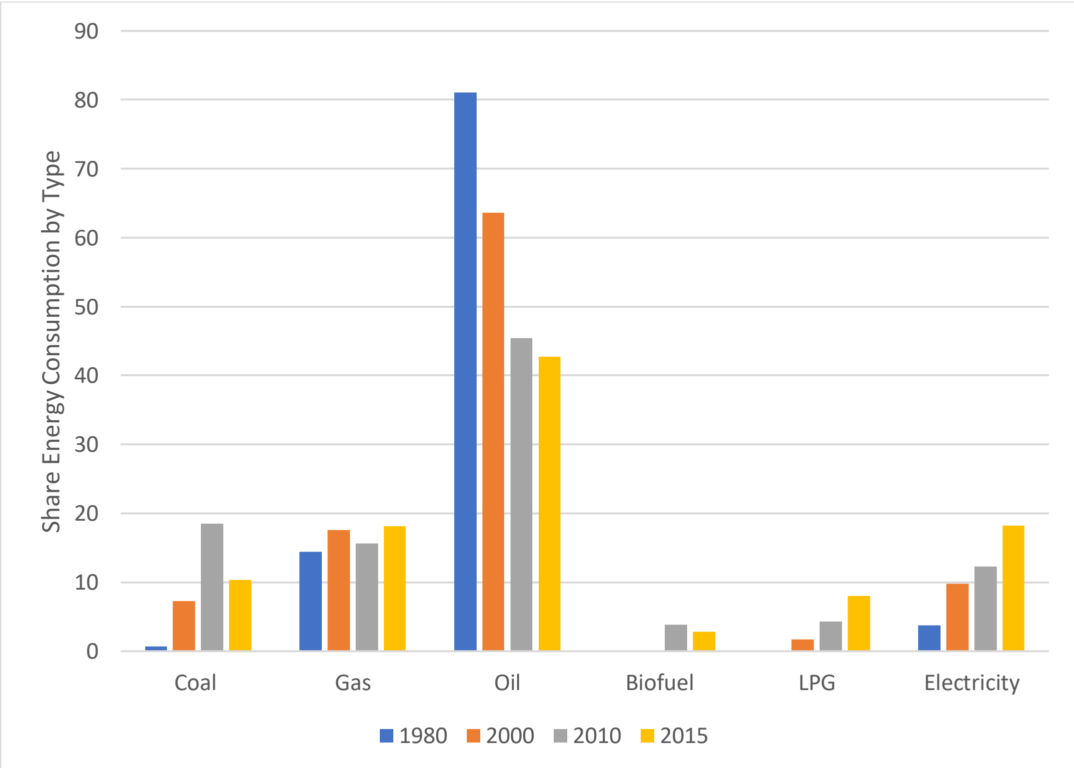
7.2. Overview of Energy Usage in Indonesia

Indonesia relies heavily on fossil fuel to expand its economic development. In 2015, more than 90% of fossil fuel was used in Indonesia's final energy consumption (including oil, natural gas and coal), where oil was the major source. From Figure 7.1, it can be seen that oil products (gasoline, kerosene, and diesel) accounted for the major share of final energy consumption in 2015, at 42.7%, a drop from 63.6% in 2000. The principal reason behind the diminishing share is the rising reliance on coal, gas and renewable energy products (including biofuel), due to government measures over the past years promoting the development of domestic coal, gas and the local renewable energy industry. The major share of fuel usage in Indonesia’s domestic energy consumption has been primarily driven by transportation, household use and electricity generation.

In 2015, the share of gas consumption accounted for around 18.1% of total energy usage, with Liquefied Petroleum Gas (LPG) use increasing significantly, from 4.3% in 2010 to 8% in 2015 (see Figure 7.1). Gas consumption was mainly used for power plants, refineries and industry (Mujiyanto & Tiess 2013). In the long run, gas usage is expected to continue to increase as government measures shifted the source of domestic energy consumption from oil to gas since 2006. The government measure was enacted as a response to rising oil prices as well as to gas as it has lower GHG emissions compared with other fuels.

It can be seen in Figure 7.1, coal consumption increased since 1980, accounting for around 10.3% in 2015. In 2010, the share of coal use in the energy mix reached around 18.5%, where this increase was potentially due to supporting coal-fired power plants[21] in fulfiling 8% of electricity growth (Mujiyanto & Tiess 2013; PLN 2014). In addition, the government also encouraged the private sector to switch their main fuel source from oil to coal, due to Indonesia's enormous coal reserve. From 2010 to 2015, electricity use increased quite significantly, from 12.3% to 18.2% (see Figure 7.1). However, this increase was still showing a modest share opposed to the level in developed countries which was around 30% (IRENA 2017). More than half of the electricity is consumed in buildings, and the rest is used in the manufacturing sector.

Figure 7. 1. Energy Consumption by Type



[21] In 2004, the government has introduced first Fast Track Programme to construct coal-fired power plants with a capacity of 10,000 Mega Watt. Even though the government aimed to diversify the energy mix in the second Fast Track Programme, coal was still the major source of energy.

The Indonesian Government has enacted a number of policies to reduce growth in energy subsidies. For instance, the use of Compressed Natural Gas (CNG) for the transport sector; conversion of kerosene to LPG in the household sector; and compulsory use of biofuels in the manufacturing industry, transportation and power generation sectors. Nevertheless, there are still several barriers to the full execution of these policies. In terms of conserving coal and gas as a source of domestic energy, the regulation also states that exports of gas and coal should be reduced periodically, thus the government needs to find a balance between domestic use and exports. In regards to this, the Ministry of Energy and Mineral Resources in 2012 has set a ban on exports of raw material mineral resources (Peraturan Menteri 2012b).

In the period 2000 to 2016, the transportation sector had the largest growth in energy consumption, reaching an average of around 9% per year. The high growth rate of final energy consumption in the transportation sector was a result of the rapid increase in the use of motor vehicles amounting to 13.99% per year from 2000 to 2013. This was comprised mostly private vehicles and commercial transport such as buses and trucks. The share of fuel consumption in the transportation sector was around 81% of total fuel consumption. Energy consumption in the transportation sector is mostly dominated by oil, and around 89% of this consumption is from the road transport sector.

One of the main causes of the high growth in the use of motor vehicles and energy consumption in the road transport sector has been the low price of fossil fuel (namely, diesel oil and premium gasoline). The low cost is determined by the government as it provides subsidies for this fuel. This has also influenced the use and the development of new energy alternatives as a substitute for fossil fuel energy such as biofuels (biodiesel and bioethanol) and CNG. IEA (2017a) suggested that to improve the current situation, the Indonesian government needs to accelerate the shift from private vehicles to public transport use and accelerate the development of a mass transportation system in Indonesia. In order to support this, the government needs to reallocate the fuel subsidies to infrastructure development, particularly to enhance the transportation system and to improve the development of energy alternatives as a substitute for the fossil fuel.

Indonesia is one of the biggest energy producer and consumer in Southeast Asia (Dutu 2016; Mujiyanto & Tiess 2013). The richness and diversity of Indonesia's energy resources, namely oil, coal, gas, geothermal and hydro have played an essential role in expanding its economic growth. Despite being rich in natural resources, Indonesia remains a relatively low energy consumer. In 2015, Indonesia's energy use per capita was only 0.88 toe, while Thailand and Malaysia were around 1.97 toe and 2.97 toe, respectively (WorldBank 2018b). Thus, the critical energy policy challenge is to cope with the increasing national energy demand of a rising economy and population. Diminishing production of oil, gas and coal could jeopardise the capacity of the energy sector to sustain economic growth.

7.3. Main Energy policy

As noted above, Indonesia has enacted several laws to improve energy efficiency. These laws are the basis of energy efficiency measures, and more detail is provided here.

7.4. Energy Law Number 30 of 2007 (Article 25: Energy Conservation)

The energy law Number 30 of 2007 is the basis for energy policymaking in Indonesia. As a basis for various government and ministerial regulations, this law outlines general foundations for the energy resources management and Indonesia's key targets for the future energy mix. Specifically, it put in place the underpinning for regulations on energy conservation and renewable energy development. It also legitimizes energy security as an important national issue and sets out to minimize dependency on imported refined oil while encouraging the use of renewable energy, including biofuels, geothermal and natural gas resources. This law is a comprehensive law which emphasizes the significance of environment conservation, sustainable development and resilience in national energy management.

This law created a framework for energy management, defined the prerogatives between parliament, central government, regional and local authorities, and established the National Energy Council. It also legislated the government to introduce the National Master Plan on Energy as the foundation for RIKEN (the National Master Plan for Energy Conservation). This plan incorporates targets for energy saving across different sectors to be fulfilled by 2025 through the implementation of energy conservation regulations. Aside from the national master plan, local governments are also authorized to stipulate their regional master plans and energy policy instruments.

This law establishes incentives for state and private companies, including energy providers, to contribute to the development, utilization and distribution of new and renewable energies.

7.5. Energy Conservation (Government Regulation No. 70 of 2009)

As an implementing regulation under the Energy Law No. 30/ 2007, this regulation stipulates the appropriate energy resources utilization and the use of energy-efficient technology; and determines the responsibilities of the local government, central government, entrepreneurs and communities. It endorses the establishment of the National Master Plan for Energy Conservation (RIKEN) as a guide for stakeholders to conserve energy in Indonesia. This instrument also defines the responsibility of key stakeholders, including importers and producers of energy appliances to carry out energy efficiency labelling. It also initiates and implements various incentives for enhancing energy efficiency and energy management amongst industrial energy users, including low-interest rates on energy conservation investments, fiscal incentives and tax exemption on imports of energy-saving appliances, mandatory audits and energy efficiency reporting. This regulation aims to enforce energy management for energy users greater than 6,000 ToE. This includes written notices to comply, fines and energy supply reductions. Several potential major industries targeted under this regulation includes textiles, iron and steel.

7.5.1. National Energy Policy (Government Regulation Number 79 of 2014)

This regulation reshapes Indonesia's energy independence by changing its energy mix to indigenous energy supplies and by re-arranging the use of energy resources from export-oriented towards domestic usages (including reducing and phasing out gradually exports of coal, natural gas and unprocessed minerals in the long term). This addresses Indonesia's energy security concerns and includes the reduction in the use of oil, expansion of the consumption of coal and renewable energy, and optimises gas use and production. It provides the platform to achieve an energy mix transformation by 2025 is 25% natural gas, 30% coal, 23% renewable resources and 22% oil. In regard to achieving that target, energy mix in Indonesia is still far below the target. In 2015, the consumption of fossil fuel had the largest share reaching for around 46% of the total energy mix, followed by coal for approximately 26%, natural gas for around 23% and renewable energy for approximately 5% (Peraturan Presiden 2017).

This regulation also addresses the government's concerns about its increasing dependency on importing energy, which is reflected in the energy subsidies on both electricity and fossil fuels. The ideology underlying the price of energy in Indonesia is 'economic equality' that ensures all Indonesians should have full access to energy affordable.

7.5.2. National Energy Plan (Presidential Regulation Number 22 of 2017)

This regulation sets out a general plan for national energy that provides a general guideline for government institutions from various sectors to set up policy and a roadmap of energy plan in each sector. This plan covers greenhouse gas emission reduction policy, energy elasticity reduction policy, and energy efficiency programmes from 2015 to 2050.

7.6. Current Policy Implementation in Manufacturing and Transport sector

Indonesia's government has introduced several policy measures to address energy efficiency-related issues, particularly in the Manufacturing sector and the Transportation sector. Several of these measures are elaborated more in this section.

7.6.1. Manufacturing Sector

The manufacturing sector is the second biggest energy-consuming sector in Indonesia after the transportation sector, accounting for around 41% of total energy consumption in Indonesia in 2016. Indonesia's government acknowledges the great possibility for energy efficiency from this sector. Thus, Government Regulation No. 70 of 2009 regarding Energy Conservation lists a set of regulations to enforce energy conservation across stakeholders in Indonesia. One of the objectives of this regulation is to enforce energy management practices on companies with energy consumption greater than 6,000 toe or 70 gigawatt-hours annually.

To enforce the implementation of the Government Regulation No. 70 of 2009, the Minister of Energy and Mineral Resources has enacted the Energy and Mineral Resources Regulation, No. 14 of 2012 regarding Energy Management in Industry (Peraturan Menteri 2012a). This ministerial regulation stipulates the procedures for implementing energy management. This regulation stipulates that such companies are to perform a mandatory energy audit and an energy efficiency public reporting, in which Indonesia currently adopts the international best practice standard of ISO 50001[22]. This international standard serves a benchmark for energy management implementation and provides policymakers a form of measurement to monitor and ensure compliance.

The implementation of energy management system involves: (1) designating an energy manager, who is in charge of conducting energy conservation plans including monitoring and evaluation. (2) formulating short, medium and long-term energy

[22] The definition of ISO 50001 is further discussed in the next section.

conservation programs, (3) implementing energy audits regularly, (4) fulfiling the energy audit recommendations, (5) conducting energy management programmes and (6) reporting to the specified authorities regarding the progress of energy conservation implementations. Industries that are targeted in this regulation include food and beverage, chemical, pulp and paper, iron and steel and textiles.

In order to speed up the enforcement of energy efficiency projects in Indonesia, the Minister of Energy also enacted Ministerial Regulation No.14 of 2016 regarding Establishment of Energy Conservation Services Companies (ESCO) (Peraturan Menteri 2016). An ESCO is a business entity that implements energy conservation services professionally and systematically based on the Energy Saving Performance Contract (ESPC). The Energy Service Performance Contract is an agreement between the ESCO and the user in which the payment stated in the ESPC will be paid based on the performance of energy saving

7.6.2. Transportation Sector

The largest energy-consuming sector in Indonesia is the transportation sector, accounting for around 51% of total energy consumption in 2016. The rapid energy consumption growth in the transportation sector provides a great prospect for developing energy efficiency policy in Indonesia. Indonesia's government has introduced five principal factors for energy conservation in the transport sector: (1) managing transport demand, 2) expansion of the public transport system, 3) traffic control management, 4) non-motorised transport and 5) decreasing air pollution.

Several of these principles have been introduced under the Transportation Ministerial Regulation No. 201 of 2013 which aims to mitigate carbon emissions. This regulation stipulates emissions mitigation in the transportation sector through the “avoid, shift and improve” approach. This regulation is primarily concentrated with fuel substitution from oil to gas, although it also stipulates other policies including encouragement of non-motorised vehicle usage, car-free days and transit-oriented development planning. Beside this regulation, the government had also enacted Ministerial Regulation No. 4 of 2009 regarding emission limits for a new vehicle.

Besides those regulations, Indonesia’s government has developed a series of measures to create sustainable transport (IEA 2015a). For example, public transport gasification, which provides conversion for buses and converter kits for taxis to run using natural gas in several major cities including Jakarta, Palembang, Bogor and Surabaya. Although the government has developed several infrastructure sites for the transport gasification, these facilities have not yet been fully developed on a large scale. The government is also developing efficient sea transport by providing a seaway corridor across domestic ports in Indonesia, including Jakarta, Belawan, Surabaya, Batam, Sorong and Makassar. In order to reduce air pollution, several local governments initiated car-free days, held in major cities on Sunday mornings, where the city's main streets are closed to provide space to hold different activities such as art, entertainment, education and sport (IEA 2015a).

To support growing energy consumption in Indonesia, several types of new renewable energy sources can be considered as alternatives by the government. Fossil fuel sources, such as diesel, kerosene and petroleum gasoline, will still be the main energy source for the transportation sector in Indonesia in the foreseeable future. However, the government needs to consider developing a market for different forms of new renewable energy sources, such as hydrogen, biofuels, methanol, and compressed natural gas (CNG) that are more environmentally friendly. For example, Indonesia is rich with gas resources, if the government can build a massive infrastructure to utilize gas resources, that is, CNG transport mode across Indonesia, then the amount of fossil fuel energy consumption can be reduced substantially.

7.7. Challenges

During the study period, the energy intensity in Indonesia's manufacturing and transportation sectors have shown great improvement (that is, decreased energy intensity). However, in terms of regulation, several major problems need to be resolved. First, a detailed and thorough implementation regulations from the energy conservation laws are still lacking. Second, many of the regulations are formulated from the viewpoint of industry, which for some extent leave officials with insufficient authority. Thirdly, inadequate use has been made of publicity and of persuasion in developing energy-efficient products and technologies. Last but not least, the development of rules of energy-efficient standard technology is still far from perfect, and most of the standards are not adaptable to the current economic circumstances.

In order to formulate sound policy instruments, a decision-maker requires a good basis of energy usage data and value-added across industries, which accurately represents reality. However, in Indonesia's official published data, energy consumption data and value-added data are only available for several entities or sectors in aggregate level. For instance, in the manufacturing sector, data is only available for the medium and large industries, while for small industries it is not yet available. Indeed, in other sectors such as transport, commercial and residential, data is only available at the aggregate economic level.

At the moment, the Indonesian government and underlying relevant departments have enacted several policy instruments to reduce Indonesia's energy consumption. However, there is lack of coordination mechanisms across ministries and related departments in governing these cross-cutting regulations. This inflicts in difficulties in the implementation of existing regulations.

7.7.1. Manufacturing Sector

The enforcement of an energy management system is essential for implementing sound energy efficiency measures for the manufacturing sector in many countries. As governing energy efficiency in the manufacturing industry is a long-term process, the Indonesian Government needs to provide long-term strategies and action plans to implement these energy efficiency policy instruments. The policy measures provide a framework to improve energy efficiency and to keep track of energy usage in commercial companies.

As mentioned earlier, Government Regulation No. 70 of 2009 establishes the threshold for companies who use more than 6,000 ToE to conduct energy management system in their companies. However, assuring the implementation and fulfilment of every aspect of this regulation and ensuring the obedience of all companies, remains a challenge. Based on the database of the Ministry of Energy that is reiterated in the IEA report (IEA 2017a), companies using energy above the threshold describe approximately 60 per cent of total manufacturing sector energy consumption in Indonesia. However, only around 120 companies out of a total of 700 companies who match the threshold are complying and reporting on their energy usage (IEA 2017a).

Government Regulation No. 70 of 2009 also establishes the basis of financial measures and fiscal incentives in promoting energy efficiency. However, at the moment, the underlying regulation under this act hasn't yet been further regulated comprehensively. Thus, the enforcement of such energy efficiency policy instruments to those industrial energy consumers is allegedly difficult, owing to the absence of fiscal incentive and financial measures.

Another challenge for the Indonesian Government when trying to improve energy efficiency in the manufacturing sector is to increase the use of energy efficient technologies, such as employing the economic and assured efficient technologies. Adopting the Minimum Energy Performance Standards (MEPS) for industrial equipment is essential to solving hindrances in optimising energy efficiency measures. Additionally, the government needs to maintain consistency of policy regulations, which is crucial for driving investment.

7.7.2. Transportation Sector

Indonesia's continuing economic growth and population growth is associated with rapid urbanisation and increasing of private vehicle ownership, which leads to severe traffic congestion. The transport sector had the highest increase in energy consumption from 2000 to 2015 in Indonesia (IEA 2017a).

The most preferred mode of private transport across Indonesia is motorcycles, specifically in cities. Based on the IEA (2017a), the energy consumption in the passenger transport has increased substantially for around four-fold during 2000 to 2015, which primarily controlled by the increase in the distance travelled per passenger (i.e. passenger kilometre). The IEA (2017a) report is consistent with the finding in this study (which was elaborated in Chapter 5). Furthermore, motorcycles consume around 23% of total transport fuel, amounting to around 80 million motorcycles across Indonesia in 2015 (IEA 2017a). Total sales of motorcycles have been growing at around 14.4% annually (AISI 2016). Cars were only responsible for around 22% of total energy consumption, where the light commercial trucks accounting for around 27% of the total fuel consumption (IEA 2017a). In spite of the increasing progress of public transportation development in Indonesia, the motorcycle remains the most popular transport for many Indonesians.

One of the essential factors in enhancing the development of energy-efficient technologies is support from the public user or consumer market, as the utilisation of the energy-efficient transport mode can be boosted through the market demand (Wang, Yuanfeng, Li & Xu 2014). At the moment, the energy-efficient transportation market is poor in Indonesia. The Indonesian Government has conducted some efforts to improve the development of energy-efficient transport. However, due to lack of support from the market, several policies were unsuccessful. For instance, the effort to conduct conversions to gas in the transport sector in 2007 to 2011. This policy stagnated as the market was not ready for this policy due to the lack of infrastructure (Setiyo et al. 2016). The uncertainty of the policy in the transportation sector in Indonesia is another drawback that holds back the development of the energy-efficient market in this sector. The uncertainty in the policy measures will further discourage the development of energy efficiency market of the transport sector in Indonesia.

7.8. Policy Recommendations

One of the most important actions to take before implementing a sound energy efficiency policy is to reformulate the institutional framework of the national policy

(Nugroho 2015). For effective enforcement, the government needs to involve all of the related key stakeholders in the process. Additionally, the government needs to also set up an institution, which has the authority to plan strategies, implement, control and enforce the energy efficiency policy. The following section provides several policy suggestions and recommendations based on the findings from the previous chapters.

7.8.1. Manufacturing

As highlighted in Chapter 4, there are five highest energy-consuming manufacturing sectors in Indonesia: (1) Food, Beverages and Tobacco; (2) Textile, Wearing Apparel and Leather; (3) Chemicals, Petroleum, Coal, Rubber and Plastic Products; (4) Non-Metallic Mineral Products; and (5) Basic Metal Industries. By focusing and prioritising to those sectors which consume for the greatest shares of energy usage is the best possible approach.

The enforcement of energy management in the manufacturing sector is critical. Policy measures mandating industries to conduct energy efficiency actions, such as government regulation No. 70 of 2009, can be an effective instrument for stimulating industries to enhance their energy efficiency. The government should oblige all industries, particularly those energy-intensive and high energy-consuming sectors, to comply with the Government Regulation No. 70 of 2009, which specifically requires industries to follow the ISO 50001 standards. ISO 50001 is the first international standard recognized in energy management, particularly in industrial sectors, to establish and arrange an optimum system and integrating the whole processes and measures to assist businesses in executing an effective and efficient energy management scheme. By adopting this ISO 50001, the top-level management can get a clear description of energy use in their company and decide an adequate and systematic program in energy management, that could ensure its company standards and systems are appropriate (Fawkes et al. 2016).

Monitoring and having control over the effectiveness of the implementation of energy management measures need to be conducted periodically. Additionally, this policy should be thoroughly formulated to be both relevant and achievable, and relevant infrastructure, costs and control for compliance needs to be also scrutinized. The basis for regulatory instruments, legal policy measures and institutional should be centralized in regulating activity in energy efficiency by preventing and enforcing energy saving activities (Fawkes et al. 2016).

In order to promote the attractiveness of energy efficiency policy, it is essential for the government to align its policy with various fiscal instruments. The role of fiscal policy, such as tax measures, not only to encourage improvements in energy efficiency, but can also be utilised to discourage the actions of inefficient energy usage (Price et al. 2005). The government may develop certain financial incentives, including grants, tax exemptions, subsidies for interest rates and ease of financing in energy efficiency projects. Inadequate incentives and insufficient energy efficiency funds are several barriers that hold back the development of the energy efficiency market. Thus, the purpose of promoting a variety of fiscal measures is to elevate the level of energy efficiency investment projects by lenders and a third party. The amount of investment accessible for energy efficiency can be raised through the creation of specific energy efficiency financings, but the government need to provide the related infrastructure in developing this energy efficiency financing scheme (Setyawan, D 2014).

In order to increase public awareness of the benefit of energy efficiency, the government needs to also provide capacity building programmes (i.e. training or consultation in regard to improve energy efficiency behaviour). Capacity building can enhance the capacity and competence of industry to initiate and carry out effective energy efficiency programs. The capacity building program can be conducted by involving various key stakeholders, such as vendors of energy efficient technology, energy service companies and the financial sector.

One of the measures that enhances manufacturing energy efficiency, is developing energy management standards as a benchmark for industrial performance. Enforcing the large manufacturers and energy-intensive industries, as well as other energy consumers in doing the energy management standard may assist good energy management. Requiring manufacturers to employ an energy manager will ease the process of keeping track the energy consumption in improving the level of energy efficiency in the industrial sector. Another important measure is to get a benchmark across industries and subsectors and share information about improving energy efficiency in the manufacturing sector.

The crucial issue for the Indonesian Government is to enforce and enhance the regulation measures under the Energy Conservation Law to become more practical. The proposed target of energy saving in the national energy planning and its implementation needs to be aligned and coordinated (Indriyanto, Fauzi and Firdaus 2011). The Indonesian Government and cross different line ministries, as well as all other related key-stakeholders, needs to support and cooperate across different industries to achieve energy saving. One of the most effective ways to achieve this is to develop and enhance a control mechanism and post-evaluation measures of the laws, policies and regulations and provide a specific period for the evaluation of the implementation (Wang, Yuanfeng, Li & Xu 2014). Government authorities need to regularly survey, monitor and get the feedback of the policy implementation, and periodically adjust and harmonize the related regulations and policy measures. To encourage the further energy saving in manufacturing, the government also needs to promote its policies and achievements to raise public awareness and increase market demand.

7.8.2. Transportation

The transport sector is one of the main sectors that uses a great deal of energy and release a high proportion of carbon emissions (Mraihi 2012). Both freight and passenger transport, in the road transport sector in Indonesia, are the main consumers of fossil fuel energy. In regard to this, the government needs to formulate strategies and policy in order to create a more sustainable transport sector that can reduce the use of energy consumption, particularly fossil fuel. To achieve this, the government needs to employ a set of policy tools, including regulations, infrastructure, economic and fiscal measures, and technological instruments to oversee different factors of transport-related energy use.

As discussed in Chapter 5, the highest energy-consuming mode in both passenger and freight transports in Indonesia is road transport, while the most energy-efficient transport mode in passenger is railway and in freight is water transport. Thus, in order to increase the use of less energy-intensive modes of transport, it is essential for the government to promote the development of most efficient transport mode —railway for passenger transport and water for transporting freight. Therefore, the government needs to enact policy, such as building the infrastructure for railways and water transport and improving the quality of the services (regularity, security, tariffs, availability and accessibility).

The results of the decomposition analysis revealed that the transportation structure effect is the primary factor affecting aggregate energy intensity to increase in Indonesia's transportation sector, particularly in freight transport. At the moment the share of water transport in Indonesia accounts for the largest share, where this mode is also considered as the most efficient transport mode compared to other modes. The second most efficient transport mode in freight is Railway, but this mode hasn't been explored much by the government considering the share of this mode to total freight transport turnover, still less compared to road transport. In spite of being a geographically vast country, the use of road transport mode in freight is far more widespread than railway transport, which has a more efficient structure. Therefore, in order to reduce the cargo barriers from high energy intensity road transport like trucks, it is essential to build railway lines and water transport infrastructure for facilitating freight.

One of the notable solutions in urban transportation planning is to shift to public transportation. Improving the quantity and quality of public transportation could reduce the use of private vehicles (Moustafa 2012). By building public transportation networks, such as an extension of the public transportation routes and integrating different kinds of public transport modes could improve the quality of public transportation (Moustafa 2012). Currently, Jakarta (the capital city) has built an integrated public transportation system, where most of the other major cities in Indonesia have not provided an adequate public transportation system. Even though Jakarta has provided a public transportation system — Transjakarta (Setyawan, H 2012) — its quality is still below expectations, as this public transport system is not punctual and is not considered comfortable (ESCAP 2017; Ilahi, Waro & Sumarsono C A 2015). Therefore, some residents prefer to use private vehicles to travel in the city for the sake of safety and convenience. By offering low prices, reliability and punctuality, the public transportation system would be more likely to attract many passengers.

From the policy perspective, interconnectivity is one key for a successful public transportation system. In order to reduce traffic congestion, the government must provide a public transportation system, such as trains and bus rapid transit that are interconnected to other modes of transportation not only in Jakarta but also in other major cities in Indonesia. Moreover, the Indonesian Railways Company (PT KAI), the one and only railway operator of services and infrastructure for all areas in Indonesia, could build and operate railroad services across long-distance provinces in Indonesia. The interconnected railway systems need to be built not only for passenger transport but also for freight services, thus it would reduce the use of inland transportation.

The government needs to formulate and provide policy measures that focus on increasing the proportion of railways mode, particularly in freight transport, compared with other modes of transport. Railways are a considerably more environmentally friendly mode of transport compared to others. However, there is infrastructure that must be built by the government, such as logistical infrastructure networks which include adequate train services, storage warehouse facilities and feeder transportation systems that connect from origin to train station and from train station to destination (Tiwari & Gulati 2013).

In regard to increasing the use of modern and more efficient energy vehicles, another key instrument is to enhance technologies for the alternative fuel and to build the requisite fuel infrastructure (like gas stations or electrical recharging stations) (Wang, Yuanfeng, Li & Xu 2014). The electric transport vehicle is referred to as one of the notable benign transport means that has the most development potential. However, the use of this new efficient technology in Indonesia is still lacking. Several inhibiting factors include lack of public awareness, expensive cost, difficulties in charging vehicles, battery technology, short mileage range.

One of the most popular modes of transport across Indonesia is motorcycles, particularly in cities. Based on the IEA report (IEA 2017a), the use of motorcycles in Indonesia increased substantially increasing nine-fold from 2000 to 2015, so now there are at least 80 million motorcycles on the road consuming approximately 23% of total fuel in the transport sector. Thus, in the future, in order to reach the target of energy efficiency in the transport sector, one of the primary measures is to further promote efficient transport equipment in Indonesia, is to replace conventional motorcycles with electric ones (IEA 2017a).

Regarding enhancing the use and efficiency of navigation transport, the government needs to extent river channels transport mode and increase passenger mileage in this means of transport. In addition, increasing the use of large tonnage shipping and improving the energy efficient technology of energy-efficient in marine transport would be some other instruments that need to be enhanced, particularly in the freight transport mode.

Optimizing energy efficiency in the transportation sector can also be done by encouraging the shift from a less efficient transport mode to a more efficient transport mode and increasing the use of cleaner fuels. In regard to this, the government needs to enhance its economic instruments, fiscal policy instruments and regulatory measures (Mraihi 2012). For instance, the imposition of tax on fuels on private cars will increase the cost of private car use and thus encourage the substitution of private transport to public transport. Moreover, fossil fuel taxation on road freight transport would urge businesses to use fewer high energy-consuming vehicles and also use vehicles with greater carrying capacity. Along with imposing taxes, the government can also provide some incentives or subsidies to those businesses who conserve energy use. Another economic incentive that can carried out is altering the fossil fuel price, that is, increasing the gasoline and diesel price in order to encourage the replacement of fossil fuel to renewable energy. Reformulating regulations is another way to enhance energy efficiency in the transport sector. For example, restrictions on the use of old vehicles on the highway and reformulating good fuel standards can encourage a further reduction in energy intensity.

7.9. Discussion

The Indonesian Government has developed and enacted legislation to reduce the increasing demand of energy consumption, particularly fossil fuel energy, such as Energy Law (2007), Energy Conservation Regulation (2009), National Energy Policy (2014) and National Energy Plan (2017). However, with the growth of Indonesia's economy, several regulations and policy measure still potentially restrain the progress of industries energy saving. For example, the implementation of several regulations is not solid and clear, as there are differing standards of energy efficiency for different manufacturing industries. This shows that the energy-efficiency laws are only directed to achieve the aggregate energy-saving target, but in terms of implementation, it is still unsatisfactory.

In regard to achieving the target of energy intensity reduction by 1% per year until 2025, as mentioned in the Government Regulation No. 79 of 2014, this study concludes that the Indonesian Government has set a target that is too low in its energy intensity reduction. As based on the analysis in Chapter 3, the Indonesian Government has easily achieved the energy intensity reduction of more than 1% per year since 2001. Reiterating the analysis of Chapter 3, during 2001 to 2011, the aggregate energy intensity in Indonesia has declined to around 19%, which means Indonesia has decreased its energy intensity by approximately 1.9% per year from 2001 to 2011. Thus, the 1.9% decrease in Indonesia’s energy intensity was higher than the 1% of energy intensity reduction in its government regulation.

Similarly, to the energy intensity reduction target, this study also found that the target to reduce Indonesia’s energy elasticity to less than 1 in 2025 (as stated in the Government Regulation No. 79 of 2014) was also too low. This study found that Indonesia has achieved the target of energy elasticity of less than 1 since 2001. Based on the data trend of energy consumption and value added in Chapter 3, it can be seen that from 2001 to 2016, the annual energy consumption growth rate in Indonesia was lower than the annual value-added growth rate. This trend has proved that the energy elasticity in Indonesia during the last two decades has been less than 1. This finding proves that the target set by the government was easily been achieved before 2025 (as stated in the Government Regulation No. 79 of 2014).

From the regulatory analysis, it emerges that the transport sector is not the highest priority sector for national policies on energy efficiency; more attention, policies and financing target the manufacturing sector, in particular, high energy-consuming manufacturers (those that consume greater than 6000 toe). This is potentially due to the difficulties of introducing effective transport policies and the high cost of these policies (for example, policies requiring large infrastructure investment).

7.10. Conclusion

As the Indonesian economy is growing, its use of energy has increased. Indonesia's energy consumption growth mainly increased aligned with economic growth. Growth in economic activity has remained the primary driving force for the increase in Indonesia's aggregate energy intensity during the study period. Aside from the Financial Crisis, the economy of Indonesia has largely experienced sustained growth. The decrease in the ratio of energy consumption to economic activity is considered as a sign of the reduction of Indonesia's energy intensity, which can also be referred to as an enhancement of Indonesia's energy productivity. Based on the findings in Chapter 3, over the full period, Indonesia experienced a pronounced shift to a more energy-intensive industry structure but sustained falls in within-industry energy intensity. This positive trend of falling within-industry energy intensity has been, to some extent, a result of energy efficiency improvements, through employing more efficient new technology, conducting energy efficient performance standards (particularly for buildings, manufactures and appliances) and changing business and household behaviour.

Manufacturing has seen, since 1971, a steady fall in overall energy intensity, and this continued after 2000. This has been due to strong declines in within-industry energy-intensive, with falling energy intensity across most industries at the three-digit level, and some structural changes (such as the falling share of value-added in the cement and lime sector) and more general industry upgrading. As concluded in Chapter 4, the five highest energy-consuming industries in the manufacturing sectors in Indonesia, including (1) Food, Beverages and Tobacco; (2) Textile, Wearing Apparel and Leather; (3) Chemicals, Petroleum, Coal, Rubber and Plastic Products and (4) Non-Metallic Mineral Products; and (5) Basic Metal industry. In regard to this, one of the best possible approaches for the government is to potentially focus and prioritise these sectors which consume the greatest share of energy usage. Continued attention to the modernisation of industrial technologies and structure seems necessary.

The transport sector is a big issue for Indonesia. Over half of energy use and share rising rapidly, even though energy intensity falling as demand rises strongly. With continuing rapid growth, transport could dominate Indonesia energy demand over the next decade. Based on the finding in Chapter 5, the highest energy-consuming mode in both passenger and freight transports in Indonesia is road transport followed by air travel, while the most energy-efficient transport mode in passenger is railway and in freight is water transport mode. If a policy is to curtail the rapid growth in the transport energy use, it needs to encourage rail, discourage air and continue to focus on the reduced energy intensity of road (prices, vehicle technology, better roads). Therefore, the government needs to employ several policy instruments, such as building the infrastructures for railways and water transports and improving the quality of the services (regularity, security, tariffs, availability and accessibility).

As concluded in chapter 6, the results of the provincial decomposition analysis in Indonesia shows that almost a half of Indonesia's provinces have improved their provincial energy intensity during the study period. The intensity effect is a key factor in reducing the provincial energy intensity across Indonesia, where it can be improved by employing energy-saving technology. Indeed, during the study period, more than half of Indonesian provinces showed their mix of economic activity became more energy intensive, whereas Indonesia also experienced rapid industrialization. As the energy intensity of more developed provinces has improved to a large extent, the less-developed provinces should also promote and apply energy-saving technologies to their provinces in order to reduce the energy intensity disparities across provinces; which finally can improve the aggregate energy intensity. Hence, the role of government is essential to promote and develop energy efficiency improvement across provinces. The government needs to also develop substantial policy, in order to further reduce disparities in energy intensity across provinces, so that the aggregate energy intensity will continue to decrease in the future.

The Indonesian Government has set out to make the country more energy-efficient, in the process reducing energy use per unit of real GDP (energy intensity), while reducing the reliance on fossil fuels. However, in terms of regulation, several major problems need to be resolved. For example, the implementation of several regulations is not clear, where several standards of energy efficiency on different manufacturing entities are insufficient. Thus, a detailed and thorough examination of the implementing regulations from the energy conservation laws are essentially required.

7.11. Limitation

The analyses and decomposition results from this dissertation provide some important findings for studies on energy efficiency performance in Indonesia. Nevertheless, this dissertation has also some limitations that should be taken into consideration in interpreting the results and when conducting further research.

The key limitation from Chapter 4 is the lack of data that is relatively difficult to obtain. Although Indonesia has improved its data quality and availability in its manufacturing sector by constructing a more accurate energy consumption hierarchy into more sub-sectors and end-uses, there are still inconsistencies in the energy consumption and value-added trend data. However, this study attempted to conduct the decomposition method with the best available multi-level disaggregation of the energy consumption hierarchy data in several years. By using this method, this study is expected to provide more valuable evidence and information which provides a significant improvement in Indonesia's energy studies. During the period of observation, the BPS has conducted some changes to the manufacturing survey and database. As a result, there have been several basic changes in the coding and the structure of the data. Therefore, due to this data limitation, this study can only focus its investigation on the years of 1980, 1990, 1997, 2000, 2010 and 2015.

In Chapter 5, data limitation has become one of the drawbacks that drives this chapter to investigate only a short period of analysis of transportation energy intensity performance. This chapter only highlighted the energy intensity changes in the transportation sector from 2000 to 2016, where this is the period of data available. In Chapter 6, a regional decomposition analysis across provinces in Indonesia was conducted to determine the driving factors affecting energy intensity changes. Similarly, with the previous chapters, this chapter also had a limitation in the lack of availability of data. This chapter only focused its analysis to the period from 2010 to 2015, as data was only available during this period.

Overall, the LMDI method that has been employed in this study does not measure other factors in the explanation of intensities, which is beyond the sectoral issues. The analysis of determinant is restricted by the demand to get a perfect decomposition, following a practice of decomposition identities. However, for instance, econometric techniques provide a more flexible and complete detail of determinants that is more useful in terms of implications (Jimenez and Mercado 2014). Although these econometric models do not allow to specify exactly the role of the industry-mix, when controlling for global sector variables, they allow other control variables to be managed Thus, such study is a potential for improvements for this thesis in the future.

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