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Article

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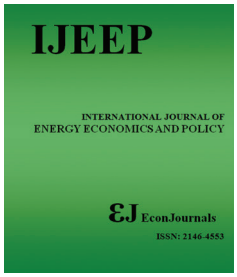

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Examining the Driving Forces Affecting Energy Intensity during Financial Crisis: Evidence from ASEAN-6 Countries

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ABSTRACT

This study observes the factors affecting the changes of energy intensity in Indonesia and five selected Association of South East Asian Nations (ASEAN) countries during the period (1971-2016) particularly measuring its impact during 1997 financial crisis. By employing the Logaritmic Mean Divisia Index, this study summaries that the changes in energy intensity in the ASEAN-6 economies was a result of the changes within industry energy intensity (intensity effect). The intensity effects also provide a proxy measure of energy efficiency activity at the sectoral level. Overall, 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. Further, all the ASEAN-6 countries showed a change in the structure index indicates that the structure of economy periodically shifted away from less energy intensive sector to more energy intensive sector.

Keywords: Energy Efficiency, ASEAN Countries, Energy Intensity, Indonesia
JEL Classifications: Q43, O13, O11

1. INTRODUCTION

Indonesia is a large energy user, with energy supply heavily based on fossil fuels and with a long history of subsidies to energy use. 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, 2015; WorldBank, 2014). 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, 2014).

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 CO_2 in 2012. This report also pointed out that since the 1960s, its emissions growth has reached an average of around 6.6% 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 were from transportation, followed by household, agriculture and services.

Tharakan (2015) found Indonesia's energy intensity[1] 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,

1 The ratio between the total energy consumption and Gross Domestic Product (GDP).

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 and 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. In this Conference of Parties 15, he pledged Indonesia's commitment to reduce its Greenhouse Gas Emissions 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.

At the moment the Association of South East Asian Nations (ASEAN) countries have developed several policies to enhance its energy efficiency (ACE, 2015). Several developments of the recent energy policies and targets in ASEAN-6 countries are can be seen in Table 1.

The goal of this study is to compare the energy intensity performance in Indonesia to other selected ASEAN countries. It 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 study employs a multiplicative Log Mean Divisia Index II (LMDI-II).

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.

Most 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 et al. (2014), Winyuchakrit and Limmeechokchai (2016), while other studies have been conducted on the Philippines, for example, Lopez et al. (2018). By employing LMDI, 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 20 years and conclude that both energy intensity and CO_2 intensity have decreased. Employing a similar method with Bhattacharyya and Ussanarassamee (2004), Chontanawat et al. (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 et al. (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. Another recent study by Setyawan (2020) concluded that the overall aggregate energy intensity of the six ASEAN countries were decreasing. This

Table 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)

study investigated the overall performances energy intensity of Indonesia to other five ASEAN countries i.e. Malaysia, the Philippines, Thailand, Singapore, and Vietnam, whereas he discovered that there was a shift in industry value added across sectors.

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 particularly during and after the 1997 financial crisis, where the temporal changes in each country are captured simultaneously. In this regard, this study will attempt to fill this gap in the current literature.

3. METHODOLOGY

In terms of the focus of energy assessment performance, Index Decomposition Analysis (IDA) can be classified into two types: temporal and spatial analysis (Ang, 2015; Ang et al., 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.

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. The aggregated energy intensity in this study is defined as:

$$I = \frac{E}{Y} \tag{1}$$

Whereas, Energy Intensity (I) is defined as Kilo Ton Oil Equivalent per million dollar USD 2010 (KTOE/ Million USD 2010), E is energy consumption in economic sectorial level (KTOE), and Y denotes value added at 2010 USD constant prices.

This research will first decompose changes in aggregate energy intensity into two fundamental factors: structural effect (Dstr) and technical/ intensity effects (Dint), whereas It will adapt the LMDI-II multiplicative energy intensity approach (Ang and Choi, 1997), as follows:

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

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

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

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

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

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.

4. ANALYSIS

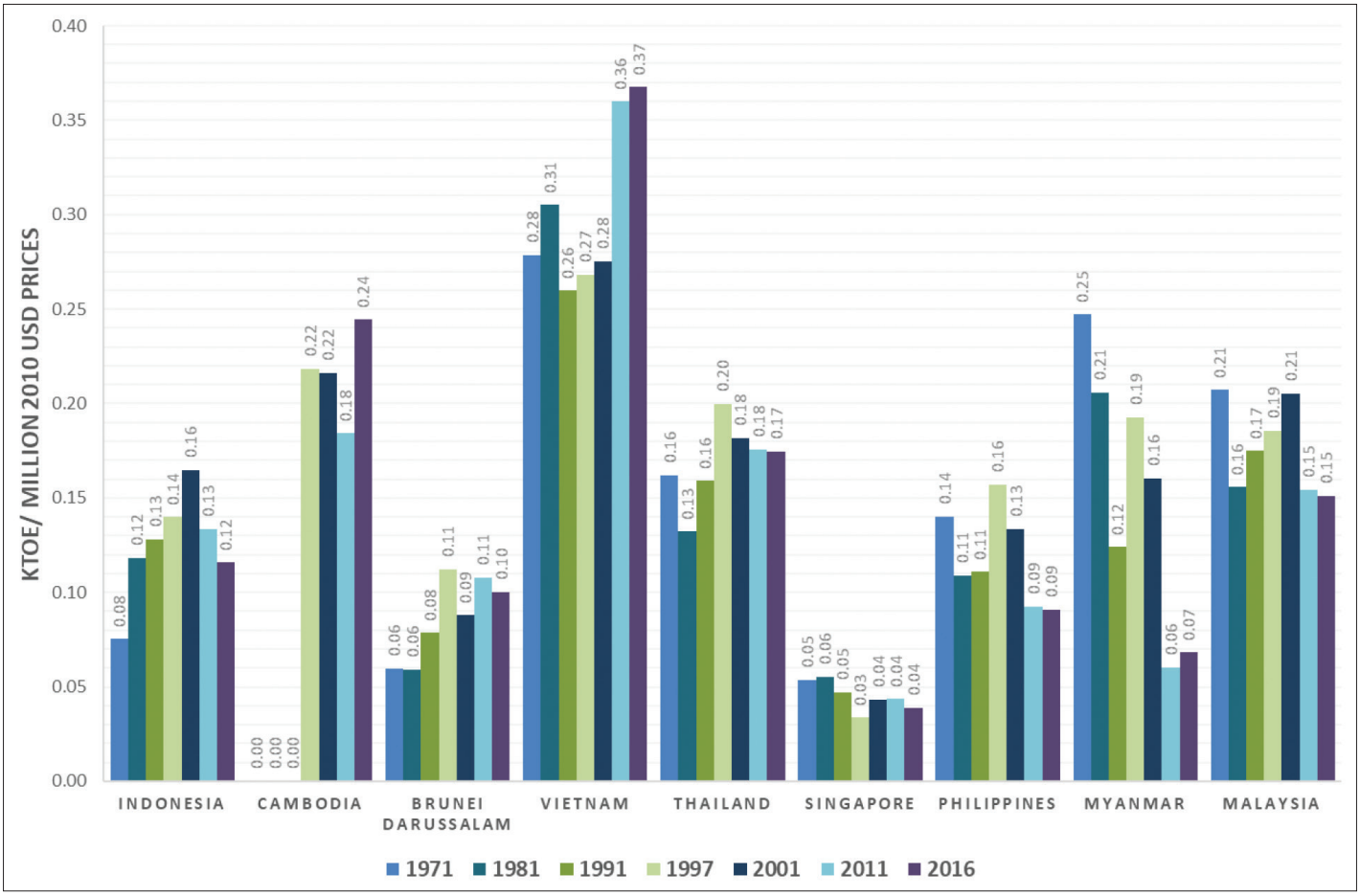
Aggregate Energy Intensity (defined as Total Final Energy Consumption per Gross Domestic Product) in ASEAN countries are moderately fluctuated in the last decades. This section analyses the driving forces affecting its energy intensity in these countries.

4.1. The Trend of Energy Intensity amongst ASEAN Countries

Figure 1 shows the energy-intensity changes in the 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 1971-1981, 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

Figure 1: Comparisons of energy intensity across ASEAN Countries



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.

4.2. Economic Structure

Overtime, all ASEAN countries experienced a remarkable growth of economic activity, however, after the 1997s financial crisis, ASEAN-6 countries experienced a slowing growth of industrial activity. Their growth followed a lower trajectory compared to the period before the economic crisis during 1970s to 1997 (Figure 2) For instance, industrial growth in Malaysia and Singapore was around 8-9% in the early 1990s but, after the crisis, the growth rate plummeted to around 3% from 1998 to 2001. During the economic crisis of 1997-2001, 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 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 Figure 3 and growth rate of value added in Figure 2 show the changes in the structure of the economy in ASEAN countries over the last 45 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 Figures 3 and 2, First, the industry sector (manufacturing) and commercial sector played a key role in the overall economic structures that accounted for around 60-80% of the total ASEAN economic output from 1971 to 2016. This sector continued to yield a large output in the 15-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

Figure 2: Value added growth of ASEAN-6

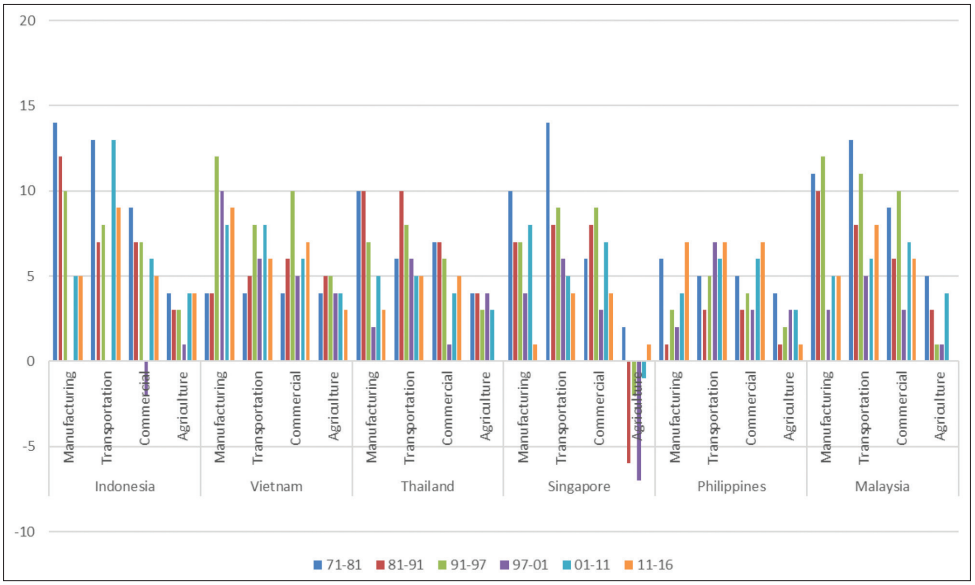
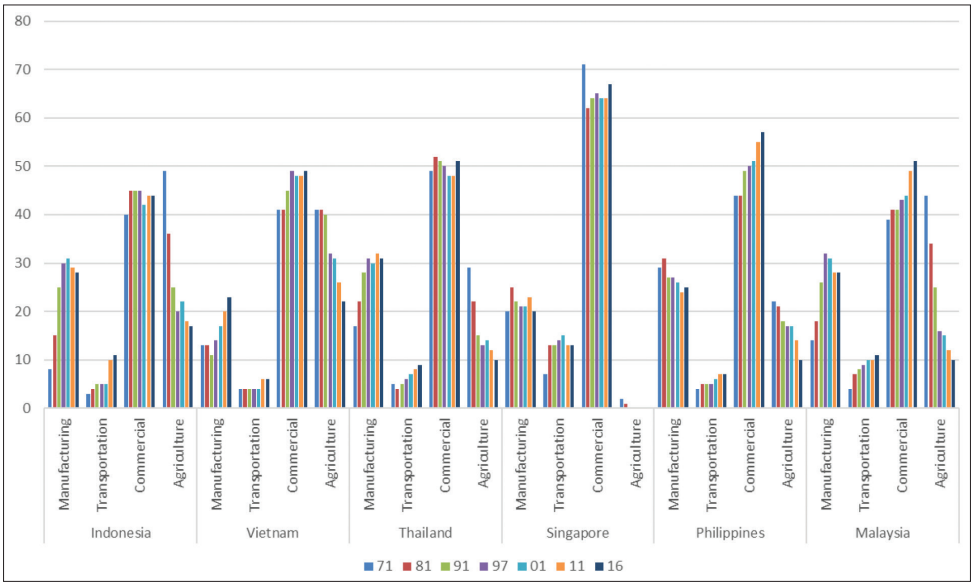


Figure 3: Value added shares of ASEAN-6



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 Figures 3 and 2 are 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 <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, Figure 3 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.

4.3. Composition of Sectoral Energy Consumption

The high growth of economic activity in ASEAN-6 also followed with high growth of its energy consumption (Figures 4 and 5). In 1971, the largest levels of energy uses were in the transportation sector, which accounted for 58% of total energy use, followed

Figure 4: Energy consumption shares of ASEAN-6

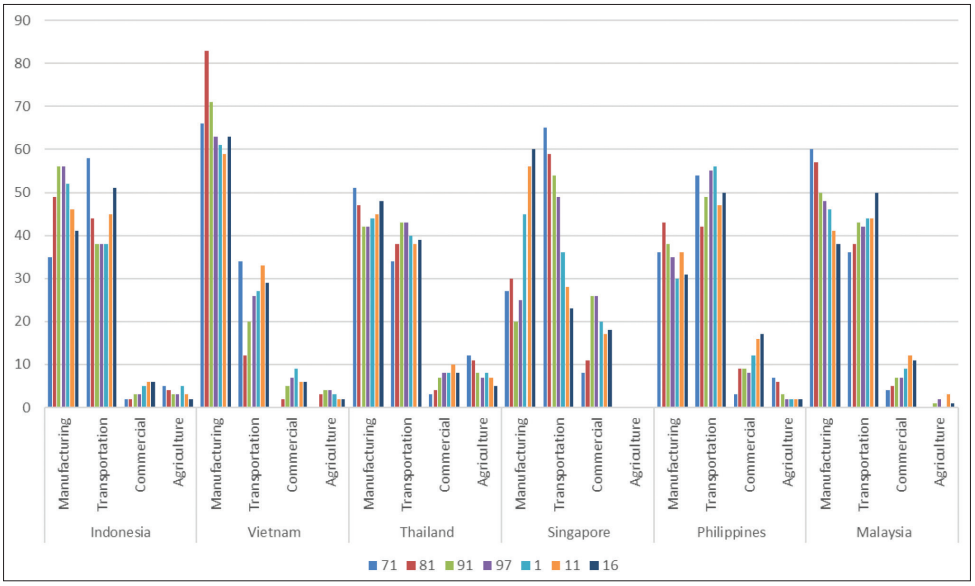
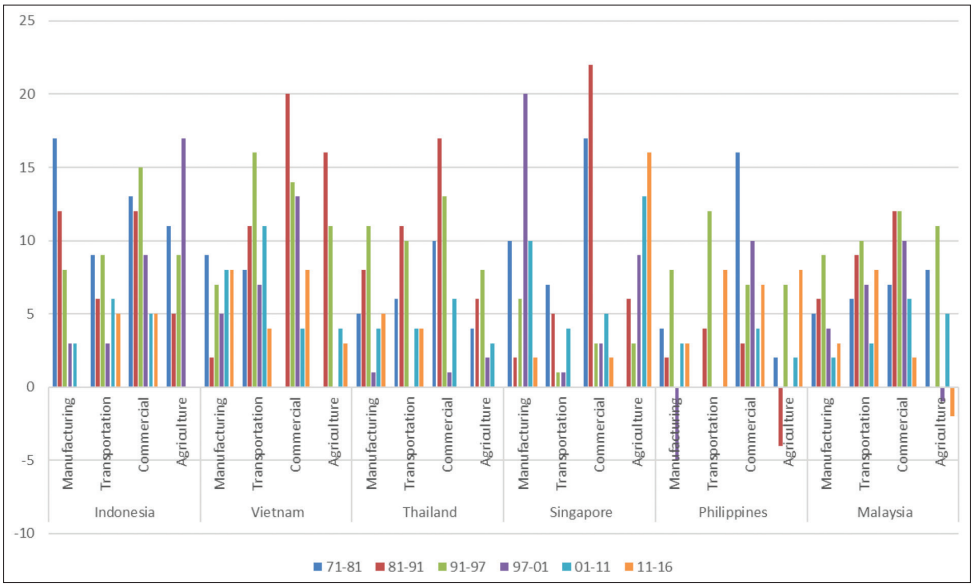


Figure 5: Energy consumption growth ASEAN-6



by manufacturing sector for around 35%, the agriculture sector had 5% and commercial <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%.

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 Figures 4 and 5, 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 5-7% 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% 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% and 10% 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.

4.4. Energy Intensity

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 (Figure 6).

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.

4.5. Decomposition Analysis of Energy Intensity

Figure 7 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. Overall, 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.

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 7 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 7, 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 7, 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

Figure 6: Aggregate energy intensity across ASEAN-6

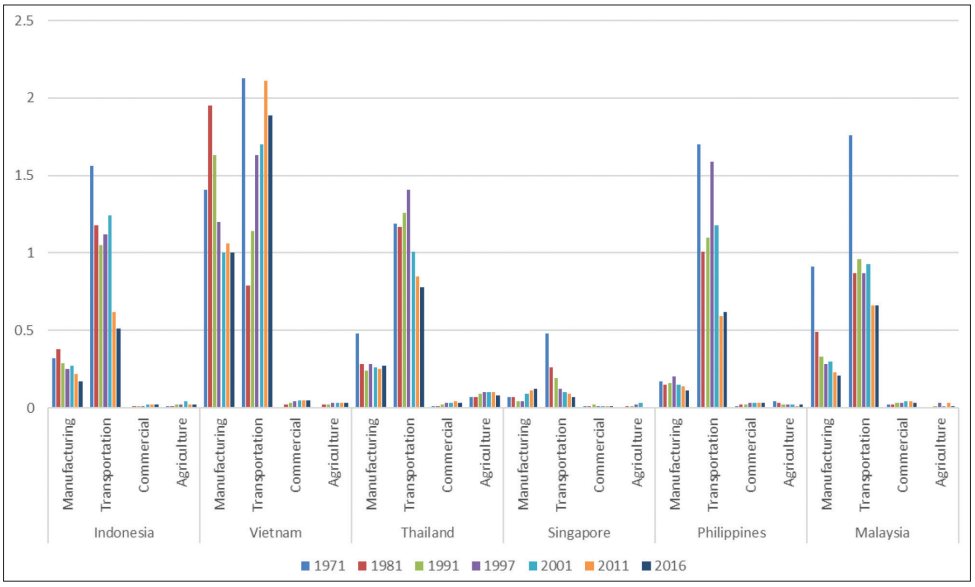


Figure 7: The trend of decomposition factors energy intensity from 1971 to 2016 (employing 1971 as the base year – Temporal decomposition)

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 and Ang (2007); González et al. (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.

4.6. Decomposition Analysis of Energy Intensity after the 1997 Financial Crisis[2]

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 energy intensity trend in ASEAN-6 differed in each country (Figure 8). 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.

2 1997 was employed as a base year because it is the year when the financial crisis hit ASEAN.

Figure 8: The trend of decomposition factors energy intensity, 1997-2016 (1997 as the base year – Temporal decomposition)

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%.

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 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 (Figure 8).

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.

5. DISCUSSION

The impact of the 1997 Financial Crisis to the aggregate energy intensity trend in ASEAN-6 differed from country to country (Figure 8). 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.

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 (Figure 8), 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 has 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.

6. CONCLUSION

Overall, it is demonstrated in this study that the aggregate trend of the changes of ASEAN-6 energy intensity in the past 45 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.

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 study 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.

To sum up, observing the sub-period decomposition analysis result, the 1% 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.

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