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Article

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Provided in Cooperation with:
International Journal of Energy Economics and Policy (IJEEP)

Reference: Nuryartono, Nunung/Rifai, Muhamad Amin (2017). Analysis of causality between economic growth, energy consumption and carbon dioxide emissions in 4 ASEAN countries. In: International Journal of Energy Economics and Policy 7 (6), S. 141 - 152.

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2017, 7(6), 141-152.

Analysis of Causality between Economic Growth, Energy Consumption and Carbon Dioxide Emissions in 4 ASEAN Countries

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ABSTRACT

Economic growth and energy consumption in 4 ASEAN countries increase in every year. Energy consumption in 4 ASEAN countries is dominated by fossil fuels which increases the carbon dioxide emission. This study examines the causality relationship between economic growth, energy consumption and carbon dioxide emissions in 4 ASEAN countries during the period of 1975-2013. Methods in this study using granger causality and vector error correction model. The result shows that economic growth and energy consumption in Indonesia and Singapore are not interconnected. While in Malaysia and Thailand, there is a direct causal relationship. A one direction relationship between economic growth and carbon dioxide emissions happened in Indonesia and Thailand, while in Malaysia and Singapore did not exist. Causal relationship between energy consumption and carbon dioxide emissions occurs Indonesia, whereas in other countries did't exist. The respond of every variables on the shock in other variables are different in each country.

Keywords: ASEAN, Carbon Dioxide Emissions, Economic Growth, Energy Consumption, Granger Causality, Vector Error Correction Model
JEL Classifications: O44, P18, Q40

1. INTRODUCTION

Sustainable development is a debatable issue, as economic development is often measured by high economic growth, increased welfare and full employment opportunities (Bermejo and Hanlon, 2014). In general, sustainable development is the condition where development meets the needs of the present generation without compromising the ability of future generations to meet their needs (Brundtland, 1987). Economic growth more likely points to quantitative change and is usually measured using the per capita gross domestic product (GDP) resulting from an economic activity over a period of time (Todaro and Smith, 2006). Every country seeks to boost its country's economic growth. One way that can be done is to establish cooperation between countries. The cooperation in Southeast Asian countries broadly known as ASEAN, was established on August 8, 1967 and consisted of 10 Southeast Asian countries, namely Indonesia, Malaysia, Philippines, Singapore, Thailand, Vietnam, Laos, Myanmar, Cambodia and Brunei Darussalam.

ASEAN was formed on the aim for promoting economic growth, social progress, and cultural development of its member countries. Based on data from the World Bank, economic growth in ASEAN countries is relatively stable in the last 10 years, amounted to 5.66% higher than the world economic growth of 2.76% during the time. This indicates that ASEAN region has the potential to become a competitive economic region. According to the World Bank, GDP per capita of a country is classified into 4 categories: High income (GDP per capita 12476 USD or more), upper middle income, lower middle income (GDP per capita 1026 USD-4035 USD) and low income (GDP per capita 1025 USD or less). Based on the given classification, there are 4 ASEAN countries that mostly represent each characteristics, Singapore as a high income country, Malaysia and Thailand as the upper middle income countries and Indonesia as the lower middle income countries.

Energy is an important part of the long-term energy availability theory that can affect economic growth (Stern, 2011). Resource experts and a number of environmental economists pay great

attention to the role of energy and its availability in economy production and the process of economic growth (Stern, 1999). Nowadays, fossil fuels are still the dominant source of energy on demand side of the world. Dependency on fossil energy, especially petroleum for consumption compliance in 4 ASEAN countries is still high which is amouted to 49% followed by gas consumption by 25%, coal consumption by 17% and electricity consumption amounted ti 9% of total energy consumption in 4 ASEAN countries (British Petroleum, 2016).

In recent years, researchers conducted research on the causality relationship between economic growth and energy consumption. The results are different in each of the countries studied. There is a one-way causal relationship between economic growth and energy consumption in Indonesia (Hwang and Yoo, 2014). Congo, Gabon and Ghana (Esso and Keho, 2016). While for other studies, it is revealed that there is no causal relationship between economic growth and energy consumption in France, Italy, Spain, Sweden, Portugal, Netherlands and Greece (Xue et al., 2015). Other studies have found a two-way causal relationship between economic growth and energy consumption in Sri Lanka (Morimoto and Hope, 2004), South Korea (Glasure and Lee, 1997) and India (Paul and Bhattacharya, 2004).

The world's dependency on fossil fuels has a serious impact on the environment. Carbon dioxide emissions released by fossil fuels are a major cause of global warming (Zhang and Cheng, 2009). Naturally, energy use will increase the level of emissions (Irfany, 2014). Global warming is caused by increasing concentrations of the greenhouse gas (GHG) effects due to human activities. In 2014, an increase in GHG concentrations by 90% came from carbon dioxide emissions and 68% of carbon dioxide emissions came from the energy sector. Thus, in energy sector, carbon dioxide emissions are mostly produced by the process of carbon oxidation in fuels (International Energy Agency, 2016).

As there are increases in energy consumption and economic growth, it is resulted the increase in carbon dioxide emissions, both in short term and long term (Shahbaz et al., 2012). Kuznets (1955), a Nobel Prize winner, hypothesized that economic growth to be inverted in U-shaped in its relation with environmental degradation, thereafter known as the Environmental Kuznets Curve (EKC) hypothesis. Based on the EKC concept, the relationship of economic activity, represented by per capita income and environmental conditions, is represented by pollutant emissions levels (Grossman and Krueger, 1991). The level of carbon dioxide emissions in 4 ASEAN countries has an average emissions level of 4.96 metric tons per capita with annual average growth of 4.13% (World Development Indicators, 2014). According to it, the economy sectors that contribute the largest carbon dioxide emissions in these 4 ASEAN countries are manufacturing and transportation with the share of the carbon dioxide emissions by 24% and 20% respectively (International Energy Agency, 2015).

In efforts for emissions mitigation, an effective policy is required to reduce the emissions without affecting the growth in economy (Irfany, 2014). The global commitment to reduce emissions levels was previously agreed upon the Kyoto Protocol through the United Nations Framework Convention on Climate Change (UNFCCC). The Kyoto Protocol regulated the implementation of emissions reductions of industrialized countries by 5 percent below the levels 1990 in the period 2008-2012 (UNFCCC, 2006). On the session of COP 18-UNFCCC in Doha, Qatar in December 2012, the consensus agreed to extend Kyoto Protocol until 2020 and setted the target of GHG emissions reduction by 18% from the levels 1990 starting in 2013-2020 (UNFCCC, 2012).

Various studies correlate the relationship between economic growth and carbon dioxide emissions (Magazzino, 2014; Abidin et al., 2015; Rezitis and Ahammad, 2015; Yildirim et al., 2014; Al Mamun et al., 2014; Alam et al., 2016). The results are different in each of the countries studied. There is a one-way causal relationship between economic growth and carbon dioxide emissions in South Africa (Menyah and Wolde-Rufael, 2010), Pakistan (Shahbaz et al., 2012), Bangladesh (Alam et al., 2012) and France (Ang, 2007). As for other studies, there is no causal relationship between economic growth and carbon dioxide emissions in the United States (Soytas et al., 2006) and Turkey (Ozturk and Acaravci, 2010). Other studies have found a two-way causal relationship between economic growth and carbon dioxide emissions in South Korea (Kim et al., 2010), India and Brazil (Pao and Tsai, 2011).

2. DATA AND METHOD

This study is conducted using the secondary time series data. The variables are per capita GDP in 2010, per capita energy consumption and per capita carbon dioxide emissions while the data period is using the annual data from 1975 to 2013. The data for this study was collected from World Development Indicators (WDI) data.

2.1. Unit Root Test

Time series data is generally stochastic or has a trend that it is not stationary which means that the data contains unit root value. A variable is said to be stationary if the average value and the variance are constant over time and the covariance value between two time periods depends only on the difference or interval between the two time periods (Gujarati, 2004). This condition is usually followed by a normal distributed residual value with zero average and a certain standard deviation (white noise).

In order to see the data stationary, the measurement is assessed using unit root test, Augmented Dickey-Fuller (ADF) test and Phillips-Perron (PP) test. Using the ADF test, the error assumption is homogeneous and independent where the lag should be predetermined unless the error in lag will affect the test results (Dickey and Fuller, 1981). Using the PP test, all variables obtained that are not stationary at level hence can be transformed to be stationary by doing the first derived process (first differencing) from the data (Box and Jenkins, 1976). The PP test employs nonparametric statistical methods to test the correlation series with unit root test (Phillips and Perron, 1988).

2.2. Co-integration Test

Co-integration test aims to determine whether the non-stationary variables are co-integrated or not. Co-integration test can be

done with Engle-Granger co-integration test and Johansen co-integration test. The Engle-Granger co-integration test uses the null hypothesis if there is no co-integration between the two variables. This method uses ordinary least squares to estimate the co-efficient of static relationships among variables (Engle and Granger, 1987). On the other hand, the Johansen co-integration test can be applied to non-stationary data at the same integration sequence level (Johansen and Juselius, 1990).

The co-integration test is done in order to obtain long-term relationship between variables that have met the requirements that all variables are stationary at the same degree of first difference. The co-integration test conducted in this study is the Johansen co-integration test. In order to see the existence of co-integration, seen from bigger value of the trace statistic than the critical value, hence it can be concluded that variables are co-integrated.

2.3. Granger Causality

Granger causality is used to test for possible causal relationship between variables (Grangers, 1969). Granger causality test is believed to be much more effective than usual. The Grangers causality equation can be seen below:

$$Y_t = a_0 + a_1 Y_{t-1} + \ldots + a_1 Y_{t-1} + \beta_1 X_{t-1} + \ldots + \beta 1 X_{t-1} \quad (1)$$

$$X_t = a_0 + a_1 X_{t-1} + \ldots + a_1 X_{t-1} + \beta_1 Y_{t-1} + \ldots + \beta_1 Y_{t-1} \quad (2)$$

Granger causality is aimed to measure the strength of relationships between variables and to indicate the direction of the causal relationship on X Y (X causing Y), on Y X (Y causing X), or X Y (X causing Y and Y causing X). The criteria in determining the causality is seen from the probability value compared to the critical value. The critical value used in this study is 5%. If the estimation of both variables stating that the probability value is <0.05, this indicates that there is causality relationship on the variables in the model.

2.4. Vector Error Correction Model (VECM)

VECM method is known as the terrestrial form of VAR method (Enders, 2014). Additional restrictions are given because of the non-stationary data at the level, but it is co-integrated. The VECM method utilizes co-integration restriction information into its specifications. The VECM specification restricts the long-term relationships of the endogenous variables to converge into their co-integration relationships, while it still allows the existence of short-run dynamics. Therefore, VECM method is often referred as the VAR design for non-stationary series which has co-integration relationships.

The basic concept of VECM method is that if at least one of the variables involved in an equation is not stationary at the data level, then the non-stationary variables are estimated by an error correction mechanism (Verbeek, 2004). This condition is due to the stationary probability (whether it is stationary or not), but in reality it has possibility for the variables to be co-integrated. This implies that there is an adjustment process from the short-term condition to the long-term condition to prevent greater errors appearance in the long-term condition.

The method used in this study is the VECM method. In equation form, the model of this study is as follows:

$$\Delta \ln GDP_t = \propto_0 + \sum_{i=1}^{p} a_i \Delta LnGDP_{t-i} + \sum_{i=1}^{p} b_i \Delta LnEne_{t-i} + \sum_{i=1}^{p} c_i \Delta LnEmi_{t-i} + \partial ECT_{t-i} + e_t \quad (3)$$

$$\Delta \ln Ene_t = \propto_0 + \sum_{i=1}^{p} a_i \Delta LnGDP_{t-i} + \sum_{i=1}^{p} b_i \Delta LnEne_{t-i} + \sum_{i=1}^{p} c_i \Delta LnEmi_{t-i} + \partial ECT_{t-i} + e_t \quad (4)$$

$$\Delta \ln Emi_t = \propto_0 + \sum_{i=1}^{p} a_i \Delta LnGDP_{t-i} + \sum_{i=1}^{p} b_i \Delta LnEne_{t-i} + \sum_{i=1}^{p} c_i \Delta LnEmi_{t-i} + \partial ECT_{t-i} + e_t \quad (5)$$

Where lnGDP, lnEne and lnEmi respectively illustrate the natural logarithm of GDP per capita, per capita energy consumption, and per capita carbon dioxide emissions, Δ is first difference, p is the optimum lag, a, b, c is the estimation parameter, and ECT is an error correction term, is a non-correlated error.

2.5. Impuls Response Function (IRF) dan Forecast Error Variance Decomposition (FEVD)

A good way to characterize the dynamic structure in a model is to analyze the response of the model if it is given a shock (Enders, 2014). There are two ways of doing this estimation: By analyzing the IRF and by the FEVD analysis. IRF analysis is a method used to determine the response of an endogenous variable to the shock of a particular variable (Amisano and Gianinni, 2012). IRF analysis is also used to view shock from other variables and how long (period) the effect will last. In support to the IRF analysis, the FEVD analysis is then used to calculate and analyze how much the random shock will effect a particular variable on endogenous variables (Amisano and Gianinni, 2012).

3. RESULTS AND DISCUSION

3.1. An Overview of Economic Growth, Energy Consumption, and Carbon Dioxide Emissions in 4 ASEAN Countries

The economy of a country can be said to grow if people's income increases over the time. GDP per capita in the 4 ASEAN countries is changing from year to year. GDP growth per capita in the 4 ASEAN countries also shows a positive trend from year to year. The development of GDP per capita of the 4 ASEAN countries for 39 years is shown in Figure 1.

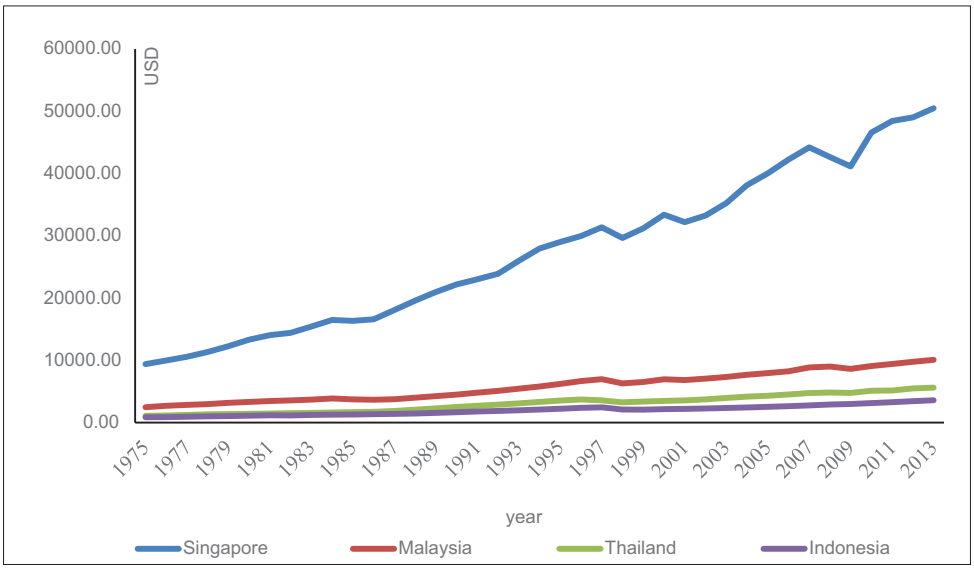
Based on Figure 1, on the top line of per capita GDP in the 4 ASEAN countries during 1975-2013 is Singapore, followed by Malaysia, Thailand and Indonesia. For Singapore, per capita GDP

growth during the given period has increased by 5.37 times from 9395.59 USD in 1975 to 50467.84 USD in 2013. This indicator makes Singapore as high income country. Meanwhile, per capita GDP of Malaysia, Thailand and Indonesia experienced an average increase by 4.51 times from 1975 to 2013. In 2013, per capita GDP in Malaysia and Thailand amounted to 10062.91 USD and 5612.69 USD respectively. According to the World Bank, a country with per capita GDP above 4036 USD is categorized as upper middle income country. Malaysia and Thailand are among the top middle income countries. While for Indonesia, per capita GDP in 2013 is below 4036 USD, therefore Indonesia is a lower middle income country.

Developed countries with bigger per capita income tend to have small and constant economic growth, year-to-year changes are getting smaller and they are also nearing the full employment condition. Meanwhile, developing countries have lower per capita income but high economic growth as it is not yet on their full employment condition. The per capita GDP growth during the period 1975-2013 in the 4 ASEAN countries has an average growth of 4.2%. The per capita GDP growth in the 4 ASEAN countries is shown in Figure 2.

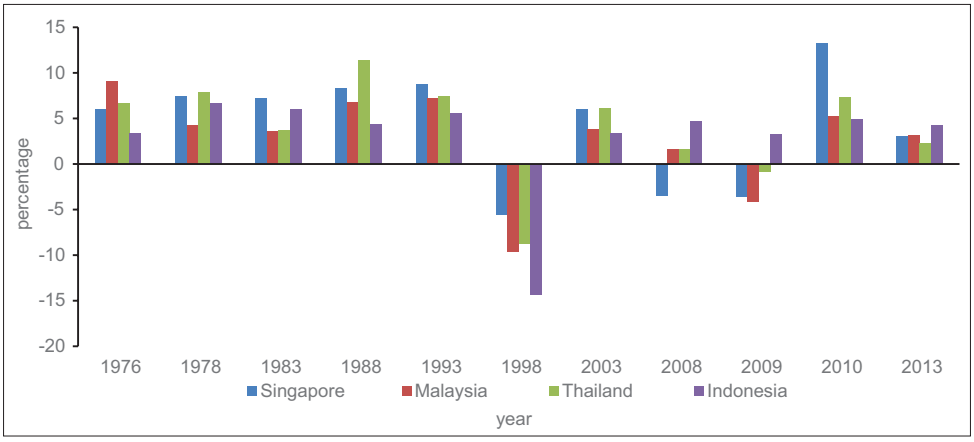
Figure 2 illustrates that the growth of per capita GDP in the 4 ASEAN countries is fluctuating every year. The growth of per capita GDP in the 4 ASEAN countries in 1975-2013 has an average growth of 4.42%. Developed countries like Singapore have a constant economic growth as the economy has reached a stable condition. When the country has reached a steady state condition, then it is relatively difficult to increase the country's economic growth. Economic growth in the 4 ASEAN countries experienced negative growth in 1998. This is due to the monetary crisis that occurred in Southeast Asia and East Asia that had brought tremendous impact on the economies of the 4 ASEAN countries. During the 1998 crisis, the economic growth of each country rocked the negative level with Singapore grew by −5.49%, Malaysia grew by −9.63%, Thailand grew by −8.69% and Indonesia grew by −14.35%. The country with the greatest impact from the economic crisis in 1998 was the country with the greatest negative economic growth.

Figure 1: Illustration of per capita gross domestic product in 4 ASEAN Countries in 1975-2013 (USD)



Source: World Bank (2017)

Figure 2: Illustration of per capita gross domestic product growth in 4 ASEAN Countries in 1975-2013



Source: World Bank (2017)

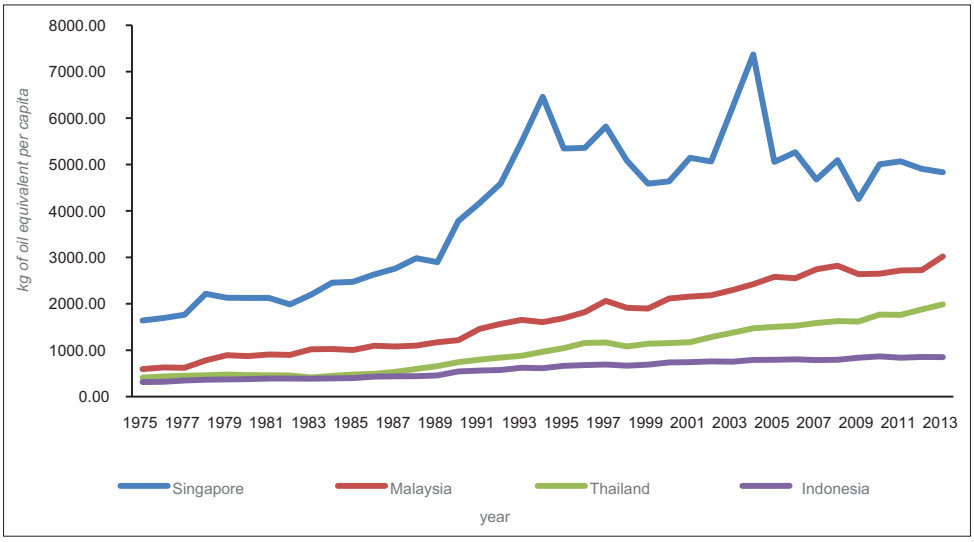
Energy consumption in the world changes every year, including in the 4 ASEAN countries. The development of energy consumption in the 4 ASEAN countries in 1975-2013 can be explained in Figure 3.

Figure 3 shows the level of energy consumption in Singapore with fluctuating developments. In 2004, energy consumption in Singapore reached its peak and began to decline for the next year, this is caused by the structure of Singapore's economy that dominated by the service sector. Energy consumption in Thailand, Malaysia and Indonesia shows having their energy consumption increasing every year. Energy consumption in the 4 ASEAN countries is still dominated by fossil energy, especially petroleum, gas and coal.

The policy of each country in developing renewable energy is still being reviewed by ASEAN through the ASEAN Plan of Action for Energy Cooperation which targeting renewable energy consumption to increase by 24% from the total energy consumption in 2025. The target of renewable energy in Indonesia through Energy Act No. 30/2007, revised in October 2014, targeted renewable energy in Indonesia in 2025 to grow by 23% and by 32% by 2050. In case of Malaysia, the target to increase renewable energy is set by 29% in 2050. Singapore targeted to increase 9% of renewable energy by 2020 and Thailand targeted renewable energy to increase by 40% by 2036 (ASEAN Center for Energy, 2016).

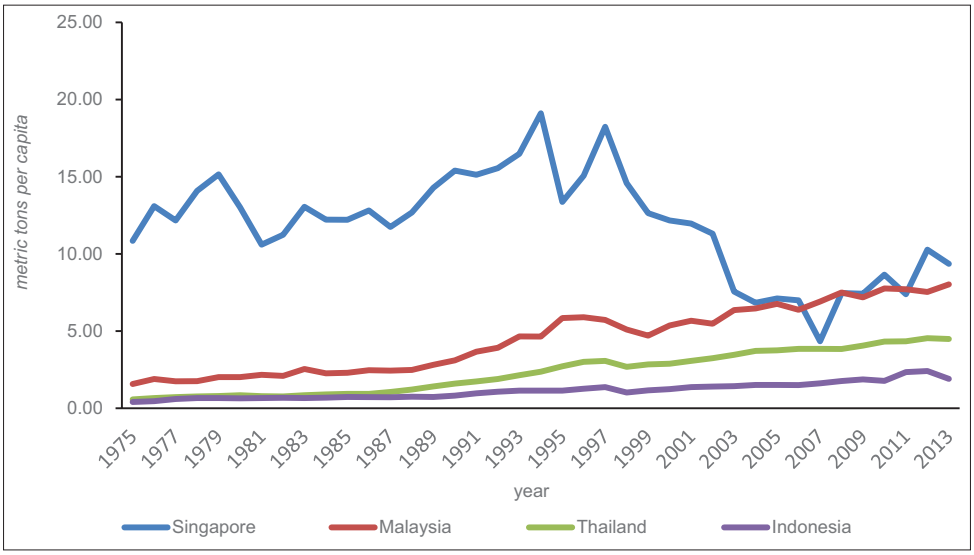
The world's dependency on energy consumption dominated by fossil fuel has a serious impact on the environment. Increased energy consumption of fossil fuels increases the carbon dioxide emissions in the air that results in GHG effects. Carbon dioxide emissions in the 4 ASEAN countries are changing every year. Changes in carbon dioxide emissions in the 4 ASEAN countries in 1975-2013 are shown in Figure 4. Continent

Figure 3: Illustration of per capita energy consumption in 4 ASEAN Countries in 1975-2013



Source: World Bank (2017)

Figure 4: Illustration of per capita carbon dioxide emissions in 4 ASEAN Countries in 1975-2013



Source: World Bank (2017)

According to Figure 4, the level of carbon dioxide emissions in the 4 ASEAN countries is growing annually. The level of carbon dioxide emissions in the 4 ASEAN countries has an average emissions level of 4.96 metric tons per capita with annual average growth of 4.13%. Singapore has the highest emissions level with an average emissions average of 11.89 metric tons per capita produced annually. The increasing in carbon dioxide emissions in Singapore tends to fluctuate, where in 1998 the emissions level reached the maximum level and subsequently decreased afterward resulted in 1.3% of carbon dioxide emissions growth level. In the case of Malaysia, Thailand and Indonesia, the emissions level grows annually with average growth level of 4.76%, 5.7%, 4.63% respectively. Overall, the growth of carbon dioxide emissions level in the 4 ASEAN countries hit the average level of 4.13% per year which could lead the causes of global warming as the increase in GHG effects as a result climate changes will be in the extrem.

3.2. Results of Unit Roots Test

The test is using the PP test in order to see the stationarity. The PP statistical value of each variable will show the results of the PP test. When PP statistic value is smaller than the McKinnon critical value, then it indicates that the data is stationary. The critical value used in this study is at the level of 5%. But there is also another way that can be used to see root of the unit through its probability value (P value). If the probability value is below α = 5% then the data does not have the unit root and the data is stationary, otherwise if the probability value is greater than α = 5%, then the data has unit root but it is not stationary.

Table 1 shows that all variables of per capita carbon dioxide emissions, per capita energy consumption and per capita GDP in all countries are not stationary at the given significance level but stationary in first difference. If the data is stationary in first difference then the co-integration test is taken. If each variable is co-integrated then the method to use is VECM while otherwise if each variable is not co-integrated the method to use is VAR first difference.

3.3. Results of Co-integration Test

The co-integration test is performed using the optimal interval in accordance with the previous test. The optimal lag in this study is 1 for all 4 ASEAN countries. Non-stationary variables at the significance level increase the potential for co-integration relationships among variables, then the co-integration test needs to be done in this study.

Based on the results, there is co-integration between the variables per capita carbon dioxide emissions, per capita GDP and per capita energy consumption in Indonesia, Malaysia, Thailand and Singapore. This indicates that the estimates used for the 4 countries using the VECM estimates.

3.4. Result of Granger Causality Test

The result of granger causality test in the 4 ASEAN countries can be seen in Table 3. Based on the results, energy consumption in Indonesia has an effect on carbon dioxide emissions while carbon dioxide emissions has no effect to energy consumption. The causality relationship between economic growth and carbon dioxide emissions is unidirectional causality relationship, where economic growth affects carbon dioxide emissions but otherwise the carbon dioxide emissions do not affect economic growth. In addition, there is no causal relationship between economic growth and energy consumption in Indonesia.

Table 1: Results of stationary test

Country	Variable	Level		First difference	
		PP t-statistic	P	PP t-statistic	P
Indonesia	Ln_Emi	−1.69	0.42	−5.66	0.00***
	Ln_Ene	−1.71	0.41	−6.07	0.00***
	Ln_GDP	−0.94	0.76	−4.50	0.00***
Malaysia	Ln_Emi	−1.11	0.69	−7.40	0.00***
	Ln_Ene	−2.87	0.05	−6.43	0.00***
	Ln_GDP	−1.34	0.59	−5.13	0.00***
Singapore	Ln_Emi	−0.33	0.55	−8.07	0.00***
	Ln_Ene	1.38	0.95	−6.49	0.00***
	Ln_GDP	6.49	1.00	−2.88	0.00***
Thailand	Ln_Emi	0.88	0.89	−2.99	0.00***
	Ln_Ene	3.95	0.99	−3.13	0.00***
	Ln_GDP	4.92	1.00	−2.11	0.03**

Source: Author's estimation. ***, **, *Denoted probability value is smaller than critical value at significance level of 1%, 5% and 10%

Table 2: Results of co-integration test

Country	Trace statistic	0.05 critical value	P**	Result
Indonesia	29.80	29.79	0.04	Co-integration
Malaysia	33.26	29.79	0.02	Co-integration
Singapore	26.03	24.27	0.03	Co-integration
Thailand	28.15	24.27	0.02	Co-integration

Source: Author's estimation

Using the causality test, there is no causal relationship between energy consumption and carbon dioxide emissions in Malaysia as economic growth and carbon dioxide emissions in Malaysia have no causal relationship. The relationship between economic growth and energy consumption has unidirectional causal relationship, where economic growth affects energy consumption but otherwise the carbon dioxide emissions do not affect economic growth. The results of causality test in Singapore showing that there is no causal relationship between all variables, (i) economic growth and energy consumption shows no causality relationship, (ii) economic growth and carbon dioxide emissions have no causal relationship, (iii) energy consumption and carbon dioxide emissions have no causality relationship. Meanwhile in Thailand, based on the results, there is no causality relationship between energy consumption and carbon dioxide emissions. Economic growth has unidirectional causal relationship with carbon dioxide emissions, where it indicates that economic growth affects carbon dioxide emissions but carbon dioxide emissions has no effect on economic growth. The relationship between economic growth and energy consumption has unidirectional causal relationship, where economic growth affects energy consumption while otherwise energy consumption has no effect on economic growth.

3.5. VECM Estimation Result

Based on co-integration test, there is co-integration between economic growth, energy consumption and carbon dioxide

Table 3: Results of granger causality in 4 ASEAN Countries

Country	ENE→EMI	EMI→ENE	GDP→EMI	EMI→GDP	GDP→ENE	ENE→GDP
Indonesia	10.24 (0.00)	0.42 (0.52)	5.19 (0.03)	0.21 (0.65)	0.71 (0.41)	0.03 (0.85)
Malaysia	1.50 (0.23)	1.09 (0.30)	3.32 (0.08)	2.93 (0.10)	7.98 (0.01)	0.00 (0.97)
Singapore	2.39 (0.13)	0.21 (0.64)	2.38 (0.13)	0.00 (0.95)	0.56 (0.45)	0.12 (0.73)
Thailand	0.19 (0.66)	4.09 (0.05)	4.49 (0.04)	2.91 (0.09)	5.49 (0.02)	0.92 (0.34)

Source: Author's estimation. Bold numbers are statistically significant at the significance level of 5%

emissions in the 4 ASEAN countries. With the co-integration and non-stationary data at the significance level, the VECM model is used in this study. The results of VECM estimation shows that in the short term there are no variables that significantly affect carbon dioxide emissions, energy consumption and economic growth in Indonesia. In the long term, economic growth significantly affects carbon dioxide emissions. The VECM estimation shows that in the short term economic growth has significant effect on carbon dioxide emissions in Malaysia. For energy consumption and economic growth, in the short term, there are no significant variables can affect these two variables. In the long term, all significant variables affect carbon dioxide emissions, energy consumption affects positively while economic growth negatively affects carbon dioxide emissions. In Singapore, the VECM estimation shows that there are no variables that significantly affect carbon dioxide emissions, energy consumption and economic growth in the short term. In the long term, economic growth and energy consumption variables do not significantly affect carbon dioxide emissions. Meanwhile in Thailand, the VECM estimation resulted in significant economic growth that has positive effect on carbon dioxide emissions and the significant variable affecting economic growth is the economic growth in lag 1, whereas no significant variables affect energy consumption. In the long term, the variable of economic growth and energy consumption significantly influence carbon dioxide emissions, energy consumption has positive effect while economic growth has negative effect to carbon dioxide emissions.

3.6. IRF and FEVD Result

The IRF analysis in this study was conducted to seek for economic growth response to energy consumption shocks and carbon dioxide emissions, carbon dioxide emissions response to economic growth and, energy consumption response to economic growth and carbon dioxide emissions. The time period used in analyzing the response of each variable is in the range of 20 years in 4 ASEAN countries.

The shocks in economic growth and energy consumption responded positively to carbon dioxide emissions in Indonesia. The response of energy consumption to carbon dioxide emissions shocks is positive in the early stages but in general it is negative. Energy consumption response to economic growth shocks is positive. Shocks in carbon dioxide emissions growth and energy consumption responded positively by economic growth in Indonesia (Figure 5).

The shocks in economic growth and energy consumption responded positively to carbon dioxide emissions in Malaysia. The response of energy consumption to carbon dioxide emissions shocks and economic growth shocks is positive. The shocks in carbon dioxide emissions and energy consumption are positively responded by economic growth in Malaysia (Figure 6).

In Singapore, the shocks in economic growth and energy consumption responded negatively to carbon dioxide emissions. The response of energy consumption to carbon dioxide emissions shocks and economic growth is positive. The shocks in carbon dioxide emissions are positively responded by economic growth, while energy consumption shocks are positively responded by economic growth in the 1st to the 5th year, afterward the response is negative (Figure 7).

In Thailand, the shocks in economic growth and energy consumption responded positively to carbon dioxide emissions. The response of energy consumption to carbon dioxide emissions shocks and economic growth shocks is positive. The shocks in carbon dioxide emissions and energy consumption are positively responded by economic growth (Figure 8).

The decomposition analysis result of the economic growth variant shows that the value variation of economic growth in the 1st year is explained by the shocks itself, carbon dioxide emissions and energy consumption. At the end of period, the most contributing shock is the economic growth of Indonesia, Malaysia and Singapore. While in Thailand, the biggest contributing shock that affects economic growth is carbon dioxide emissions (Figure 9).

The result of energy variance decomposition analysis in the 4 ASEAN countries shows that variation of energy consumption value in the 1st year is explained by the shocks itself and the shocks in carbon dioxide emissions. New economic growth shocks appeared in the 2nd year. At the end of the period, the most contributing shock is energy consumption in Indonesia and Singapore. While in Malaysia and Thailand, the biggest contributing shock is carbon dioxide emissions (Figure 10).

The result of decomposition analysis of the carbon dioxide emissions variant in the 4 ASEAN countries shows that the variation of carbon dioxide emissions value in the 1st year is explained by the shocks itself by 100%. In 2nd year, the contribution of carbon dioxide emissions shock decreases and the rest is explained by shocks in energy consumption and economic growth. In the 3rd year onwards, the contribution of carbon dioxide emissions continues to decline, while the contribution of energy consumption and economic growth increases. At the end of the period, the biggest contribution shock is carbon dioxide emissions in Malaysia, Thailand, and

Figure 5: Impulse response function in Indonesia

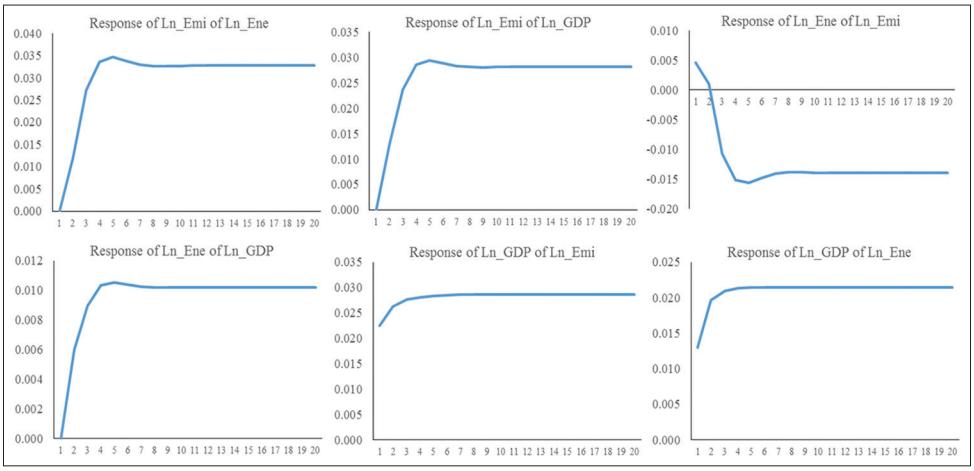


Figure 6: Impulse response function in Malaysia

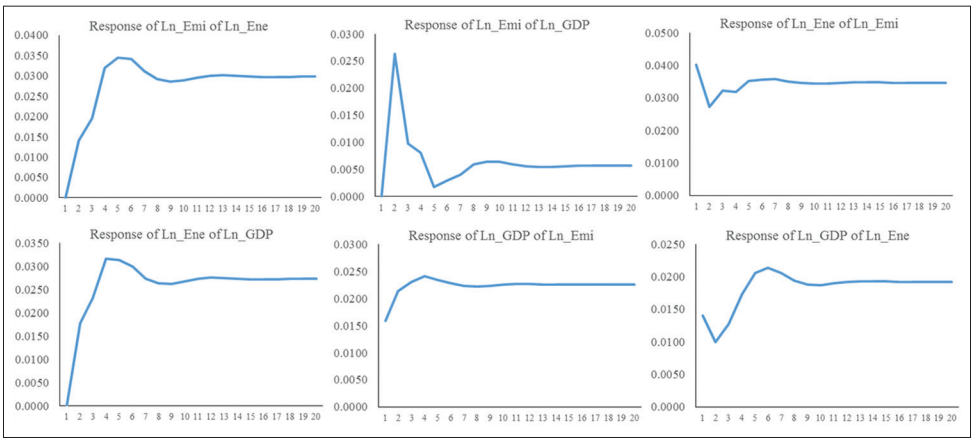
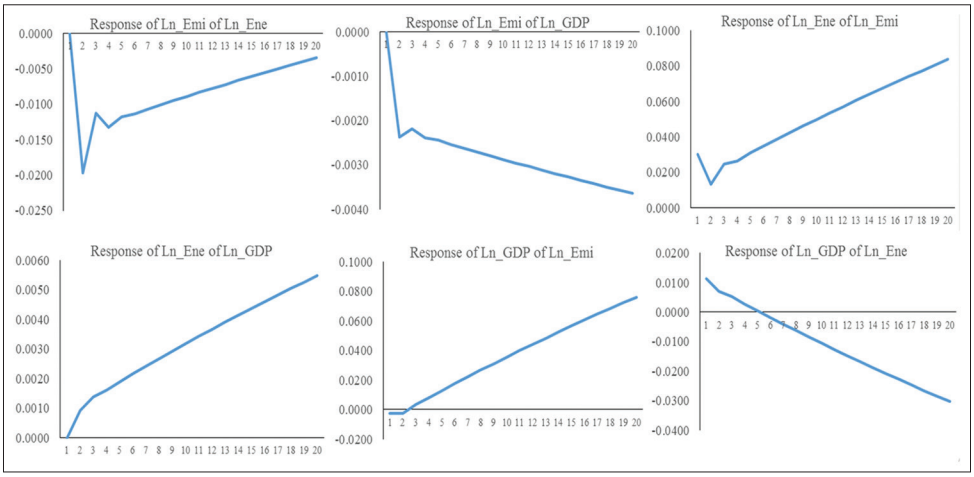


Figure 7: Impulse response function in Singapore



Singapore. While in Indonesia, the biggest contribution is energy consumption (Figure 11).

4. CONCLUSIONS

Based on the analysis and discussion results, as previously described, it can be drawn into few conclusions. Using the Granger Causality test, it shows that the causality relationship between economic growth and energy consumption in Indonesia and Singapore has no relationship between each variable. While in Malaysia and Thailand, there is a direct causal relationship between economic growth and energy consumption. Economic growth affects energy consumption in Thailand and Malaysia. The causal relationship between economic growth and carbon dioxide

Figure 8: Impulse response function in Thailand

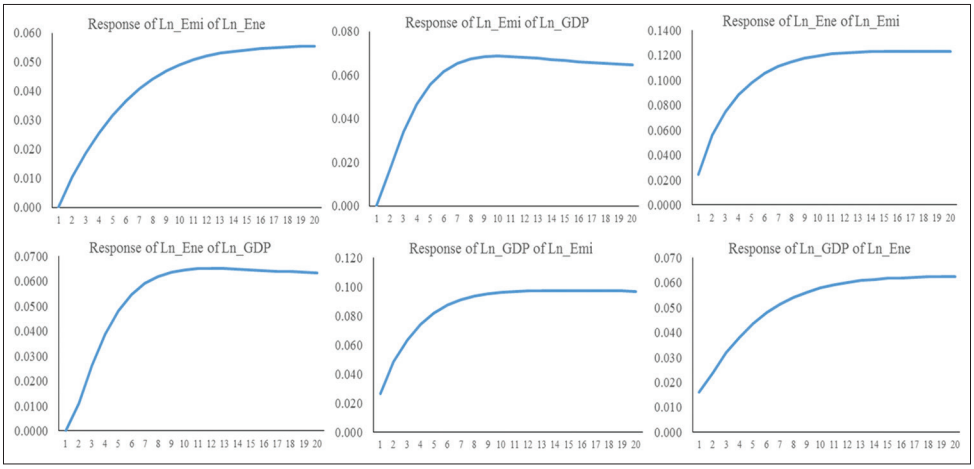
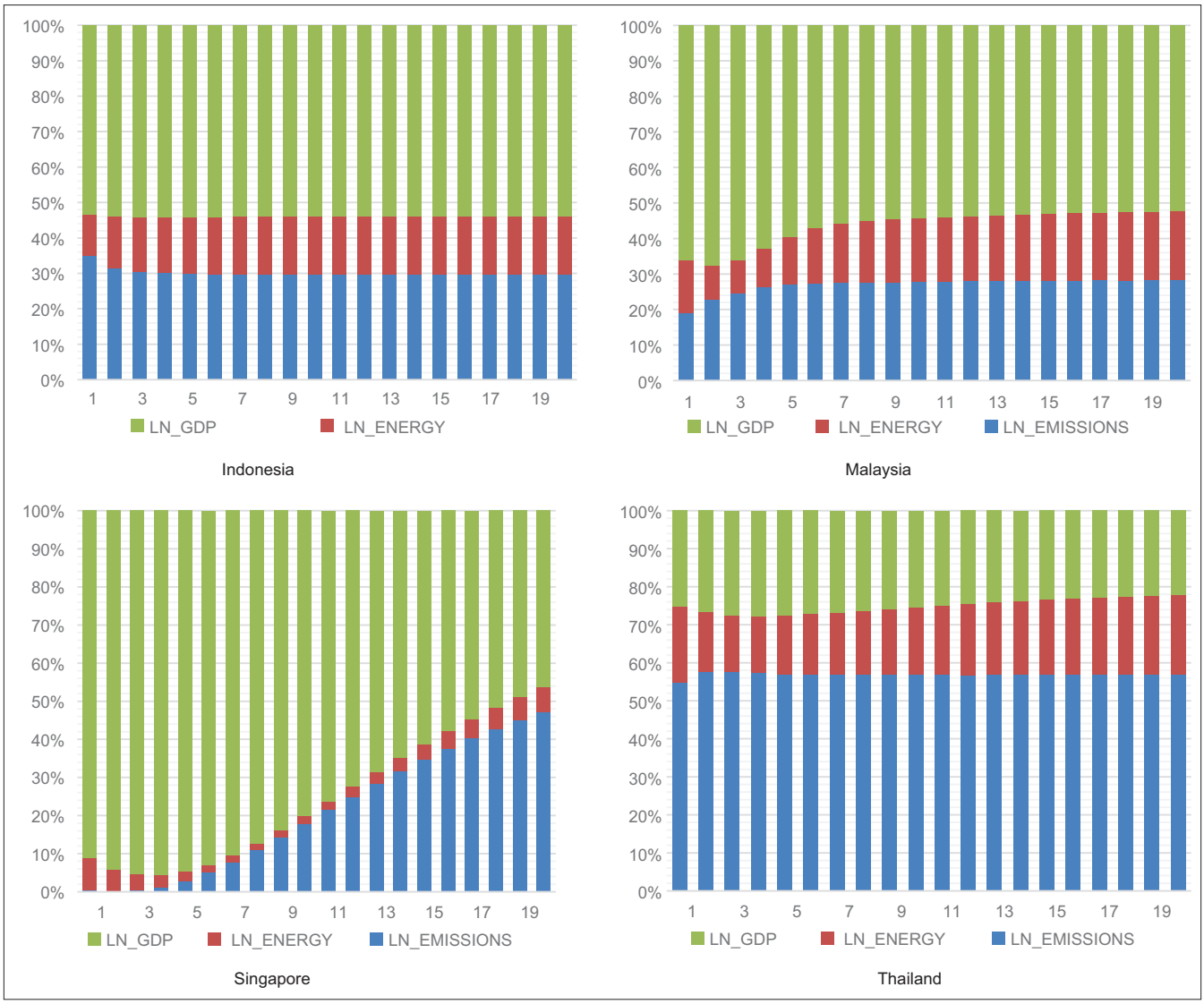


Figure 9: Variant decomposition of economic growth in 4 ASEAN Countries



emissions in Singapore and Malaysia has no causal relationship. A causal relationship exists in Thailand and Indonesia where economic growth affects carbon dioxide emissions. The causal relationship between energy consumption and carbon dioxide emissions in Malaysia, Thailand and Singapore has no causal relationship. While in Indonesia there is a direct causal relationship.

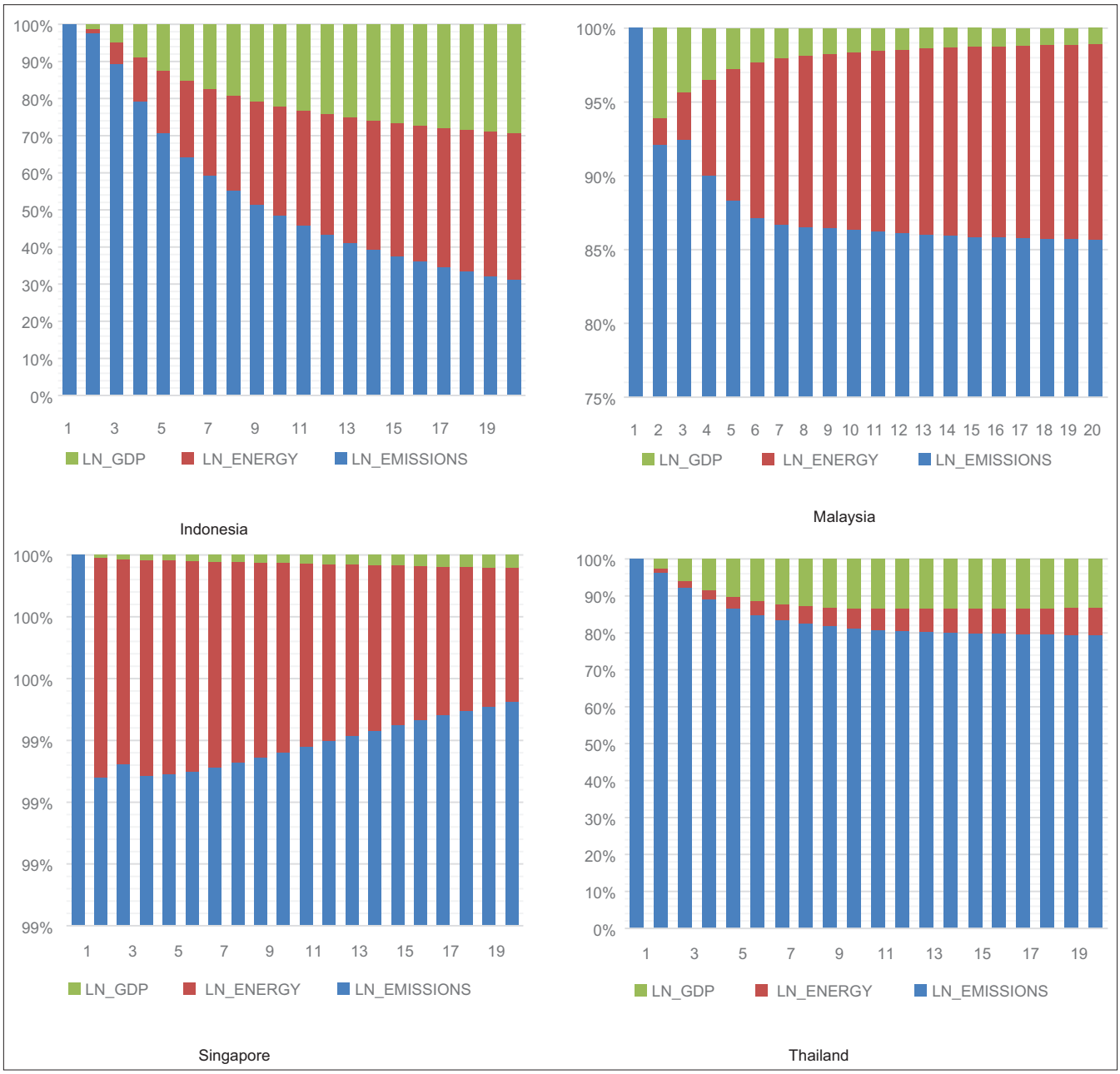
Figure 10: Variant decomposition of energy consumption in 4 ASEAN Countries

Using VECM test, it shows that in the short term there are no significant variables affecting carbon dioxide emissions in Indonesia and Singapore. While in Malaysia and Thailand, economic growth has significant effect on carbon dioxide emissions. In the short term, there are no significant variables affecting energy consumption in the 4 ASEAN countries. Also in the short term, the significant variable affecting economic growth is the t−1 economic growth in Thailand, whereas in other countries, there are no significant variables affecting economic growth. In long term, economic growth significantly affects carbon dioxide emissions in Indonesia, Malaysia and Thailand. Energy consumption significantly affects carbon dioxide emissions in Malaysia and Thailand. While in Singapore, in the long term, there is no significant variable affecting carbon dioxide emissions.

Based on IRF test, it shows that the shocks in economic growth and energy consumption responded positively by carbon dioxide emissions in Indonesia, Malaysia and Thailand, while in Singapore it responded negatively. The response of energy consumption to economic growth shocks is positive across all 4 ASEAN countries. The shocks in carbon dioxide are positively responded by economic growth in 4 ASEAN countries. The response of economic growth to energy consumption shocks is positive in Malaysia, Thailand and Indonesia, while in Singapore, the shock of energy consumption is responded negatively by economic growth.

Based on FEVD results, it shows that the shocks that contribute the most to carbon dioxide emissions are carbon dioxide emissions in Malaysia, Thailand, and Singapore. While in Indonesia, the biggest contribution is energy consumption. The shocks that contribute the most to energy consumption are energy consumption in Indonesia and Singapore. While in Malaysia and Thailand, the biggest contribution is carbon dioxide emissions. The shocks that contribute the most to economic growth are economic growth

Figure 11: Variant decomposition of carbon dioxide emissions in 4 ASEAN Countries



in Indonesia, Malaysia and Singapore. While in Thailand, the biggest contribution that affects economic growth is carbon dioxide emissions.

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