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Can Energy Intensity Impede the CO_2 Emissions in Indonesia? LMDI-Decomposition Index and ARDL: Comparison between Indonesia and ASEAN Countries

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ABSTRACT

In several ways, the AEC has increased connectivity between the businesses, merging business activities, and funneling them to end customers. Moreover, it increased energy consumption and increased CO_2 emissions in ASEAN countries. This study analyzed the driving factors of carbon emissions in ASEAN and identified the differences between member countries based on decomposing the extended Kaya identity via the logarithmic mean divisia index (LMDI) method. Since the energy intensity effect "EI-effect," gross domestic effect "GDP-effect," population effect "POP-effect" and CO_2 emission effect "CO_2-effect" were a mixture of I(0) and I(1), Johansen cointegration test cannot be applied. Hence the study deployed an autoregressive distributed lag (ARDL). This study's ARDL model captured a long-run and short-run relation of the whole cointegrated variables in ASEAN countries. Based on a panel of cross-country and time-series observations, the study analyses that the ARDL model was used to cover a model of short-and long-run implications. Based on the result, we identified the root cause of significantly increasing CO_2 emission in the past 36 years. This study's result was that a positive long-run relationship interacted with a mostly negative short-run relationship between the energy intensity' EI-effect,' gross domestic effect' GDP-effect,' population effect' POP-effect "and CO2 emission effect' CO2-effect."

Keywords: ASEAN, LMDI-Decomposition Index, ARDL, VECM
JEL Classifications: P18, P28, Q47

1. INTRODUCTION

Three scenarios were used for the projected demand and energy supply period in Indonesia, such as Business As Usual (BaU), the Continuous Development Scenario (PB), and the Low CARBON Scenario (RK) (Suharyati et al., 2019). The same basic gross domestic income (GDP) growth assumption is used in these three scenarios, with average GDP growth of 5.6% per year and population growth of 0.7% for the same population. Kebijakan Energy National (KEN) targeted a renewable energy mix in the primary energy mix at least 23% in 2025 and minimizes the petroleum use by <25% in 2025. Besides, energy efficiency was also targeted down 1% per year to encourage energy consumption savings in all sectors. The projected demand for the national final energy scenario BaU, PB, and RK will increase with the average growth per year. Industrial and transportation sectors will still dominate the final energy demand until 2050 as conditions in the year 2018. In the year 2050, the industrial sector will dominate more than the other sectors. Meantime the total projected Indonesia CO_2 emissions in 2030 would increase to 912 million tones CO_2eq (BaU), 813 million tons CO_2eq (PB), 667 million tones CO_2eq (RK). Also, per capita emission indicators showed an increase of 1.7 tones of CO_2/capita in 2018-6.4 tons of CO_2/capita (BaU), 5.3 tons of CO_2/capita (PB), 3.3 tones of

CO_2/capita (RK) in 2050, in line with increasing emissions and population growth.

In 2016, the ASEAN Economic Community ("AEC") emerged. In 2018, with a total GDP of USD 3.0 trillion, AEC is actually the world's fifth largest economy (The ASEAN Secretariat, 2019). Indonesia was destined to play an important role. Within the AEC role, Indonesia has a crucial market. Indonesia will be all-eyed by undeniable trends like urbanization and consumerism. Indonesia is one of 10 ASEAN members and the AEC, i.e., Brunei, Cambodia, Indonesia, Malaysia, Myanmar, Singapore, Thailand, Laos, the Philippines, and Vietnam. Since then, a few Multilateral Free Trade Agreements have been ratified by Indonesia and the AEC, leading to a reduction in market barriers for neighboring countries. Together with six free trade agreement partners: India, China, Japan, Korea, Australia, and New Zealand, the 'Regional Comprehensive Economic Partnership ("RCEP") was formed. In many areas such as production and the supply chain, linking business activities and channeling to end customers, the AEC and RCEP have increased cooperation between the various business sectors. It will ultimately increase the consumption of energy and increase CO_2 emissions.

Many factors affect the relationship between energy and economic development. Detailed indicators between energy use and activity were necessary to give a reasonable interpretation of the aggregated indicators for the country as a whole. Increased activity and economic growth were the most important explanations of total energy use in the economy. This study was to analyse the driving factors of carbon emissions in ASEAN and identify the differences between member countries based on decomposing the extended Kaya identity via the Logarithmic Mean Divisia Index (LMDI) method during 1971-2017. It was to respond to the question on How has carbon abatement in ASEAN over the past 36 years? What will happen if the trend was going to continue? After assessing the decomposition values, we launch the measurement model's robustness through granger causality and vector error correction model (VECM). Furthermore, the performance evaluation model was also discussed. Based on the result, we identify the root cause of significantly increasing CO2 emission in the past 36 years.

2. LITERATURE REVIEW

Decomposition analysis is performed to decompose increases in CO_2 emissions into many predefined variables. Laspeyres index was used in the early 1990s. The Laspeyres index and the Divisia index are the overall index decomposition analysis (IDA) to date. The Laspeyres index calculates the percentage change over time in certain aspects of a category of items, using values-based weights for a particular base year. The Laspeyres index method results are measured in the same way as LMDI, but with a percentage change from the base year to year t. However, the Divisia index is a weighted sum of the logarithmic growth rates where the weights are the share of the total value of the components. IDA is more widely accepted as a decomposition method because of the simplicity of adoption, ease of use, and relatively low data requirement. In terms of their benefits and drawbacks, Ang (2015) summarizes the IDA processes then advocated, for general use, the logarithmic mean divisia index (LMDI). The IEA is pioneering LMDI, and then most of the researchers follow after. The addictive LMDI decomposition and extended KAYA identity are used in this paper to capture the various effects of energy consumption shifts.

Ma and Stern, 2008; Zhang (2019) use LMDI as decomposition analysis in their studies coupled with the expanded Kaya identity. Integrating Kaya identity and LMDI for decomposition into total energy-related CO_2 also have been performed in the construction sector by Ma and Cai (2018). The research about the decoupling study between economic growth and CO_2 emissions to measure critical determinants of or energy use emerged when the OECD put it as its environmental strategy. Additionally, research such as Kojima and Bacon (2009) and de Freitas and Kaneko (2011) shows that popularity increases due to the combination of index decomposition. Some researchers have combined decomposition or decoupling analysis and LMDI methods with econometric methods like practical VECM (Jiang and Liu, 2014; Moutinho et al., 2015; Zhang and Su, 2016). Despite national reach, others decide to study in the different sectoral industry (Zhao et al., 2016). Toba and Seck (2016) clarified how different decomposition factors are interlinked. They thought that incorporating elements of the energy systems that contribute to the climate and community would promote energy policy. Meantime, Zhang and Su (2016) select ten indicators of rural household energy consumption, then placed all at four-dimension share factors: Social, economic, technological, and environmental. This paper used the same methodology as Pui and Othman (2019a). Pui and Othman (2019b) explored the economic, technological, and social aspects of the aggregate decomposition process.

The purpose is to gauge the relative strength of these four effects on emission changes. The paper decomposes four factors into four effects considering all the POP-effects, GDP-effects, EI-effects, and CO_2-effects using the LMDI approach. Firstly, we analyze the change in energy consumption in four effects. Then we deployed the VECM to investigate the causality between POP-effects, GDP-effects, EI-effects, and CO_2-effects relating to CO2 emissions growth in ASEAN countries, including Indonesia. It is used The pooled mean group estimator and causality analysis.

3. METHODOLOGY/MATERIALS

This study employed the addictive LMDI decomposition method. Under LMDI, one factor can be decomposed into different elements, and LMDI can measure the influence of those factors over one factor. In This study, authors can compose CO2 into POP-effect, GDP-effect, EI-effect and CO_2-effect factors for Indonesia and ASEAN countries from 1971 to 2016. The Data of CO_2 gas emission, GDP, population, Primary energy consumption was taken from IEA. To capture the different effects of energy consumption changes, the decomposition addictive LMDI model was used to get four aspects: population effect, GDP effect, energy intensity effect, and CO_2 effect. Decomposition Effect equations as follows:

$$\Delta EC_{Total} = \left(\Sigma L\left(POP^{T}, POP^{0}\right) Ln\left(\frac{POP_{effect^{T}}}{POP_{effect^{0}}}\right)\right) + \left(\Sigma L\left(GDP^{t}, GDP^{0}\right) Ln\left(\frac{GDP_{effect^{T}}}{GDP_{effecr^{0}}}\right)\right) + \left(\Sigma L\left(EI^{T}, EI^{0}\right) Ln\left(\frac{PEC_{effect^{T}}}{PEC_{effect^{0}}}\right)\right) + \left(\Sigma L\left(CO2^{T}, CO2^{0}\right) Ln\left(\frac{CO2_{effect^{T}}}{CO2_{effect^{0}}}\right)\right) \quad (1)$$

Where:

ΔEC_{Total}=Energy consumption

$$\Delta \text{POP} - \text{effect} = \left(\Sigma L\left(GDP^{t}, GDP^{0}\right) Ln\left(\frac{GDP_{effect^{T}}}{GDP_{effecr^{0}}}\right)\right)$$

was population effect

$$\Delta \text{GDP - effect} = \left(\Sigma L\left(GDP^{t}, GDP^{0}\right) Ln\left(\frac{GDP_{effect^{T}}}{GDP_{effecr^{0}}}\right)\right)$$

was GDP effect

$$\Delta \text{EI} - \text{effect} = \left(\pounds L\left(EI^{T}, EI^{0}\right) Ln\left(\frac{PEC_{effect^{T}}}{PEC_{effect^{0}}}\right)\right)$$

was energy intensity effect

$$\Delta \text{CO2} - \text{effect} = \left(\pounds L\left(CO2^{T}, CO2^{0}\right) Ln\left(\frac{CO2_{effect^{T}}}{CO2_{effect^{0}}}\right)\right)$$

was CO2 effect

After applying the LMDI KAYA analysis, the next step was used data panel analysis where the combination of time series and cross-section data. By accommodating in both the model of information related to cross-section variables and time series, the data panel was substantially able to reduce omitted variables' problem, the model that ignores the relevant variables. The long-run model panel data regression model in the study was as follows:

$$\text{EI-effect}_{it} = \alpha + \beta 1 \text{ POP-effect}_{it} + \beta 2 \text{ GDP-effect}_{it} + \beta 3 \text{ CO2-effect}_{it} + e_{it} \quad (2)$$

We set the basis for understanding the contradicting effects of energy intensity on population, GDP and CO_2 intensity by concentrating on effects at varying time horizons. The findings are analyzed using the ARDL. We connect our short-and long-run effects to the notable predictive framework on the effects of energy intensity (Cansino et al., 2019). Our econometric method emphasizes us to estimate short-run effects relevant to the region. The framework can also be defined as a panel error-correction model (ECM), where short-and long-run effects from a panel ARDL model are mutually measured. When the data was strictly I(0) or purely I(1) or a mixture of both but not I(2), the ARDL model was sufficient. The entry of I(2) variables in the analysis should be avoided since the ARDL model only provides critical boundary values for the I(0) and I(1) series. Therefore, this research conducts ADF and PP tests to determine the order in which targeted variables are integrated. These two tests in econometric literature have been widely used. The results of both root unit tests have been included in Table 1. All the variables were checked by both the unit root checks I(1).

By reformulating Eq.(2) above as an ARDL(p, q,…, q) model. ARDL model as forecasting model for energy intensity effect "EI-effect," gross domestic effect "GDP-effect," population effect "POP-effect" and CO2 emission effect "CO2-effect," can be written as follows:

$$EI-effect_t = \alpha + +\varnothing EI-effect_{t-1} + \sum\nolimits_{j=1}^{k} \beta_j X_{j.t-1} + \sum\nolimits_{j=1}^{q} \alpha_I \Delta EIeffect_{t-1} + \Sigma_{j=1}^{k}\Sigma_{i=0}^{q}\delta_{j,t}\Delta X_{j.t-1} + \varepsilon_t \quad (3)$$

$$GDP-effect_t = \alpha + +\varnothing GDP-effect_{t-1} + \sum\nolimits_{j=1}^{k} \beta_j X_{j.t-1} + \sum\nolimits_{j=1}^{q} \alpha_I \Delta GDPeffect_{t-1} + \Sigma_{j=1}^{k}\Sigma_{i=0}^{q}\delta_{j,t}\Delta X_{j.t-1} + \varepsilon_t \quad (4)$$

$$POP-effect_t = \alpha + +\varnothing POP-effect_{t-1} + \sum\nolimits_{j=1}^{k} \beta_j X_{j.t-1} + \sum\nolimits_{j=1}^{q} \alpha_I \Delta CO2effect_{t-1} + \Sigma_{j=1}^{k}\Sigma_{i=0}^{q}\delta_{j,t}\Delta X_{j.t-1} + \varepsilon_t \quad (5)$$

$$CO2-effect_t = \alpha + +\varnothing POP-effect_{t-1} + \sum\nolimits_{j=1}^{k} \beta_j X_{j.t-1} + \sum\nolimits_{j=1}^{q} \alpha_I \Delta CO2effect_{t-1} + \Sigma_{j=1}^{k}\Sigma_{i=0}^{q}\delta_{j,t}\Delta X_{j.t-1} + \varepsilon_t \quad (6)$$

In order to comply with the requirements, we embed a VECM into an ARDL (p, q) model. VECM was a model used to analyze *multivariate time series* data that was not a stationer. In other words, the VECM model was a VAR Model that has a linear cointegration relationship, which can be written:

$$\Delta y_t = \alpha\beta^T y_{t-1} + \Gamma_1 \Delta y_{t-1} + \ldots + \Gamma_{p-1}\Delta y_{t-p+1} + U_t 0, \Gamma_i = -(I - A_1 - \ldots A_t) \quad (7)$$

The α and β parameters have a dimension N x R, where N was the number of coefficients, and R was the cointegration). The degree of cointegration indicates several long-term relationships between the $Y\text{-}_t$ and the model that we make, so that cointegration can be said was the main requirement of using VECM.

4. RESULTS AND FINDINGS

4.1. Data

There were 3128 total data observations on the original data among nine ASEAN countries taken from World Development Indicators (World Bank) and the International Energy Association (IEA). From 1971 to 2017, except for Brunei Darussalam. In Table 1, the descriptive statistical test results on CO2, EI-effects, GDP-effects, POP-effects, and CO_2-effects values show a mean average with the data distribution having a maximum value, minimum value, and standard deviations for each decomposition variable.

Table 1: ASEAN' CO_2 Descriptive Analysis

Description	Brunei	Cambodia	Indonesia	Malaysia	Myanmar	Philippines	Singapore	Thailand	Vietnam
Mean									
CO_2	0.274	0.845	20.476	8.619	1.126	4,465	1,771	9,914	7,607
Pop effects	0.169	0.130	5.991	3.761	0.191	2,257	1,238	1,986	1,329
GDP effects	−0.086	0.409	14.126	6.099	0.879	2,537	2,163	8,243	4,939
Energy intensity	0.220	−0.086	−5.647	−3.574	−0541	−1,529	−0,536	0,233	−1,032
CO_2 effects	−0,028	0,392	6,006	2,334	0,597	1,201	−1,095	−0,549	2,371
Median									
CO_2	0.258	0.432	14.825	5.767	0.521	3.155	1.629	7.826	3.994
Pop effects	0.177	0.095	5.691	3.671	0.189	2.201	1.182	1.968	0.909
GDP effects	−0.072	0.387	13.749	7.112	0.620	1.942	2.163	8.792	2.868
Energy intensity	0.230	−0.251	−3.507	−2.011	−0.433	−1.109	0.264	−0.196	−1.254
CO2 effects	−0.013	0.185	3.990	2.040	0.213	0.152	−1.011	1.427	1.016
Standard Deviation									
CO_2	0.926	1.051	22.530	13.048	3.450	7.522	3.510	13.400	13.868
Pop. effects	0.042	0.065	3.070	2.340	0.069	0.596	1.027	0.731	0.949
GDP effects	0.316	0.278	18.016	7.453	0.941	3.864	2.457	10.059	5.658
Energy intensity	1.254	0.816	20.416	9.441	1.090	3.743	8.589	7.512	5.429
CO_2 effects	1.060	0.828	23.831	15.231	2.338	5.275	7.984	7.291	9.069
Minimum									
CO_2	−1.548	−0.001	−14.141	−41.005	−5.017	−11.909	−6.301	−29.894	−10.375
Pop effects	0.034	0.077	1.405	0.595	0.096	1.393	−1.157	0.982	0.531
GDP effects	−1.315	−0.113	−74.242	−19.801	−1.215	−6.477	−4.222	−28.031	−4.007
Energy intensity	−3.327	−1.391	−74.141	−34.666	−2.610	−9.785	−34.214	−21.594	−21.761
CO_2 effects	−2.421	−1.678	−55.866	−65.574	−4.345	−10.903	−21.240	−20.585	−8.338
Maximum									
CO_2	4.786	3.827	83.796	40.102	19.012	23.470	15.757	34.383	76.418
Pop. effects	0.245	0.306	10.818	7.468	0.464	3.699	4.027	3.748	3.986
GDP effects	0.635	1.067	36.811	19.194	2.853	11.897	9.960	30.067	21.427
Energy intensity	3.662	3.110	56.858	30.056	3.996	7.363	11.799	22.234	13.665
CO_2 effects	2.952	2.422	94.709	33.878	11.699	14.942	23.312	13.759	56.673

4.2. Decomposition Analysis

As explained in the previous paragraph, to determine each emission reduction factor's significance, this study used the KAYA identity to decompose the CO_2 component into the population effect, GDP effect, energy intensity effect, and CO_2 intensity effect. The sum of all four of these factors was equal to that of CO_2. The principal driving force of CO_2 emissions was the Kaya identity.

4.2.1. ASEAN energy situation

The energy intensity components first weakening happened throughout 1985 until 1990 due to the decline of oil price. Oil price was drastically declining in September 1985 from USD 69.97 per barrel to only USD 31.11 per barrel in February 1986. Indonesia's GDP growth has also decreased by about 2.1%, 7.3%, and 7.8% in 1985, 1986, and 1987, respectively. The second decline occurred in the Asian crisis year-round 1997 up to 1998.

4.2.2. Population effect

Another factor that aggravates the increase in CO_2 emissions was the population effect, characterized by urbanization (Zhao et al., 2016). Based on the Figure 1, for almost 46 years from 1971 to 2017, Brunei's CO_2 emissions were generated solely based on the population effect. Unfortunately, if the decomposition was based on the proportion of the population over CO_2, Malaysia, Singapore, and Indonesia were ranked 1st, 2nd, and 3rd of the highest population effect than Brunei Darussalam last decade, Table 2. Urbanization was the correct indication of the outcome of decomposition. The majority of factors have contributed to CO_2 emissions due to the energy increases being consumed by households. Fortunately, over the last decade, the outcome shows that Brunei's GDP impact was taking off due to Brunei's government enhancing the private sector's growth to diversify outside the hydrocarbon economy. The completed decomposition on a yearly based for ASEAN countries can be seen in Appendix Table 1.

4.2.3. GDP effect

The results showed that the GDP effect was the most influential factor in the annual increase in CO_2 emissions (Zhao et al., 2016), followed by Indonesia's population impact, as shown in Figure 1 and most ASEAN countries. This study found that Malaysia was the most crucial GDP effect contributing to CO_2 emissions, based on the percentage of the GDP effect over CO_2 emissions in the last decade followed by Singapore and Thailand. Overall, over the 1971-2017 study period for the ASEAN countries, the GDP effect caused CO_2 emissions to increase by 2514.18 million tons. The effect of GDP, characterized by the share of GDP production, was in line with existing literature (Mitić et al., 2017). The completed decomposition on a yearly based for ASEAN countries can be seen in Appendix Table 2.

4.2.4. Energy intensity effect

Most of the energy intensity effect was due to the decrease in total CO_2 emissions. By improving the technical aspect intensity (Cansino et al., 2019; Mitić et al., 2017), energy intensity in most ASEAN countries has hampered their CO_2 emissions. Singapore was the only country able to tackle CO_2 emissions through energy efficiency from 1971 to 2017, Figure 1. The cornerstone of regulating rising CO_2 emissions has been energy efficiency. The energy intensity effect was linked to a decrease in CO_2 emissions over the period. Based on the percentage of the energy intensity effect on CO_2 emissions over the last decade, this study found that Malaysia, Brunei, and Indonesia were the ASEAN countries' champions, as can be seen from the Table 1. The completed decomposition on a yearly based for ASEAN countries can be seen in Appendix Table 3.

4.2.5. Carbon intensity effect

Carbon intensity was the emission rate of a given CO_2 relative to the primary energy consumption intensity (Mitić et al., 2017; Zhao et al., 2016). Only Singapore benefited from the carbon intensity effect on CO_2 emissions and impeded CO_2 emissions for almost 46 years from 1971 to 2017, as shown in Figure 1. This study found that, based on the percentage effect of carbon intensity

Figure 1: ASEAN' CO_2 LMDI decomposition analysis

Table 2: ASEAN' LMDI decomposition analysis

Year	Population effects		GDP effects		Energy intensity effects		CO_2 intensity		ΔCO_2	Countries
1971-2017	8.0	61.5%	−4.0	−31.2%	10.00	80,0%	−1.00	−10.2%	13.0	Brunei Darussalam
1995-2017	3.0	22.7%	9.0	71.3%	−2.00	−15,1%	9.00	68.3%	19.0	Cambodia
1971-2017	276.0	2182.8%	650.0	5147.1%	−260.0	−2057.5%	276.0	2188.6%	942.0	Indonesia
1971-2017	173.0	1370.3%	281.0	2222.3%	−164.0	−1302.3%	107.0	850.4%	396.0	Malaysia
1971-2017	9.0	69.7%	40.0	320.1%	−25.00	−197.1%	27.0	217.4%	52.0	Myanmar
1971-2017	103.81	822.3%	116.68	924.3%	−70.34	−557.2%	55,24	437.6%	205.39	Philippines
1971-2017	57.0	451.2%	100.0	788.3%	−25.00	−195.2%	−50.0	−398.9%	81.0	Singapore
1971-2017	91.0	723.7%	379.0	3003.7%	11.00	84.8%	−25.0	−199.9%	456.0	Thailand
1971-2017	61.0	484.2%	227.0	1799.5%	−47.00	−376.2%	109.0	864.1%	350.0	Vietnam

Table 3: Unit root

Description	Individual effects				Individual effects, individual linear trends			
	POP-effect (Level)	CO_2-effect (Level)	EI-effect (Level)	GDP-effect (Level)	POP-effect (Level)	CO_2-effect (Level)	EI-effect (Level)	GDP-effect (Level)
Levin, Lin and Chu t*	0.5258	0.0000	0.0000	0.0442	0.9709	0.0000	0.0002	0.0000
Im, Pesaran and Shin W-stat	0.4361	0.0000	0.0000	0.0000	0.0336	0.0000	0.0000	0.0000
ADF - Fisher Chi-square	0.2502	0.0000	0.0000	0.0000	0.0117	0.0000	0.0000	0.0000
PP - Fisher Chi-square	0.1562	0.0000	0.0000	0.0000	0.2668	0.0000	0.0000	0.0000
	(1st Diff)				(1st Diff)			
Levin, Lin and Chu t*	0.5258				0.0000			
Im, Pesaran and Shin W-stat	0.4361				0.0000			
ADF - Fisher Chi-square	0.2502				0.0000			
PP - Fisher Chi-square	0.1562				0.0000			

on CO_2 emissions over the last decade, CO_2 emissions have also been reduced in Malaysia, followed by Singapore and Indonesia, Table 2. The completed decomposition on a yearly based for ASEAN countries can be seen in Appendix Table 4.

4.2.6. Indonesia energy situation

Below is the Indonesia's CO_2 LMDI decomposition analysis:

Indonesia's energy began when the rise in oil prices in the 1970s led to a windfall in Indonesia's export revenue. Exports contributed to high GDP rates, averaging more than 7% between 1968 and 1981, but then, due to falling oil prices, growth slowed to an average of 4.5% per year between 1981 and 1988. At the end of the 1980s, economic reforms took place, including the rupee's managed devaluation to improve exports' competitiveness and the deregulation of the financial sector. Foreign investment flowed to Indonesia, especially to the export-oriented manufacturing sector, and Indonesian GDP accounted for more than 7% on average from 1989 to 1997. In 1998, real GDP contracted 13.1%, and the economy reached its low point with real GDP growth of 0.8% in mid-1999. Indonesia's real GDP growth reached 6% in 2012, decreasing steadily to 5.1% in 2004 and 5.6% in 2005. After Joko Widodo succeeded Susilo Bambang Yudhoyono, the government avoided foreign direct investment control to improve the economy.

In 2016, Indonesia managed to increase its GDP growth by slightly above 5%-17. Indonesia's demand for energy reflects the size of the country's economy; Indonesia's consumption of primary energy has also increased rapidly, with an annual average growth rate of 5.157% during 1971-2017. The total supply of primary energy was more than 10,462.6 PJ. Since 1971-2017, Indonesia has experienced robust emissions growth of around 20,48 metric tons per year, driven only slightly by strong economic growth and moderately improved energy intensity. For the IEA, total CO_2 emissions from 1971 to 2017 in Indonesia were recorded at 941,40 metric tons for 46 years from 1971 to 2017. Indonesia has pledged to reduce by 29.41% its emission intensity by 2030. Due to the vigorous and required economic activity, Indonesia's emissions may continue to grow strongly in the next decade.

For Indonesian leaders, maintaining a stable and sufficient energy supply in Indonesia has become extremely challenging. Based on Figure 2, the primary energy supply folds more than 49 times. GDP components and components of population growth have been responsible for determining increased energy demand. Just in Figure 1 and the map. 1 Through decomposition analysis, the GDP components clearly show that they play a more critical role in promoting the growth of energy demand and energy intensity components to play their role in soaking energy demand over the year 1971-2017. Only in the Asian crisis, which started in 1997-1998, did GDP and energy-intensity components decrease. The Decomposition for ASEAN countries can be seen in Appenidx Figure 1.

This study currently proposes that it would be a good time for Indonesia and ASEAN countries to deploy energy renewable energy sources faster. For Indonesia, the Government must promote the introduction of the Energy Efficiency Saving Industry development initiatives in Indonesia (Nasip and Sudarmaji, 2018). To mobilize alternative funding through retrofitting programs in Indonesia, the ESCO can unlock the possibilities and benefits of Energy Efficiency Saving Industry (Sudarmaji and Ardianto, 2020). The use of the national nudge program is another way for the government to make the energy efficiency program efficient. "Nudges" framings are acceptable not only for particular manufacturing sectors but also in many other fields. According to (Sudarmaji and Thalib, 2020), the impetus for reducing electricity use in rural areas has been impacted by social norms and curtailment by Nudge framing. Architectural solutions for energy conservation were included in the definition of "Nudge." In many nations, this notion is commonly used. The definition of "Nudge" can be used to frame rewards for other fields of industry. The 'Nudge' principle could result from decreased CO2 emissions

Table 4: Optimal lags

Lag	LogL	LR	FPE	AIC	SC	HQ
1	−3720,62	NA	19521,93	21,2308	21.40642*	21,30069
2	−3691,983	55.97323*	18169.82*	21.15899*	21,51023	21.29877*

Figure 2: Indonesia CO_2 LMDI decomposition analysis

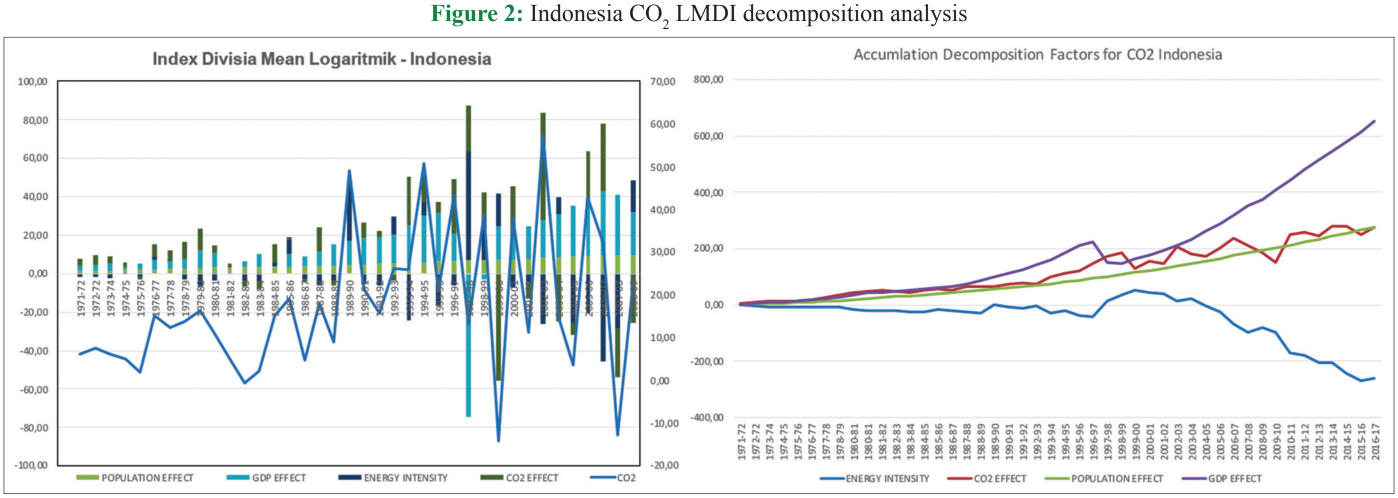

Table 5: Pedroni residual cointegration

Test	No deterministic trend (SIC)				Deterministic intercept and trend (HQJC)			
	Stat.	Prob.	Weight Stat.	Prob.	Stat.	Prob.	Weight Stat.	Prob.
Panel v-statistic	2.975	0.002	0.650	0.257	−2.200	0.986	−3.078	0.999
Panel rho-statistic	−12.546	0.00	−7.769	0.00	−10.269	0	−9.250	0.00
Panel PP-statistic	−14.409	0.00	−11.035	0.00	−22.853	0	−15.137	0.00
Panel ADF-statistic	−13.803	0.00	−8.661	0.00	−0.259	0.397	−8.998	0.00

Table 6: ARDL test

Variable	Dependent variable D (EI-EFFECT)			Dependent variable D (CO2-EFFECT)			Dependent variable D (GDP-EFFECT)			Dependent variable D (POP-EFFECT)		
	Coef	t-Stat	Prob.*	Coef	t-Stat	Prob.*	Coef	t-Stat	Prob.*	Coef	t-Stat	Prob.*
						Short Run Equation						
ECT	−0.878	−2.434	0.016*	−0,712	−5,006	0.00**	−0,468	−2,221	0,027*	−0,060	−2,514	0,013*
						Long Run Equation						
CO2-effect	0.304	5.109	0.00**	−	−	−	0.009	0.112	0.910	−0.111	−8.238	0.00**
GDP-effect	−0.525	−6.977	0.00**	0.096	0.874	0.382	−	−	−	0.206	10.079	0.00**
POP-effect	1.808	4.195	0.00**	−0.432	−0.698	0.485	0.490	2.107	0.036*	−	−	−
EI-effect	−	−	−	−0.913	−6.005	0.00**	0.094	1.208	0.228	0.199	3.425	0.00**

* denotes significant at the 0.05 level & ** at 0.01 level

by reducing energy usage in future energy-saving projects (Krstic and Krstic, 2015).

4.3. The Pooled Mean Group Estimator

The dependent variables in this study were energy Intensity, and there were three free variables, namely population-effect (X1), GDP-effect (X2), and CO_2-effect (X3). The empirical framework of the analysis has the following components:

1. Panel unit root tests
2. Panel optimal lags selection
3. Panel cointegration tests
4. Panel VEC model estimations
5. Panel causality analysis tests
6. Innovative accounting approach

4.3.1. Unit root and cointegration

Unit root and cointegration factors can be seen from the Table 3.

The test results of Table 3 show that overall, variable EI-effect, GDP-effect, and CO2-effect indicate stationary at level. POP-effect indicates stationary at 1st differences.

Based on the LR, FPE, AIC, SC, and HQ, obtaining the optimal lag length was two, Table 4. The authors select the max second lags for deploying the panel VEC model.

The integration study findings were summarized in Table 5. Pedroni's cointegration probability approach was a test based on HQIC with a max lag of 9 provided proof at a significance level of 0.05 to reject the null hypothesis for panel rho, panel PP and panel ADF.

4.3.2. Causality analysis result

The short-term causality model using VEC Granger causality/block Exogeneity Wald tests and pairwise granger causality tests for robustness tests was estimated in this research. Statistically, based on Table 6, there was no short-run granger causality for EI-effect, GDP-effect, POP-effect, and CO_2-effect individually and jointly in the first model. In the second model, economic aspects have the causality of short-run granger at 0.01 level of 0.01 and economic aspects with the causality of short-run granger at 0.05 level of technical aspects. At 0.10 level, both jointly have short-run granger causality. In the last model, all economic and technological aspects have short-term granger causality at 0.10 and 0.05 stages, both individually and jointly, with social aspects.

Table 7: Pairwise granger causality tests

Null hypothesis	F-statistic	Prob.
GDP-effect does not Granger Cause EI-effect	16.714	0.000*
EI-effect does not Granger Cause GDP-effect	1.255	0.286
POP-effect does not Granger Cause EI-effect	13.005	0.000*
EI-effect does not Granger Cause POP-effect	0.861	0.424
CO_2-effect does not Granger Cause EI-effect	5.513	0.004*
EI-effect does not Granger Cause CO_2-effect	2.153	0.118
POP-effect does not Granger Cause GDP-effect	32.260	0.000*
GDP-effect does not Granger Cause POP-effect	4.367	0.013**
CO_2-effect does not Granger Cause GDP-effect	0.808	0.446
GDP-effect does not Granger Cause CO_2-effect	19.714	0.000*
CO_2-effect does not Granger Cause POP-effect	7.066	0.001*
POP-effect does not Granger Cause CO_2-effect	11.485	0.000*

*Significant level at the 0.01 level, **at 0.05 level

Based on Table 7, statistically, on the Pair-wise Granger Causality Tests, there was uni-direct granger causality between EI-effect, GDP-effect, POP-effect, and CO2-effect at 0.01 level.

Table 8: VEC granger causality/block Exogeneity Wald tests

Variable	Dependent variable							
	D (EI-effect)		D (GDP-effect)		D (POP-effect)		D (CO2-effect)	
D (EI-effect)	-	-	9.498	0.009 *	1.435	0.488	18.777	0.000*
D (GDP-effect)	8.679	0,013*	-	-	5.207	0.074**	25.896	0.000*
D (POP-effect)	6.412	0,0405*	2.569	0.277	-	-	0.523	0.769
D (CO2-effect)	139.822	0.000*	5.925	0.052**	1.079	0.583	-	-
JOINT	152.628	0.000*	14.955	0.021 *	8.529	0.202	41.717	0.000*

*denotes significant at the 0.05 level and **at 0.10 level

Unfortunately, there was No-direct granger causality for POP-effect.

4.3.3. Robustness check (ARDL)

In Table 6, respectively, long-term and short-term results were published. The long-term results show that POP-effect, and CO_2-effect has a significant positive effect on EI-effect instead GDP-effect has negative effect. Table 8 also shows that the four models' approximate results show that the ECT coefficient are almost negative, −0.878, −0,712, −0,468 and −0,060 with long-term statistical causality. It has been shown that the long-term balance of EI-effect, GDP-effect, POP-effect, and CO_2-effect is valid significant with 0.01% and 0.05%. It means that the previous period's imbalance shocks reconnected into a long-run equilibrium. In other words, there is a long-term causality between EI-effect, GDP-effect, POP-effect, and CO_2-effect.

5. CONCLUSION

This study has broken down the driving factors for CO_2 emissions in Indonesia and the ASEAN countries on an aggregate basis. This study found that the rise in CO_2 emissions was mainly due to GDP or economic growth, (Saunders, 2015) accompanied by population expansion (urbanization). This study aims to improve energy intensity, particularly in the sense of another strategy to boost energy efficiency in the economic field, as effective emission control strategies. Energy intensity should not be confused with energy efficiency. Energy efficiency involves the use of technology to perform the same function, requiring less energy. More efficient use of energy at all stages of the supply/demand chain could reduce the negative impacts of energy usage while still enabling much economic growth. Improved energy efficiency at the national level means a decrease in fuel imports, thus decreasing foreign exchange pressures and increasing the availability of scarce energy resources to be used. Thus, it will enable increased energy-dependent behaviors to lead to the population's economic well-being as a whole. Increased energy usage also benefits society as a whole, mainly by decreased negative environmental impacts of energy consumption. Energy efficiency refers to the activity or service that can be generated with a given quantity of energy. Further analysis can also consider whether the low-carbon economic goal of Indonesia was technically competent. Our findings also illustrate how powerful the energy intensity was and could be a key component and driving force of economic growth in ASEAN countries. Whether future economic development can be restricted to climate-based policies leads to trade-offs.

The study analyses that the ARDL model was used to cover a model with short-and long-run consequences based on a panel of cross-country and time-series observations. Based on the outcome, the root cause of dramatically rising CO2 emissions over the past 36 years has been established. This analysis's outcome was that a positive long-run relationship interacted with a mainly negative short-run relationship between the "EI-effect," gross domestic effect "GDP-effect," population effect "POP-effect" and CO_2 emission effect "CO_2-effect" of energy intensity. Authors focus on the groups instead of individual analysis, which means that the authors realized that information is lost by taking a panel perspective. However, using panel data rather than time series can increase the total number of observations and their variations and reduce the noise coming from the individual time series. Heteroscedasticity does not become an issue. The panel data also best suited from developing countries due to short periods for a variable were rampant, often sufficient for fitting time-series regressions. Meanwhile, heterogeneity (differences) among units in the panel, but the special panel data techniques can take this heterogeneity into account by allowing for subject-specific variables. The panel data also suits for studying dynamic changes due to repeated cross-section sectionals observations.

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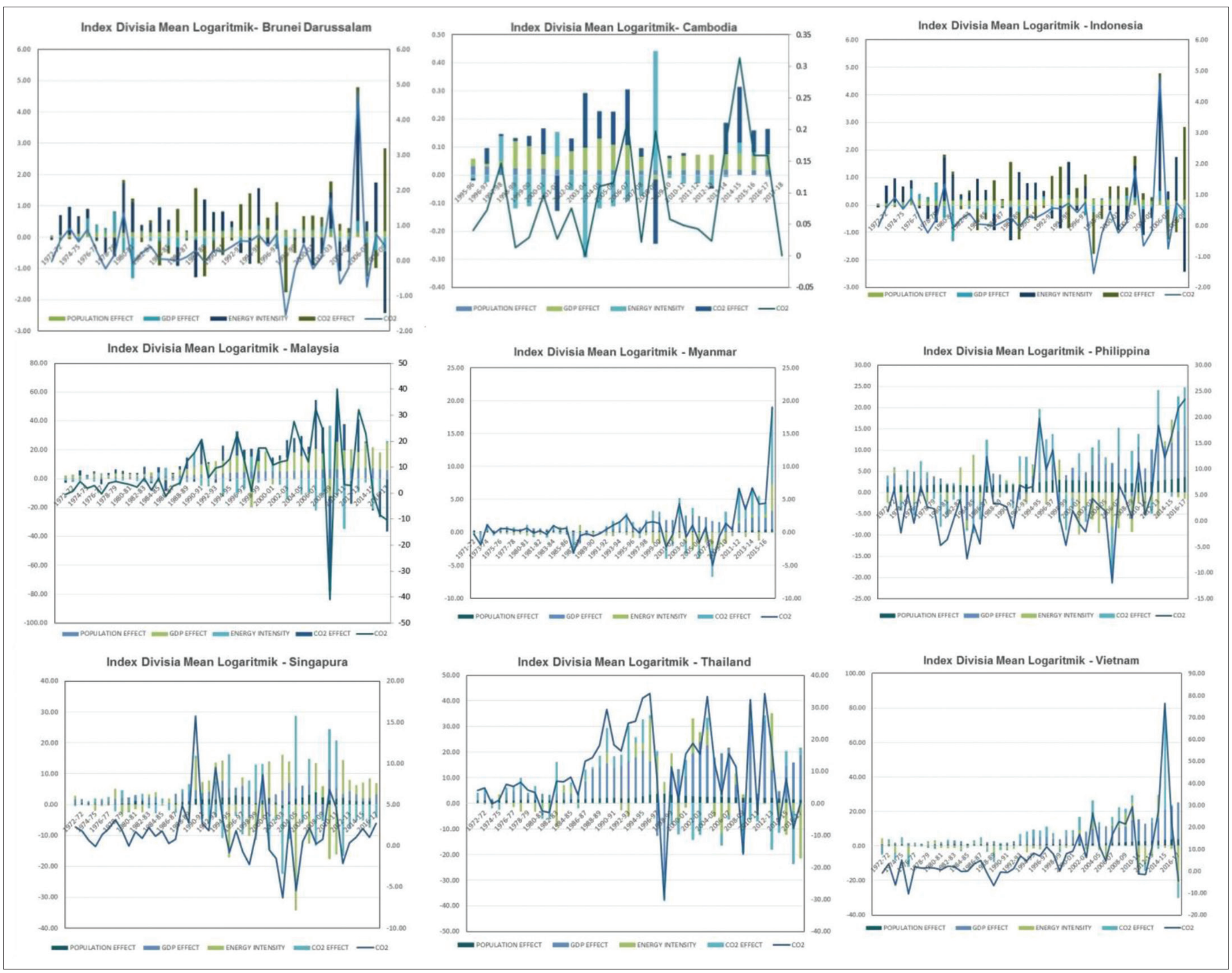
APPENDIX 1

First decomposition factors

Figure 1: ASEAN LMDI decomposition analysis



APPENDIX 2

Table 1: Population Effects over CO_2

Year	BRU	CAM	INA	MAL	MYN	PHI	SIN	THA	VIET
1971-75	0,2674	-	8.443	3.470	0.954	7.622	1.288	5.364	3.558
1976-80	0.735	-	13.388	5.192	1.084	8.991	2.424	6.485	3.043
1981-85	0.821	-	17.222	7.535	1.136	8.265	2.176	6.747	3.981
1986-90	0.883	-	20.621	11.811	0.720	9.042	6.248	9.593	4.182
1991-95	1.095	0.090	27.892	18.101	0.648	11.217	11.226	11.821	4.091
1996-97	0.222	0.090	6.514	4.789	0.186	2.937	2.555	3.748	0.943
1997-98	0.208	0.093	6.782	4.894	0.195	3.054	2.538	3.672	0.982
1998-99	0.185	0.092	7.066	4.947	0.209	2.969	0.604	3.412	0.957
1999-00	0.183	0.086	7.215	5.117	0.217	2.902	1.373	3.160	0.947
2000-01	0.182	0.084	7.377	5.153	0.201	2.887	2.252	2.888	0.984
2001-02	0.177	0.081	7.704	5.155	0.178	2.823	0.755	2.735	1.058
2002-03	0.164	0.078	8.159	5.197	0.187	2.777	(1.157)	2.597	1.130
2003-04	0.200	0.077	8.637	5.430	0.189	2.739	0.967	2.558	1.252
2004-05	0.134	0.079	8.721	5.769	0.173	2.652	1.778	2.556	1.421
2005-06	0.162	0.085	8.993	5.947	0.151	2.415	2.284	2.443	1.492
2006-07	0.189	0.097	9.458	6.204	0.132	2.255	3.124	2.317	1.594
2007-08	0.149	0.107	9.521	6.647	0.110	2.272	4.027	2.239	1.811
2008-09	0.192	0.120	9.495	6.496	0.096	2.291	2.318	2.127	2.095
2009-10	0.185	0.139	9.492	6.539	0.107	2.406	1.419	2.099	2.459
2010-11	0.177	0.150	9.749	7.029	0.126	2.542	1.794	2.121	2.738
2011-12	0.211	0.161	10.339	7.117	0.165	2.615	2.129	2.136	2.835
2012-13	0.206	0.169	10.475	7.330	0.221	2.807	1.404	2.139	2.939
2013-14	0.199	0.184	10.684	7.468	0.272	3.025	1.138	1.972	3.125
2014-15	0.183	0.225	10.818	7.163	0.324	3.190	1.048	1.730	3.592
2015-16	0.147	0.269	10.389	6.545	0.361	3.418	1.168	1.474	3.986
2016-17	0.185	0.306	10.404	5.945	0.464	3.699	0.082	1.232	3.935

Table 2: GDP effects over CO_2

Year	BRU	CAM	INA	MAL	MYN	PHI	SIN	THA	VIET
1971-75	0.441	-	13.506	7.853	0.375	9.258	5.070	7.741	−1.519
1976-80	(0.792)	-	30.795	10.041	1.843	6.983	8.071	14.214	−1.670
1981-85	(0.803)	-	16.615	3.460	0.546	−12.212	4.934	12.433	5.947
1986-90	(0.491)	-	50.911	22.644	−1.728	4.073	13.601	55.918	5.847
1991-95	0.139	0.081	97.644	47.605	3.001	6.293	18.559	74.189	15.399
1996-97	(0.367)	0.034	14.182	8.507	0.592	3.689	3.522	−12.630	4.320
1997-98	(0.261)	0.068	−74.242	−19.801	0.649	−3.855	−4.222	−28.031	3.309
1998-99	0.071	0.361	−3.084	7.201	1.487	1.175	3.801	9.898	2.797
1999-00	0.059	0.307	17.657	13.666	2.082	2.935	5.400	10.092	4.600
2000-01	0.055	0.212	11.577	−3.937	1.675	0.993	−3.052	7.685	4.603
2001-02	0.153	0.197	16.701	7.809	1.671	2.001	2.651	16.915	5.425
2002-03	0.110	0.296	19.318	9.392	2.180	3.813	4.570	21.457	6.708
2003-04	(0.148)	0.391	22.031	12.890	2.377	6.307	6.055	20.051	8.443
2004-05	(0.097)	0.545	26.372	9.936	2.422	3.976	3.691	13.608	9.690
2005-06	0.350	0.486	26.184	11.314	2.330	4.583	3.940	17.041	9.354
2006-07	(0.167)	0.535	33.273	14.540	2.114	6.365	3.389	19.439	10.213
2007-08	(0.425)	0.361	31.622	10.728	1.609	3.432	−2.682	5.026	8.710
2008-09	(0.453)	(0.113)	22.617	−11.982	1.390	(0.662)	−2.780	−5.054	9.106
2009-10	0.182	0.382	33.876	19.194	1.283	8.518	9.960	29.084	12.380
2010-11	0.333	0.496	35.002	12.643	0.745	3.025	3.502	1.603	12.556
2011-12	(0.084)	0.537	36.811	13.371	1.204	7.615	1.364	30.067	10.012
2012-13	(0.503)	0.557	34.585	11.102	1.767	8.788	2.904	10.759	10.558
2013-14	(0.521)	0.592	32.027	17.587	2.001	8.024	2.182	2.843	12.836
2014-15	(0.255)	0.728	32.794	14.737	2.053	8.557	0.919	12.912	17.452
2015-16	(0.457)	0.877	34.465	11.518	1.891	11.108	0.972	14.422	18.676
2016-17	(0.011)	1.067	36.549	18.535	2.853	11.897	3.196	17.513	21.427

Table 3: Intensity effects over CO_2

Year	BRU	CAM	INA	MAL	MYN	PHI	SIN	THA	VIET
1971-75	2.300	-	−8.420	−5.411	(0.570)	−4.802	−1.341	(0.086)	−3.460
1976-80	1.302	-	−11.152	−2.817	−2.032	−5.167	−3.316	−11.255	2.844
1981-85	1.012	-	1.441	2.170	0.057	7.197	1.870	−6.165	−5.186
1986-90	1.065	-	11.899	−3.441	0.391	(0.247)	8.634	5.591	−6.950
1991-95	0.011	(0.037)	−30.454	−27.152	−2.425	1.077	-2.653	17.320	−8.367
1996-97	0.461	(0.074)	−5.801	-7.077	(0.483)	0.070	2.753	14.756	(0.245)
1997-98	0.013	0.295	56.858	10.594	(0.447)	4.728	-5.879	4.605	0.580
1998-99	(0.090)	(0.449)	19.481	−2.678	−1.642	(0.573)	−11.451	6.163	−1.444
1999-00	(0.196)	(0.421)	16.853	(0.954)	−1.749	−1.206	−4.583	−6.089	−1.260
2000-01	(0.909)	(0.274)	−7.076	4.065	−2.282	−9.785	11.799	−1.618	0.394
2001-02	(0.530)	0.386	−4.613	−4.151	−1.311	−2.994	−3.944	13.474	2.752
2002-03	1.157	(0.238)	−26.280	−14.061	(0.886)	−6.244	11.526	3.661	−2.115
2003-04	(0.933)	−1.391	8.879	(0.652)	−1.582	−9.494	7.051	6.130	4.307
2004-05	(0.378)	(0.560)	−25.396	−11.080	−2.610	−6.393	−34.214	−5.227	−2.380
2005-06	3.662	(0.583)	−20.405	−10.119	−2.043	−8.004	(0.975)	−11.644	−6.889
2006-07	0.312	(0.546)	−45.544	−22.119	−1.538	−8.350	−12.545	−4.693	0.803
2007-08	1.587	(0.524)	−28.986	−11.021	−2.391	(0.512)	9.431	4.151	2.355
2008-09	−1.968	3.110	16.358	30.056	−2.314	−8.621	3.767	1.359	7.442
2009-10	0.532	(0.097)	−15.523	−11.804	−1.737	−2.567	−17.521	7.549	10.268
2010-11	1.964	(0.280)	−74.141	−34.666	(0.555)	−4.536	−16.159	−4.254	−14.875
2011-12	(0.283)	(0.264)	−8.136	−1.860	0.339	−2.323	10.932	(0.098)	−9.467
2012-13	−2.887	(0.397)	−26.136	−9.305	(0.748)	−5.651	3.666	22.234	−5.571
2013-14	2.429	(0.074)	2.733	−2.728	0.440	0.980	3.090	−8.085	13.665
2014-15	−3.327	0.452	−41.832	−21.043	−1.250	5.520	5.256	−12.343	−1.299
2015-16	1.518	0.156	−25.180	−8.658	0.496	−1.013	6.352	−3.141	−1.628
2016-17	2.275	(0.095)	10.829	1.512	3.996	−1.436	3.806	−21.594	−21.761

Table 4: Energy primary effects over CO_2

Year	BRU	CAM	INA	MAL	MYN	PHI	SIN	THA	VIET
1971-75	(0.218)	-	13.649	3.797	−1.397	−1.538	1.107	2.724	−7.634
1976-80	0.238	-	35.580	3.004	0.747	−7.238	1.641	7.444	2.827
1981-85	(0.337)	-	6.022	0.794	0.349	−10.759	−2.522	8.624	2.915
1986-90	(0.568)	-	18.841	24.187	−3.831	7.640	−1.441	22.167	−7.144
1991-95	1.412	(0.017)	44.345	23.391	5.317	31.048	−11.041	30.879	16.515
1996-97	0.434	0.171	28.635	6.535	(0.426)	7.082	−9.547	1.836	5.980
1997-98	−1.508	0.027	23.965	5.155	1.057	−3.152	5.334	−10.140	2.776
1998-99	(0.414)	0.045	15.398	7.788	1.561	−8.241	8.556	−8.087	−2.199
1999-00	0.426	0.139	−55.866	(0.399)	0.870	−2.569	6.441	−6.031	3.629
2000-01	0.444	0.358	26.219	5.493	−1.758	5.398	−11.533	6.463	3.165
2001-02	0.301	(0.548)	−8.534	3.295	(0.774)	−3.894	(0.944)	−14.309	7.518
2002-03	0.344	0.199	56.212	12.059	2.874	4.019	−21.240	−12.294	0.536
2003-04	0.225	0.922	−25.047	9.892	−1.661	3.443	−11.126	4.657	12.463
2004-05	0.146	0.459	−6.137	13.915	1.128	1.714	23.312	1.851	2.631
2005-06	0.613	0.623	28.185	4.782	−1.963	−10.903	−4.707	−4.897	0.738
2006-07	−1.078	1.167	35.077	33.878	0.096	6.678	8.245	−1.522	4.243
2007-08	(0.553)	0.214	−24.815	18.152	−4.345	(0.877)	−10.553	0.051	9.604
2008-09	2.650	−1.678	−25.429	−65.574	0.039	7.569	−2.507	−14.366	2.856
2009-10	−2.042	0.080	−33.806	26.174	1.733	2.956	13.021	−6.319	4.225
2010-11	−2.171	0.080	94.709	18.256	0.076	0.208	15.533	−2.747	−1.743
2011-12	0.068	(0.017)	10.776	−15.650	4.980	−2.599	−16.565	2.277	−5.001
2012-13	2.952	(0.094)	−13.394	23.061	2.202	12.526	−7.603	−18.158	2.684
2013-14	−2.421	1.152	32.369	0.636	4.026	0.097	−5.333	−3.509	−1.848
2014-15	1.960	2.422	2.737	−1.088	3.140	(0.898)	−5.089	5.641	56.673
2015-16	(0.341)	1.249	−29.406	−17.808	1.707	8.219	−7.431	−20.585	1.012
2016-17	−1.851	1.673	26.013	−36.371	11.699	9.310	−4.369	3.108	−8.338