DETERMINANTS OF CARBON EMISSION AND REBOUND EFFECT IN ASEAN COUNTRIES: KAYA AND LMDI DECOMPOSITION

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Abstract: All ASEAN countries have achieved extraordinarily high growth rates in their history of economic development. They relied on new energy efficiency technologies to reduce their energy intensity while avoiding the rebound effect. Academics debate told that the rebound effect happened due to the false policies. Hence, the other strategy to stimulate increased energy efficiency in the economic sector is essential for government policy in overcoming resource constraints. This study used the logarithmic-mean Divisia index (LMDI) decomposition and KAYA identity to recognize the determinant factors of carbon emissions and rebound effect changes in ASEAN countries. This study also analyzed the factors behind the shift in ASEAN's carbon emissions and identified the differences between ASEAN member countries. The carbon emissions are decomposed into the population, GDP growth, energy intensity, and carbon intensity. One of the purposes of this paper advocated enhancing efficiency, notably in the energy efficiency sector's plan to encourage government measures. According to the research findings, substantial energy rebounds in Indonesia have revealed that energy efficiency gains in Indonesia may be related to the rebound effect. Indonesia sought to go in this direction, with the national energy policy aiming to lower energy efficiency by 1% each year to stimulate energy savings in all sectors.

Keywords: ASEAN, energy efficiency, kaya index, LMDI, rebound effect

Abstrak: *Semua negara ASEAN telah mencapai tingkat pertumbuhan yang luar biasa tinggi dalam sejarah perkembangan ekonomi mereka. Mereka mengandalkan teknologi efisiensi energi baru untuk mengurangi intensitas energi mereka sambil menghindari efek rebound. Debat akademisi mengatakan bahwa rebound effect terjadi karena kebijakan yang salah. Oleh karena itu, strategi lain untuk mendorong peningkatan efisiensi energi di sektor ekonomi menjadi penting bagi kebijakan pemerintah dalam mengatasi kendala sumber daya. Penelitian ini menggunakan dekomposisi indeks logaritmik-mean Divisia (LMDI) dan identitas KAYA untuk mengetahui faktor-faktor determinan perubahan emisi karbon dan rebound effect di negara-negara ASEAN. Studi ini juga menganalisis faktor-faktor di balik pergeseran emisi karbon ASEAN dan mengidentifikasi perbedaan antara negara anggota ASEAN. Untuk itu emisi karbon (CO2) didekomposisi menjadi populasi, pertumbuhan PDB, intensitas energi, dan intensitas karbon. Salah satu tujuan dari makalah ini adalah mendorong peningkatan efisiensi, terutama dalam rencana sektor efisiensi energi untuk mendorong langkah-langkah pemerintah. Menurut temuan penelitian, rebound energi yang besar di Indonesia telah mengungkapkan bahwa peningkatan efisiensi energi di Indonesia mungkin terkait dengan efek rebound. Oleh karenanya Indonesia disarankan untuk berupaya menuju ke arah peningkatan energi efisiensi ini. Dengan kebijakan energi nasional yang sesuai diharapkan tujuan penurunan efisiensi energi sebesar 1% setiap tahun akan dapat terjadi dan pada akhirnya akan mendorong penghematan energi di semua sektor.*

Kata kunci: *ASEAN, efisiensi energi, Kaya Index, LMDI, rebound effect*

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INTRODUCTION

Energy efficiency is one indicator that consists of both energy use itself and the driving forces behind energy use. Growth in energy use is linked to economic growth, goods and services, population, buildings, and transport. Energy indicators specific are helpful because they link energy use to relevant activity measures like GDP and production value. Energy indicators are a valuable tool for policymakers and can also predict future development in energy use.

The ASEAN Economic Community ('AEC') was founded in 2016. AEC was the world's fifth-largest economy in 2018, with a gross GDP of USD 3.0 trillion (ASEAN Secretariat, 2019). Indonesia was destined to be a significant player. Indonesia is an important market for the AEC. Undeniable patterns such as urbanization and consumerism will engulf Indonesia. Brunei, Cambodia, Indonesia, Malaysia, Myanmar, Singapore, Thailand, Laos, the Philippines, and Vietnam are ten ASEAN and AEC participants. Since then, Indonesia and the AEC have ratified a host of Multilateral Free Trade Agreements, lowering market barriers for neighboring countries. The 'Regional Comprehensive Economic Partnership ('RCEP') was also established with six free trade agreement partners: India, China, Japan, Korea, Australia, and New Zealand. The AEC and RCEP have enhanced collaboration between the different business sectors in many ways, including development and the supply chain, connecting business operations, and channeling to end customers. It would increase energy demand and CO_2 emissions in the long run.

A variety of factors influence the relationship between energy and economic growth. The most popular reasons for total energy usage in the economy were increased activity and economic development. To provide a fair understanding of the country's aggregated indicators as a whole, energy use and operation were needed. Using the Logarithmic Mean Divisia Index (LMDI) method to decompose the extended Kaya identity, this study examined the driving factors of carbon emissions in ASEAN and identified discrepancies between member countries from 1971 to 2017. It was in response to a query about how carbon abatement has progressed in ASEAN over 36 years. What would happen if the current pattern continues? The model for evaluating efficiency was also discussed. Based on the findings, we identify the root cause of dramatically rising CO_2 emissions in the last 36 years.

Previous academic debates have reached an agreement on what needs to be done to overcome barriers to implementing energy efficiency (Brown and Conover, 2009; Dobbs et al. 2013; Gerarden et al. 2015; Schleich and Gruber, 2008). There are two barriers to energy efficiency in neoclassical economic theory, which are also found in the energy efficiency industry in Indonesia, namely the "market barrier" and the "non-market barrier" (O'Malley et al. 2003). Meanwhile, Jaffe dan Stavins (1994) argue that market barriers did not explain the energy efficiency gap but explained the concept of market barriers which refer to market factors that were not utilized. On the other hand, O'Malley et al. (2003) noted that several non-economic theories might be used to address the energy efficiency gap. The U.S. Department of Energy (2016) also confirmed the existence of several other non-market barriers.

This study aimed to examine the socio-economic characteristics and characteristics that can affect the increase in CO_2 emissions and the possibility of rearranging energy efficiency programs in Indonesia. There is potential for billions of dollars of energy sector capital to be saved by programs targeted solely at the housing sector (Karali et al. 2015). Without saving, Indonesia will have to build 95 new power plants with a power of 500 MW which will require billions of dollars in investment in the next 20 years. With a comprehensive energy efficiency program in the housing sector, Indonesia can reduce the peak load in 2030. For this reason, the author wants to know the obstacles that exist, why it is complicated to adopt energy efficiency technology and programs in Indonesia, and how to best deal with and reduce the rebound effect after savings occur. As explained in the background of this research, several factors might influence households' typical characteristics and socioeconomic characteristics in adopting energy efficiency.

METHODS

This paper used the addictive LMDI decomposition and extended KAYA identity to capture the different effects of energy consumption changes. Decomposition analysis is performed using the same equation to decompose changes in energy consumption into several pre-defined factors. The popular index decomposition analysis (IDA) is the Laspeyres and Divisia indices. The Laspeyres index measures the percentage change in some aspect of a group of items over time, using weights based on values for some base year. However, the Divisia index is a weighted sum of the logarithmic growth rates, where the weights are the components' share of the total value.

Due to the flexibility of acceptance, ease of use, and a relatively low data requirement, IDA is more widely accepted as a decomposition tool. Ang (2015) summarizes the IDA methods regarding their advantages and disadvantages. Ang (2015) then advocated the Logarithmic Mean Divisia Index (LMDI) for general use. Several studies have also applied extended Kaya identity using LMDI (Ma & Stern, 2008; Wang et al. 2014; Zhang, 2019). Ma and Cai (2018) and Ma, Cai, and Cai (2018) have conducted studies combining Kaya identity and LMDI for the decomposition of total energy-related CO_2 in the construction sector.

These decomposition ' effects' lead to a change in the carbon reduction expressed in the Kaya. The famous KAYA equation formula is as follows:

$$PEC = POP \times \frac{GDP}{POP} \times \frac{Primary\,Energy}{GDP} \times \frac{Energy\,Consumption}{Primary\,Energy} \quad (1)$$

Description: PEC (Primary Energy Consumption); GDP (Gross Domestic Product – Using IPP); Energy Intensity (Primary Energy/GDP); Consumption Intensity (EC/Primary Energy).

To forecast CO_2 – this paper adds CO_2 emissions in the LMDI model. The equation formula is as follows:

$$CO2 = Pop \times \frac{GDP}{POP} \times \frac{Primary\,Energy}{GDP} \times \frac{CO2}{Primary\,Energy} \quad (2)$$

Use addictive LMDI Analysis = **Decomposition Effect**

Decomposition Effect =

$$\left(\Sigma L(POP^T, POP^0) Ln\left(\frac{POP_{effectT}}{POP_{effect0}}\right)\right) + \left(\Sigma L(GDP^t, GDP^0) Ln\left(\frac{GDP_{effectT}}{GDP_{effecr0}}\right)\right) + \left(\Sigma L(PEC^T, PEC^0) Ln\left(\frac{PEC_{effectT}}{PEC_{effect0}}\right)\right) + \left(\Sigma L(CO2^T, CO2^0) Ln\left(\frac{CO2_{effectT}}{CO2_{effect0}}\right)\right) \quad (2a)$$

$\Delta E_{intensity}$ is a proxy for technological improvement or technological change (Cansino et al. 2019); hence, energy intensity can change energy consumption and change economic growth. On the other hand, improvements in $\Delta E_{intensity}$ could be a backfired effect, commonly called the Rebound effect (RE), on energy consumption.

$$\Delta E_{Energy\text{-}efficiency} = \Delta E_{tot} - \Delta E_{Pop} - \Delta E_{GDP} \quad (3)$$

$$\gamma^1_{total} = \gamma^1_{GDP} + \gamma^1_{POP} + \gamma^1_{intensity} \quad (4)$$

From equation (4), we concluded that if $\gamma^1_{total} \geq 1$ expresses strong decoupling efforts, it implies that the country's energy consumption decreases while the national economy grows. Moreover, if $0 < \gamma^1_{total} < 1$, it expresses weak decoupling efforts so that the inhibiting effect of country energy consumption is more vulnerable than the effect of economic growth. Finally, if $\gamma^1_{total} \leq 0$, it expresses that there were no decoupling efforts.

$$\frac{Energy\,Consumption}{Y{=}GDP} = \Delta EI = \frac{\Delta PEC}{PEC}$$

When energy intensity decreases by 1%, it will reduce the same 1% reduction in energy costs. In other words, the resulting energy saving of 1% will be the same as the decrease in energy intensity or can be written, as follows:

$$\frac{\Delta PEC}{PEC} 1_{GDP} = \frac{\Delta EI}{EI} \quad (5)$$

It can be concluded that Expected Energy Saving (EES) is not the same as Actual Energy Saving (AES) because of the rebound effect. However, the expected energy saving of 1% does not necessarily occur because, at the same time, the rebound effect increases energy consumption. The formula of Rebound Effect (RE) can be written as follow:

$$RE = \frac{\frac{\Delta PEC}{PEC}1y - \frac{\Delta PEC}{PEC}}{\frac{\Delta PEC}{PEC}1y} = 1 - \frac{\frac{\Delta PEC}{PEC}}{\frac{\Delta PECI}{PECI}} = \frac{\frac{\Delta GDP}{GDP}}{-\frac{\Delta EI}{EI}}$$

$$\frac{\frac{\Delta GDP}{GDP}}{\frac{\Delta GDP}{GDP} - \frac{\Delta PEC}{PEC}}$$

$$= \frac{\frac{\Delta PEC}{PEC}1GDP - \frac{\Delta PEC}{PEC}}{\frac{\Delta PEC}{PEC}1GDP}$$

The difference between the Expected Energy Saving Target Ratio (ESTR) with Actual Energy Saving (AES) can be said to be the difference. The condition Of Zero RE = 0 will occur when the decline of 1% energy intensity will cause an increase of 1% energy consumed in generating the output economy as it did before.

To capture the different effects of energy consumption changes, the addictive LMDI decomposition is used to get four aspects: population effect, GDP growth effect, energy intensity effect, and CO_2 intensity effect. It becomes popular when (International Energy Association) IEA uses LMDI to forecast CO_2, followed by most energy researchers. They used to use the Laspeyres index in early 1990, then AMDI. The Data of CO_2 gas emission, GDP, population, primary energy consumption were taken to decompose the factors of GDP-effect, Growth-effect, CO_2-effect & Energy Intensity effect, consisting of 3.128 observation data. The data was coming from IEA and comprised data for Indonesia and ASEAN countries from 1971 to 2017.

Therefore, the hypotheses of this study include:

H1: Does the total population of Indonesian people affect the amount of carbon dioxide (CO_2) output each year overweight compared with other ASEAN countries?

H2: Does Indonesia's GDP affect the amount of carbon dioxide (CO_2) output each year overweight compared with other ASEAN countries?

H3: Does the applied energy efficiency policy affect the amount of Carbon dioxide (CO_2) output each year overweight compared with other ASEAN countries?

H4: Does the implemented carbon efficiency policy affect the amount of Carbon dioxide (CO_2) output each year overweight compared with other ASEAN countries?

Computable General Equilibrium, LMDI, Cobb-Douglas, and Input-output methods are approaches for calculating Energy Rebound Effects or proving Jevon's paradox or Khazzoome Brookes Postulate. Yang and Li (2017) and González et al. (2014) used the LMDI to analyze the energy consumption in PR China and uni-European. LMDI method can be found at Cansino et al. (2019) for analyzing the backfire effect or Jevon's paradox in Spain caused by energy efficiency actions. Q. Wang et al. (2018) looked into the rebound impact of energy consumption in China's three industrial sectors.

RESULTS

Indonesia's energy situation

Indonesia's energy started when the rise of oil prices in the 1970s resulted in a windfall in export revenues for Indonesia. The export contributed to high GDP rates. Economic reforms took place at the end of the 1980s, including a managed devaluation of the rupiah to improve export competitiveness and deregulation of the financial sector. Foreign investment flowed to Indonesia, particularly to the export-oriented manufacturing sector, and from 1989 to 1997, the Indonesian GDP honored an average of more than 7%. Real GDP contracted by 13.1% in 1998, and the economy reached its low point in mid-1999 with real GDP growth of 0.8%. Indonesia's real GDP growth reached 6% in 2012, steadily decreasing to 5.1% in 2004 and 5.6% in 2005. After Joko Widodo succeeded SBY, the government took steps to ease foreign direct investment regulation to stimulate the economy. Indonesia increased its GDP growth slightly above 5% in 2016 – 17. Indonesia's energy demand reflects its economic size; Indonesia's primary energy consumption has also increased rapidly, with an average annual growth rate of 5,157% during 1971 to 2017. The total supply of direct energy supply consists of more than 10,462.6 PJ.

Indonesia increased its GDP growth by about 5% in 2016. Indonesia's demand for primary energy has risen at an average annual rate of 5.157% over the last forty years, from 1971 to 2017. all of the direct energy supply was greater than 10,462.6 PJ Indonesia's emissions have increased just 2048 tons per year since 1971 due to moderate economic growth and only moderate energy intensity improvement. Total CO_2 emissions in Indonesia spanned the 46 years from 1971 to 2017 and 940 metric tons in that time frame. Indonesia has set a target of reducing its emission intensity by 29.41% by 2030. Indonesia's emissions will continue to rise rapidly, as a result of the business climate change it will face in the coming decade."

For the Indonesian leaders, keeping the country's energy security has become extremely difficult. As shown in Figure 1 and Table 1, the primary energy source folds 49 times. GDP (or economic) components and population growth are the key factors behind the rise in energy demand. Using decomposition analysis, it can be seen that the GDP components are playing a more critical role in spiking energy demand and energy intensity. The 1997 to 1998 Asian crisis was the only time when GDP and energy intensity components decreased. An example of the Decomposition for ASEAN Countries 3 is depicted in the graph in Figure 1.

Decomposition analysis

Ensuring Indonesia's reliable and adequate energy supply has become increasingly challenging for Indonesia's leaders. Whereas primary energy supply folds more than 49 times, the determinant factors leading to rising demand for energy were caused by GDP components and population growth components. Figure 2 through decomposition analysis clearly shows that the GDP's components have a more significant role in encouraging the growth of energy demand and energy intensity components to play their function in soaking demand for energy throughout 1971 to 2017. Decreased part of the GDP and energy intensity components occurred only in the Asian Crisis, which began during 1997 to 1998.

As seen in Figure 3 and Figure 4, the first weakening of energy intensity components happened from 1985 until 1990 due to the decline in oil prices. 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 during the Asian Crisis year-round 1997 up to 1998. As seen in Figure 4, the fall of the GDP component is also jointly equal among ASEAN countries, including Indonesia.

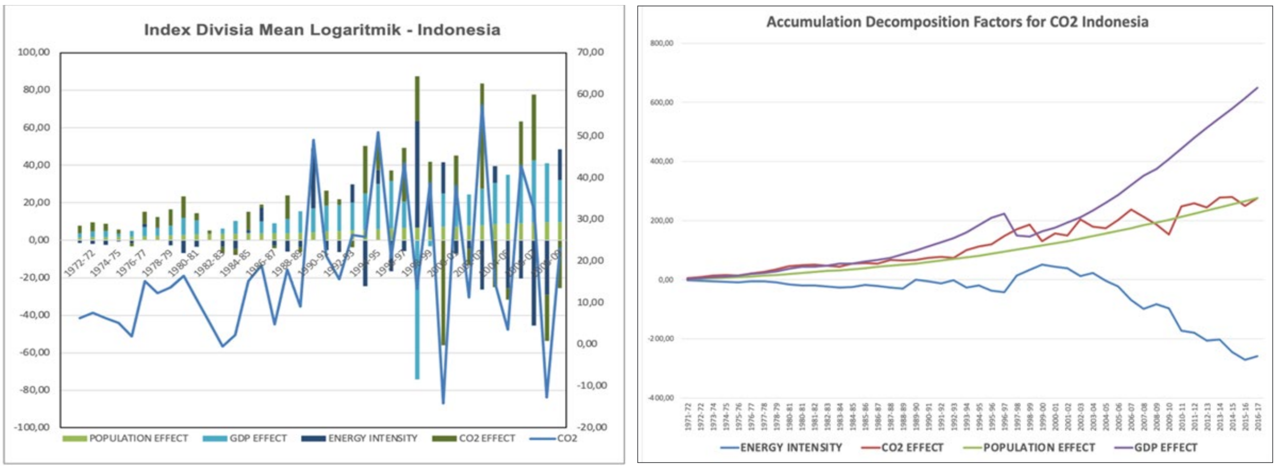

Figure 1. Indonesia CO2 LMDI decomposition analysis

Table 1. Population effects over CO_2

Year	Brunei	Cambodia	Indonesia	Malaysia	Myanmar	Philipines	Singapore	Thailand	Vietnam
1971-75	13.23%	-	31.07%	35.74%	-149.57%	72.31%	21.04%	34.07%	-39.29%
1976-80	49.58%	-	19.51%	33.67%	66.03%	251.87%	27.49%	38.40%	43.20%
1981-85	118.44%	-	41.70%	53.98%	54.40%	-110.06%	33.69%	31.18%	51.99%
1986-90	99.19%	-	20.16%	21.40%	-16.19%	44.09%	23.11%	10.29%	-102.86%
1991-95	41.23%	76.66%	20.01%	29.22%	9.90%	22.60%	69.77%	8.81%	14.80%
1996-97	29.62%	40.57%	14.96%	37.55%	-140.92%	21.32%	-356.31%	48.61%	8.57%
1997-98	-13.44%	19.21%	50.76%	581.45%	13.41%	394.09%	-113.87%	-12.28%	12.84%
1998-03	47.60%	42.54%	28.54%	36.45%	19.87%	-1770.26%	209.65%	23.79%	12.63%
2003-08	21.11%	17.49%	56.23%	26.08%	-14.23%	286.75%	2476.26%	15.91%	9.25%
2008-13	-131.42%	24.28%	35.98%	91.97%	6.44%	34.30%	85.69%	16.45%	22.34%
2013-17	-248.50%	8.81%	27.04%	686.41%	4.12%	18.09%	49.18%	-100.02%	12.05%

Rebound Analysis

We investigated how CO_2 changes over time to attribute changes to Population, Gross Domestic Product, Energy Intensity (Energy per unit GDP), and Carbon Intensity (CO_2 per unit energy). Results found that Indonesia's rebound effect mirrors its energy consumption, showed in Figure 5. The most noticeable rebound effect took place in the year 1977-1978. It happened due to the rise in oil prices in the 1970s. Hence, it resulted in an export revenue windfall that contributed to sustained high economic growth rates, with an average growth of over 7% between 1968 and 1981. In the middle of 1979, oil prices rose due to a decline in oil output following the Iranian revolution and global oil supplies. The price of crude oil has more than doubled to $39.50 per barrel over the next 12 months. Moreover, it has contributed to a high economic growth rate for Indonesia.

Economic instruments should also be complements to ensure energy conservation and emission reduction results. In Figure 5, Indonesia, results have experienced more than 16 times super conservation and 30 times backfire effect, taking the rebound measurement (Saunders, 2015). The results show that, between 1971 and 2017, the energy rebound effect amounted to an average of 198.4%, implying that Indonesia cannot merely rely on technical means to reduce energy consumption and emissions. The average rebound effect has been around 249.44%, with an upward trend in the last decade, indicating missed the expected energy savings. The results show that GDP is mainly responsible for increasing CO_2.

According to IEA, energy and carbon intensity have improved in recent years, returning to levels not seen since the 1990s. GDP growth has been weaker since the global financial crisis and continues until the current situation. Moreover, the current COVID-19 pandemic brings the global economy back into recession. Three combined effects – slightly lower economic growth, improved energy intensity, improved carbon intensity – led to a slower increase in global CO_2 emissions.

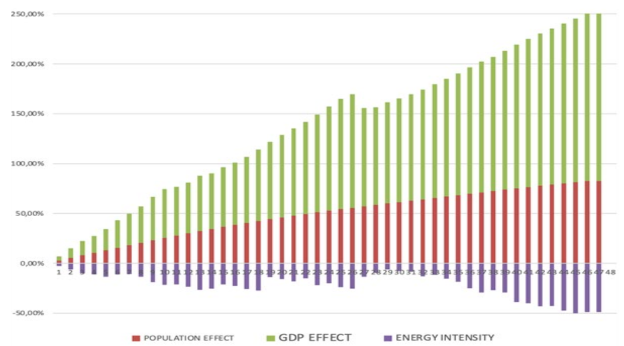

Figure 2. Indonesia decomposition growth factors 1971-2017 With 1971 = 100

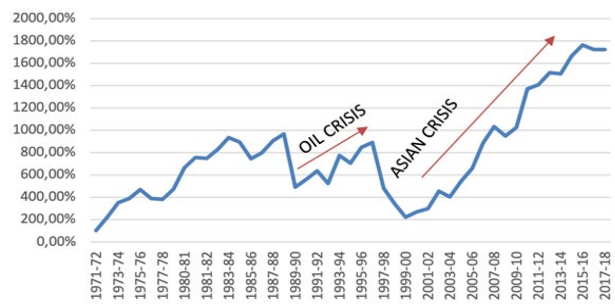

Figure 3. Accumulation energy intensity 1971-2017

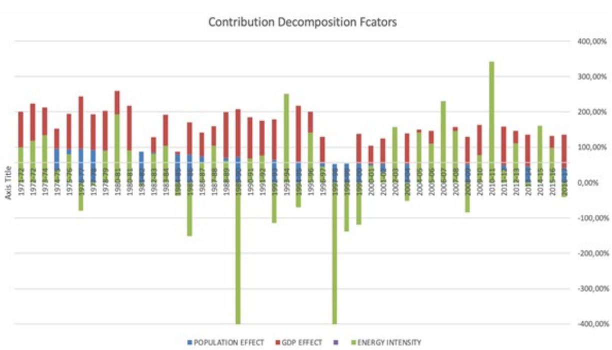

Figure 4. Indonesia decomposition factors: Pop-effect, GDP-effect, EI-effect & CO2-effect 1971-2017

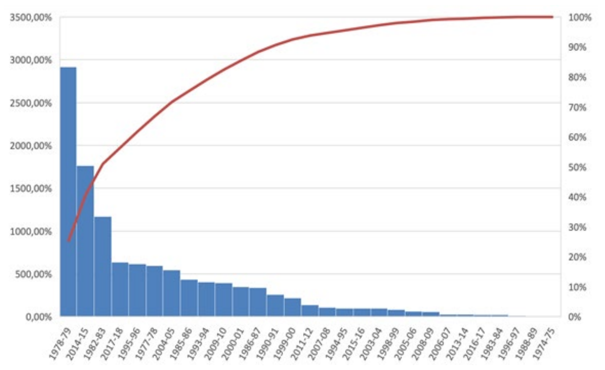

Figure 5. Indonesia decomposition factors:Pop-effect, GDP-effect, EI-effect & CO2-effect 1971-2017

Decomposition of changes in CO_2 emissions

Indonesia has had robust emissions growth of around 20.48 metric tons per year since 1971 to 2017, driven by strong economic growth and moderately improved energy intensity (Figure 5). Total CO_2 emissions in Indonesia from 1971 to 2017 have been reported at 941.40 metric tons for 46 years, from 1971 to 2017 for the IEA. Indonesia has pledged to reduce its emission intensity by 29.41% by 2030. Indonesia's emissions may continue to grow strongly due to vigorous and needed economic activity in the next decade. As explained in the previous paragraph, this paper used KAYA identity to decompose the CO_2 component into Population effect, GDP effect, energy intensity effect, and CO_2 intensity effect to determine each emission reduction factor's significance. The sum of these four factors is equal to the sum of CO_2. The Kaya identity is the primary driving force of CO_2 emissions.

Population Effect

The population effect, characterized by the urbanization share, is another factor that aggravates the increase in CO_2 emissions. Based on the absolute number, Brunei's CO_2 emissions have been produced solely based on population effect for almost 46 years since 1971 to 2017, as shown in Figure 6. Unfortunately, if the decomposition is based on the percentage of the population over CO_2, Malaysia, Singapore, and Indonesia ranked 1st, 2nd & 3rd of the highest in population effect compared to Brunei Darussalam last decade (Table 1). The good sign of the decomposition result was urbanization. The majority of factors contributing to CO_2 emission due to the households consuming the energy increases. Fortunately, over the last decade - the result shows that Brunei's GDP effect is taking off due to Brunei's government improving the private sector development to diversify beyond the hydrocarbon economy.

GDP Effect

In line with existing literature, the impact of GDP is characterized by the share of production in GDP. Results found that the GDP effect was the most compelling factor in the annual increase in CO_2 emissions, followed by Indonesia's population effect (Figure 5) and for most ASEAN countries. This paper found that based on the percentage of the GDP effect over CO_2 emissions in the last decade, the most significant GDP effect that contributed to CO_2 emissions was Malaysia, see Figure 7 followed by Singapore and Thailand (Table 2). Overall, the GDP effect caused CO_2 emissions to increase by 2514.18 million tons over the study period 1971-2017 for the ASEAN countries.

Energy Intensity Effect

The energy intensity effect was mainly attributed to the decline in total CO_2 emissions. By improving the technical aspect, energy intensity has impeded CO_2emissions in most ASEAN countries (Sudarmaji et al. 2021b). From 1971 to 2017, Singapore was the only country to tackle CO_2 emissions through energy efficiency. Energy efficiency has been the cornerstone to control rising CO_2 emissions. The energy intensity effect has been associated with reducing CO_2 emissions over the period. This paper found that based on the percentage of the Energy Intensity effect on CO_2 emissions in the last decade, Malaysia, Brunei, and Indonesia were the ASEAN countries' champions (Table 3).

Table 2. GDP Effects on CO_2

Year	Brunei	Cambodia	Indonesia	Malaysia	Myanmar	Philipines	Singapore	Thailand	Vietnam
1971-75	15.2%	-	49.7%	80.88%	-58.7%	87.84%	82.77%	49.2%	16.8%
1976-80	-53.4%	-	44.9%	65.1%	112.25%	195.63%	91.51%	84.2%	-23.7%
1981-85	-115.8%	-	40.2%	24.8%	26.2%	162.62%	76.40%	57.5%	77.67%
1986-90	-55.1%	-	49.78%	41.02%	38.8%	19.9%	50.30%	60.0%	-143.8%
1991-95	5.2%	69.1%	70.03%	76.85%	45.9%	12.7%	115.34%	55.3%	55.7%
1996-97	-48.9%	15.6%	32.58%	66.70%	-448.8%	26.8%	-491.3%	-163.8%	39.28%
1997-98	16.8%	14.1%	-555.6%	-2352.7%	44.7%	-497.5%	189.41%	93.77%	43.27%
1998-03	23.9%	138.40%	47.3%	48.6%	182.36%	-1346.3%	732.54%	106.2%	60.1%
2003-08	-12.3%	91.0%	173.00%	51.6%	-204.7%	573.43%	2926.14%	98.7%	56.7%
2008-13	71.1%	61.1%	118.3%	118.13%	57.5%	73.9%	141.33%	102.94%	93.4%
2013-17	432.97%	29.2%	86.9%	1578.70%	25.5%	53.7%	104.03%	-744.2%	57.9%

Carbon Intensity Effect

Carbon intensity is the emission rate of a given CO_2 relative to a country's primary energy consumption intensity. This paper found that based on the percentage carbon intensity effect over CO_2 emissions in the last decade, Malaysia, followed by Singapore and Indonesia, (Table 4) were also curbed CO_2 emissions. Based on the absolute number, only Singapore benefited from the carbon intensity effect over CO_2 emissions and impeded CO_2 emissions for almost 46 years since 1971 to 2017.

Managerial Implication

The results of this study are expected to be a source of information regarding the socio-economic characteristics and characteristics that affect CO_2 emissions and the rebound effect that occurs in Indonesia. This research is expected to benefit practical management; therefore, this research is expected to contribute to how energy-efficient ideas can be applied to produce energy-saving and avoid the rebound effect. This research is also expected to contribute to the Indonesian Government's public policy encouraging the energy efficiency industry.

Table 3. Energy Intensity Effects over CO_2

Year	Brunei	Cambodia	Indonesia	Malaysia	Myanmar	Philipines	Singapore	Thailand	Vietnam
1971-75	79.1%	-	-30.98%	-55.72%	89.3%	-45.56%	-21.9%	-0.5%	38.2%
1976-80	87.8%	-	-16.3%	-18.3%	-123.77%	-144.74%	-37.6%	-66.64%	40.4%
1981-85	145.9%	-	3.5%	15.5%	2.7%	-95.83%	29.0%	-28.49%	-67.74%
1986-90	119.7%	-	11.6%	-6.23%	-8.79%	-1.20%	31.9%	6.0%	170.9%
1991-95	0.4%	-31.59%	-21.8%	-43.83%	-37.08%	2.2%	-16.5%	12.9%	-30.3%
1996-97	61.4%	-33.16%	-13.3%	-55.49%	366.6%	0.5%	-383.96%	191.4%	-2.2%
1997-98	-0.82%	61.1%	425.5%	1258.8%	-30.81%	610.2%	263.8%	-15.40%	7.6%
1998-03	-30.39%	-100.35%	-1.2%	-25.3%	-157.82%	2564.8%	183.4%	25.1%	-4.2%
2003-08	107.6%	-141.59%	-138.2%	-47.8%	191.7%	-761.47%	-6353.61%	-14.8%	-2.2%
2008-13	357.3%	68.1%	-78.11%	-73.5%	-45.1%	-64.21%	-144.78%	41.5%	-20.9%
2013-17	-1007.85%	3.9%	-34.18%	-782.47%	10.7%	5.5%	264.8%	704.8%	-9.1%

Table 4. Carbon Intensity Effects over CO_2

Year	Brunei	Cambodia	Indonesia	Malaysia	Myanmar	Philipines	Singapore	Thailand	Vietnam
1971-75	-7.51%	-	50.22%	39.11%	218.96%	-14.60%	18.08%	17.30%	84.31%
1976-80	16.06%	-	51.86%	19.48%	45.48%	-202.76%	18.60%	44.08%	40.14%
1981-85	-48.57%	-	14.58%	5.69%	16.73%	143.27%	-39.05%	39.85%	38.08%
1986-90	-63.78%	-	18.42%	43.82%	86.14%	37.25%	-5.33%	23.77%	175.73%
1991-95	53.13%	-14.15%	31.81%	37.76%	81.29%	62.55%	-68.62%	23.01%	59.76%
1996-97	57.90%	77.03%	65.78%	51.24%	323.12%	51.40%	1331.56%	23.81%	54.37%
1997-98	97.42%	5.63%	179.35%	612.46%	72.74%	-406.85%	-239.29%	33.92%	36.30%
1998-03	58.87%	19.40%	25.42%	40.25%	55.59%	651.74%	-1025.57%	-55.10%	31.48%
2003-08	-16.40%	133.05%	9.01%	70.08%	127.19%	1.30%	1051.21%	0.18%	36.26%
2008-13	-197.05%	-53.55%	23.86%	-36.60%	81.20%	55.98%	17.76%	-60.89%	5.16%
2013-17	923.38%	58.09%	20.28%	-1382.64%	59.68%	22.70%	-318.04%	239.46%	39.09%

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

From the analysis, this paper found that significant energy rebounds in Indonesia and ASEAN countries have shown that energy efficiency improvements in Indonesia and ASEAN can be associated with the rebound effect. Indonesia aims to move towards, and the national energy Policy (KEN) aims to reduce energy efficiency by 1% per year to encourage energy savings in all sectors. In 2050, the industrial sector will dominate more than other sectors, with a share of 37% in the low carbon or Rendah Kalori (RK) scenario. In 2050, electricity demand will be more dominant at 33% (RK), respectively. It includes, among other things, the provision of appropriate policy measures to control CO_2 emissions. This paper decomposed the driving factors for CO_2 emissions in Indonesia and ASEAN countries at an aggregate level. This paper found that the increase in CO_2 emissions was primarily due to GDP or economic expansion, followed by population (urbanization). This paper proposes improving energy efficiency, particularly in the other strategy to stimulate increased energy efficiency in the financial sector, as appropriate emission control strategies. Future research may include an analysis of the decomposition of sub-sectoral activities within the industry.

The most pronounced rebound effect occurred between 1971 and 2017, with an average energy rebound effect of 198.4%. The average rebound effect is about 249.44%, with an upward trend occurring in the last decade. These results imply that Indonesia cannot rely solely on technical aspects to reduce energy consumption and emissions. However, economic instruments are needed, which must also be prepared to ensure energy conservation and emission reduction results run as they should. It is indicated that the expected energy savings did not occur.

Four factors are used to see the amount of CO_2 produced by Indonesia and ASEAN countries. Based on the results obtained and contextualized on the population effect, it was found that the absolute amount of Brunei's CO_2 emissions produced based on the population effect for nearly 46 years from 1971 to 2017 was the best. Based on the order of percentage, population effect on CO_2, placing Malaysia, Singapore, and Indonesia in the first, second & third highest rank compared to Brunei Darussalam in the last decade. The increasing household energy consumption causes the contributor to CO_2 emissions in Indonesia. For this reason, answering hypothesis 1 and this study confirms that Indonesia's population has a very low (underweight) effect on CO_2 emissions compared to other ASEAN countries. Therefore, in Hypothesis 1, the authors reject the formulation of the hypothesis.

Based on the percentage effect of GDP on CO_2 emissions in the last decade, the GDP effect is hypothesized to be the most significant factor contributing to CO_2 emissions. The study found that Singapore followed Malaysia, and Thailand was the most affected country. Overall, the GDP effect caused CO_2 emissions to increase by 2,514.18 million tons during the 1971 to 2017 study period for ASEAN countries. From the results of this study, it can be concluded that Indonesia's GDP affects CO_2 emissions but is not the worst compared to ASEAN countries. Therefore, the authors reject hypothesis 2.

The energy intensity factor in ASEAN countries has dramatically increased. It is indicated by the increasing application of technology in many industries. Therefore, it can be said that the energy intensity of ASEAN countries can inhibit the resulting CO_2 emissions. Energy efficiency has become the basis for controlling the increase in CO_2 emissions. This study found that based on the percentage effect of Energy Intensity on CO_2 emissions in the last decade, Malaysia, Brunei, and Indonesia are the countries that have the highest energy intensity. So if the results are contextualized to answer hypothesis 3, the authors can confirm that the Indonesian population affects CO_2 emissions but is still inferior to Malaysia and Brunei. Therefore the author can state that hypothesis 3 is unaccepted, and the author rejects hypothesis 3.

Meanwhile, Based on absolute figures of Carbon intensity, only Singapore benefited from the effect of carbon intensity on CO_2 emissions, and CO_2 emissions were inhibited for nearly 46 years from 1971 to 2017. These results are obtained from calculations. If contextualized to answer hypothesis 4, the authors emphasize that Indonesia's carbon intensity affects CO_2 emissions but is still underweight compared to other ASEAN countries. Therefore, the authors reject hypothesis 4.

Recommendations

This research suggests that now is a good time for Indonesia and the Association of Southeast Asian Nations (ASEAN) countries to increase renewable energy deployment. The government is responsible for implementing the Energy Efficiency Saving (EEDI) projects in Indonesia (Nasip and Sudarmaji, 2018a, 2018b). Those programs use alternative finance instruments such as bank and pension funds project support (Sudarmaji et al. 2021a). Other aspects of the government's energy conservation policy can be more effective with the national nudges. Similarly, nudges are accepted in several different industries besides manufacturing. As a study shows (Sudarmaji et al. 2022), social norms and restraints have influenced electric use in rural areas in 'nudging.' Energy conservation solutions were included in the 'nudges.' It usually occurred in many countries, and 'nudging' can be used in many industries. Carbon dioxide emissions can lower the energy needed in future energy-conservation projects.

Further research may also consider whether Indonesia's low-carbon economic target has been technically competent. Our results also highlight how strong the rebound effect in ASEAN countries is, and it could be a key component and a driving force for economic growth. It leads to trade-offs, whether future economic growth can be limited to climate-based policies. Currently, this paper proposes that it would be a good time for Indonesia and ASEAN countries to deploy renewable energy sources more quickly.

REFERENCES

Ang BW. 2015. LMDI decomposition approach: A guide for implementation. *Energy Policy* 86. https://doi.org/10.1016/j.enpol.2015.07.007

ASEAN Secretariat. 2019. *Integration Report 2019.*

Brown MH, Conover B. 2009. Recent Innovations in Financing for Clean Energy. Southwest Energy Efficiency Project, October.

Cansino JM, Roman-Collado R, Merchan J. 2019. Do Spanish energy efficiency actions trigger JEVON'S paradox? *Energy* 181: 760–770.

Dobbs R, Pohl H, Lin DY, Mischke J, Garemo N, Hexter J, Matzinger S, Palter R, Nanavatty R. 2013. Infrastructure productivity: how to save $1 trillion a year. In McKinsey Global Institute (Issue January).

Gerarden TD, Newell RG, Stavins RN. 2015. Assessing the Energy-Efficiency Gap. *National Bureau of Economic Research Working Paper Series January* 1–74.

González PF, Landajo M, José Presno M. 2014. The Driving Forces of Change in Environmental Indicators: An Analysis Based on Divisia Index Decomposition Techniques. *Lecture Notes in Energy* 25. https://doi.org/10.1007/978-3-319-07506-8

Jaffe AB, Stavins RN. 1994. The energy- efficiency gap What does it mean? *Energy Policy* 22(10): 804–810.https://doi.org/10.1016/0301-4215(94)90138-4

Karali N, McNeil MA, Letschert V, de la Rue du Chan S. 2015. Potential Impact of Lighting and Appliance Efficiency Standards on Peak Demand: The Case of Indonesia Nihan Karali. Ernest Orlando Lawrewnce Berkeley Natioanal Laboratory, August.

Ma C, Stern DI. 2008. Biomass and China's carbon emissions: A missing piece of carbon decomposition. *Energy Policy* 36: 2517–2526.

Ma M, Cai W. 2018. What drives the carbon mitigation in Chinese commercial building sector? Evidence from decomposing an extended Kaya identity. *Science of the Total Environment* 634: 884–899. https://doi.org/10.1016/j. scitotenv.2018.04.043

Ma M, Cai W, Cai W. 2018. Carbon abatement in China's commercial building sector: A bottom-up measurement model based on Kaya-LMDI methods. *Energy* 165: 350–368. https://doi.org/10.1016/j.energy.2018.09.070

Nasip I, Sudarmaji E. 2018a. Government measures to promote new retrofitting business and financing option in Indonesia. *International Journal of Engineering and Technology (UAE)* 7 (3.25 Special Issue 25). https://doi.org/10.14419/.v7i3.12.16173

Nasip I, Sudarmaji E. 2018b. Managing tax dispute due to IFRS-16 on the retrofits implementation in Indonesia. *International Journal of Engineering and Technology (UAE)* 7(3). https://doi.org/10.14419/ijet.v7i3.21.17160

O'Malley E, Scott S, Sorrell S. 2003. The economics of energy efficiency: Barriers to cost- effective investment. In Policy Research Series. Saunders, H. D. 2015. Recent evidence for large rebound: Elucidating the drivers and their implications for climate change models. *Energy Journal* 36(1):

23–48. https://doi.org/10.5547/01956574.36.1.2

Schleich J, Gruber E. 2008. Beyond case studies: Barriers to energy efficiency in commerce and the services sector. *Energy Economics* 30: 449–464.

Sudarmaji E, Achsani NA, Arkeman Y, Fahmi I. 2021a. Alternative PSS Business Models of ESCO: Towards an Innovative New Model. *Indonesian Journal of Business and Entrepreneurship* 7(3), 296–306. https://doi. org/10.17358/ijbe.7.3.296

Sudarmaji E, Achsani NA, Arkeman Y, Fahmi I. 2021b. Can energy intensity impede the co2 emissions in indonesia? Lmdi-decomposition index and ardl: Comparison between Indonesia and Asean countries. *International Journal of Energy Economics and Policy* 11(3): 308–318. https://doi.org/10.32479/ijeep.11212

Sudarmaji E, Achsani NA, Arkeman Y, Fahmi I. 2022. Decomposition Factors Household Energy Subsidy Consumption in Indonesia: Kaya Identity and Logarithmic Mean Divisia Index Approach. *International Journal of Energy Economics and Policy* 12(1): 355–364. https://doi.org/10.32479/ijeep.12629

U.S. Department of Energy. 2016. Solid-State Lighting R&D Plan (Issue June, p. 3).

Wang Q, Gao Z, Tang H, Yuan X, Zuo J. 2018. Exploring the direct rebound effect of energy consumption: A case study. *Sustainability (Switzerland)* 10(1). https://doi.org/10.3390/ su10010259

Wang W, Liu X, Zhang M, Song X. 2014. Using a new generalized LMDI (logarithmic mean Divisia index) method to analyze China's energy consumption. *Energy* 67: 617–622. https://doi.org/10.1016/j.energy.2013.12.064

Yang L, Li Z. 2017. Technology advance and the carbon dioxide emission in China – Empirical research based on the rebound effect. *Energy Policy* 101(October 2016): 150–161. https://doi.org/10.1016/j.enpol.2016.11.020

Zhang Y. 2019. Energy Rebound Effect Analysis Based on Technological Progress. *IOP Conference Series: Earth and Environmental Science* 300(4). https://doi.org/10.1088/1755-1315/300/4/042035ppendix 1