Damayanti, Setia; Sudarmaji, Eka; Masrio, Herlan

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The Critical Role of Energy Intensity in Decarbonizing ASEAN: Integrating Growth and Emissions Reductions

Setia Damayanti[1], Eka Sudarmaji[2]*, Herlan Masrio[2]

[1]Magister Rekayasa Infrastruktur dan Lingkungan, University of Pancasila, Indonesia, [2]Fakultas Ekonomi and Bisnis, University of Pancasila, Indonesia. *Email: esudarmaji@univpancasila.ac.id

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ABSTRACT

This research analyzes drivers of CO_2 emissions across ASEAN countries from 1971 to 2017 to inform effective policies for sustainable decarbonized development. The goal is to identify critical factors influencing emissions growth and reductions to guide strategic climate mitigation planning. Data includes 3128 emissions, GDP, population, and energy consumption observations from 9 ASEAN nations. Results using the Kaya Index and Logarithmic Mean Divisia Index decomposition reveal GDP growth and population as primary drivers of increasing emissions, while energy efficiency dampens growth. Indonesia saw the highest emissions growth, driven by population and economic expansion. Thailand's phenomenal GDP growth of 3003.7% led to its emission increases. Singapore and the Philippines achieved notable reductions. Findings suggest integrated policies like clean energy, efficiency gains, infrastructure planning, and low-carbon economic reform are needed. Transitioning towards affordable clean energy systems with proactive leadership can enable ASEAN to sustain growth while mitigating climate risks. Further research should identify optimal policy mixes to maximize socio-economic progress and welfare while meeting urgent emission targets tailored to each nation. This study provides vital insights into key factors influencing ASEAN emissions and highlights pathways towards sustainable decarbonized development. The analysis of historical trends aims to inform strategic policymaking for decarbonization.

Keywords: Decarbonization, ASEAN Countries, Logarithmic Mean Divisia Index, Energy Efficiency Optimization, Sustainability
JEL Classifications: P18, P28, Q47

1. INTRODUCTION

The Association of Southeast Asian Nations (ASEAN) has emerged as one of the most economically vibrant regions in the world. Comprised of 10 countries including Indonesia, Malaysia, Singapore, Thailand, and others, ASEAN represents a significant engine of global economic growth. ASEAN wields tremendous economic influence, with a combined GDP of over $3 trillion and over 630 million people. However, this rapid growth has not come without consequences, especially concerning fossil fuel consumption, greenhouse gas emissions, and environmental degradation. Tackling these interconnected issues requires a multipronged strategy centred on deploying clean energy technologies and advancing energy efficiency policies across the ASEAN nations. Over the past few decades, ASEAN has transitioned from a developing region to a global economic powerhouse. Since 2000, its GDP growth has averaged around 5% annually, outpacing the global average and other emerging markets. Several factors have facilitated this rapid ascent. ASEAN benefits from abundant natural resources, a strategic geographic location, and proximity to major markets like China, Japan, and India. By lowering trade barriers and establishing the ASEAN Economic Community (AEC), member nations have become more integrated into regional and global supply chains. ASEAN also possesses a growing young workforce that expands the consumer base and labour pool.

However, the technology and manufacturing boom underlying ASEAN's growth has increased the region's energy consumption and carbon dioxide (CO_2) emissions. As living standards rise along with incomes, energy demand for transportation, appliances, cooling, and mobility has surged. ASEAN's primary energy consumption expanded by nearly 60% between 2000 and 2017. Although the energy mix varies, ASEAN relies heavily on fossil fuels like oil, gas, and coal to meet its energy needs. As a result, CO_2 emissions rose from 1.2 billion metric tons in 2000 to 1.8 billion metric tons in 2016. This growth puts ASEAN on an environmentally unsustainable trajectory. Rising greenhouse gas emissions have far-reaching environmental repercussions. Air pollution from the energy and transportation sectors has degraded urban air quality across ASEAN cities. Haze from agricultural fires and land clearing also frequently blankets cities like Singapore and Kuala Lumpur. Deforestation and habitat loss driven by economic expansion threaten ASEAN's rich biodiversity.

Moreover, climate change poses significant risks to ASEAN nations, which are most vulnerable to rising sea levels, changing precipitation patterns, and extreme weather. Climate change will significantly impact ASEAN's agricultural productivity, water resources, coastal regions, and human health. A 2018 ADB report estimates Southeast Asia could suffer 11% lower GDP per capita by 2100 if global temperatures rise by 3°C. Minimizing climate change and its disruptive impacts will require steep reductions in CO_2 and other emissions alongside adaptation measures. Thus, curbing pollution while sustaining economic growth represents a significant policy challenge for ASEAN governments.

ASEAN must deploy clean energy technologies and infrastructure on a large scale to shift towards an environmentally sustainable growth model. Renewable energy sources like solar, wind, hydro, and geothermal offer zero-emission alternatives to replace fossil fuel power generation. ASEAN nations have set ambitious renewable energy targets to source 23% of primary energy from renewables by 2025. However, renewables only comprised 15% of the ASEAN energy mix in 2017. Accelerating renewables growth requires mobilizing investments in solar parks, wind farms, grid infrastructure, and storage solutions tailored to Southeast Asia's climate and resources. Decarbonization is crucial for ASEAN countries due to their heavy reliance on fossil fuels for energy generation and the significant impact of climate change on the region. According to a study analyzing the status of fossil and renewable energies in Southeast Asia, ASEAN nations emitted 1.65 Gtpa CO_2 in 2020 and are among the most vulnerable to climate change (Reference Article 2).

The increasing energy consumption and emissions pose environmental and economic risks, making decarbonization a pressing priority. To understand the decarbonization pathways for ASEAN, it is essential to examine the current energy landscape in the region. According to a study on energy economics and energy phenomena, the energy industry in ASEAN is heavily regulated, and energy fuels, particularly fossil fuels, play a significant role in economic growth and development. However, renewable energies' contribution to the total primary energy consumption (TPEC) has decreased in the last two decades despite the increasing installation capacity. This indicates the need for more ambitious and practical solutions to transition to cleaner energy sources.

Improved energy efficiency and the adoption of clean technology innovations serve to reduce the demand for fossil fuels. Moreover, it is proven that clean technology innovation can reduce the vast growth in fossil fuel energy consumption for today's industry. However, investment in technological innovations is often costly when first discovered. However, the initial investment cost will decrease over time as its widespread use in the market increases (Sorrell, 2014). That is why a collective effort is needed to utilize this technology widely. At the time of writing, the price of fossil fuels is relatively high, which will encourage technological innovation from the demand side. As new technological innovations to meet growing energy demands evolve, understanding how these technologies will impact the existing energy value chain is critical to navigating the energy transition successfully.

These papers highlight the significance of energy efficiency measures, flexibility, and the integration of low-carbon technologies in achieving decarbonization goals in the energy system. Rising CO_2 emissions from fossil fuel combustion are driving dangerous climate change. While renewable energy growth is crucial, improving energy efficiency across all sectors also offers significant untapped potential to reduce emissions. However, most climate policy focuses heavily on scaling up renewable energy and often overlooks enhanced energy efficiency's significant emission reduction potential. More research is needed to optimize energy efficiency improvements as a core decarbonization strategy alongside renewables deployment. Bridging this research gap will help inform policies and technical solutions to exploit the full mitigation potential of energy efficiency advances. This research analyzes drivers of CO_2 emissions across ASEAN countries from 1971 to 2017 to inform effective policies for sustainable decarbonized development. The goal is to identify critical factors influencing emissions growth and reductions to guide strategic climate mitigation planning.

2. LITERATURE REVIEW

The strategic management literature provides insights and solutions, especially in increasing the implementation of clean energy in line with the current limited availability of fossil energy (Capellán-Pérez et al., 2015). The critical problem is developing and marketing clean energy technology more successfully, including increasing clean energy adoption. Meanwhile, (Rogers, 2009) argues that, despite the apparent benefits of clean energy, implementing newly selected innovative concepts related to clean energy is often complicated. For this reason, direct economic incentives, such as subsidies/grants, soft loans, and indirect fiscal incentives, such as tax credits provided by the government to increase the use of clean energy, are needed to reduce upfront investment costs. (Barkhordar, 2019; Al Irsyad and Nepal, 2016; Sudarmaji et al., 2022; Wang et al., 2017). Therefore, other strategies to encourage policies to increase clean energy in the economic sector are essential for the government in overcoming the constraints of fossil fuel sources. Clean energy projects will reduce carbon emissions and the barriers to fossil energy availability that hinder many industries in many countries. The findings that there are so many Unconsolidated Government Policies by researchers (An et al., 2022; Chen, 2016; Fisher and

Rothkopf, 1989; Giri et al., 2021; Jänicke 2012) hinder policies on the energy economy. It was found that the policy of poor coordination between regulations and laws has hindered efforts to promote clean energy. A similar situation is found in many developing countries, where the clean energy industry is still in its early stages of development and is still scarce. Of course, the situation is different in developed countries.

China, the world's top emitter of carbon dioxide, has used LMDI research to pinpoint the leading causes of emissions rise and create mitigation measures. For instance, Han and Jiang, (2022) discovered that the effectiveness of industrial structure adjustment considerably increases carbon emission efficiency. According to (Zhang and Wang, 2009), changes in production patterns, particularly shifts in energy intensity within each sector between 1992 and 2002, were the key contributors to China's drop in energy-related carbon intensity. Zhu et al. (2012), computed the energy consumption carbon emissions and emission intensity in China from 1997 to 2007 using the calculation technique and carbon emission coefficients accepted by IPCC (2006). The six driving elements for the United States' carbon emissions are labour input impact, investment effect, carbon coefficient effect, energy structure effect, energy intensity effect, and technological state effect Jiang et al. (2019). Liu et al. (2016), assumed that, under the CR and ILCE scenarios, the share of coal will significantly decrease from 2009 to 2050 while the share of natural gas and renewable energy will significantly increase due to changes in the energy structure, increased energy efficiency, and changes in technical energy merit. In order to analyze changes in China's national and regional power sector carbon emissions from 2003 to 2017, Chang et al. (2021)**,** used the Logarithmic Mean divisia index (LMDI) model.

Regional power sector carbon emissions are estimated using the production and consumption accounting principle. Similarly, the European Union has improved its climate policy and evaluated the effectiveness of its emissions reduction objectives using LMDI. For instance, the Logarithmic Mean Divisia Index (LMDI) was discovered by Förster et al. (2014) to provide insights into five effects: Affluence, energy intensity, carbon intensity, conversion efficiency, and structural change. Decarbonization and energy efficiency are crucial components of climate change mitigation. The findings from the various models indicate that increasing energy efficiency is the main tactic for attaining moderate climate objectives (Marcucci and Fragkos, 2015). Serrano-Puente and Murciego, (2021), Additionally, we proceed in a way that balances energy intensity and energy efficiency metrics, and we can distinguish between technical and observed end-use energy efficiency, taking into account potential rebound effects and other factors.

This allows us to analyze more potential influencing factors than those typically examined. In 2021, Dolge and Blumberga (2021), Five separate factors-the industrial activity impact, structural change effect, energy intensity, fuel mix effect, and emission intensity effect-are used to determine changes in total energy-related CO_2 emissions in the manufacturing sector. Román-Collado and Economidou (2022), Establish a strategy for an allocation diagram method for charging the end-use sectors, including both productive and unproductive sectors, with the burden of meeting primary energy needs and carbon dioxide emissions. Denis et al. (2014), Ambitious energy efficiency in every sector, as achieved in the example scenario, results in half the economy's ultimate energy intensity between now and 2050. Serrano-Puente and Murciego, (2021), found that using this methodological approach, it is possible to give an allocation diagram scheme for tying end-use sectors, including both productive and unproductive ones, to the responsibility of primary energy needs and carbon dioxide emissions.

3. METHODS

ASEAN has witnessed significant changes in its environmental and economic indicators from 1995 to 2017. The variables in the study, which included CO_2 gas emissions, GDP, population, and primary energy consumption, were divided using the Kaya Index, the Logarithmic Mean Divisia Index (LMDI), and the (Ang, 2015) technique. With the exception of Brunei Darussalam, the original data from the World Development Indicators (World Bank) and the International Energy Association (IEA) covering the nine ASEAN nations from 1971 to 2017 had 3128 total data observations. These techniques help in understanding the drivers behind changes in these variables. The environmental and economic factors in ASEAN countries are intricately linked. As economies grow, so does energy consumption, which often increases CO_2 gas emissions. However, the relationship is not always linear. Economic growth's adverse environmental effects can be lessened through policies that support energy efficiency and renewable energy sources. In this equation, population increase is also essential. Although a growing population might stimulate economic growth, it can also put pressure on resources and raise emissions. Urban planning and sustainable population management are essential for balancing environmental protection and economic growth.

In addition, assessments of the GDP, population, CO_2, and energy intensity (EI) effects are crucial for comprehending the subtleties of these relationships. While the population effect evaluates the impact of population expansion on these variables, the GDP effect investigates how changes in GDP affect energy consumption and emissions. The effect considers the GDP's energy intensity while concentrating on the direct effects of CO_2 emissions. The Logarithmic Mean Divisia Index (LMDI) technique has become a potent and adaptable instrument for examining and comprehending the causes of carbon emissions and, as a result, for developing decarbonization plans (Murni et al., 2022). This study examines the use of the LMDI approach in decarbonization, emphasizing its benefits, drawbacks, and practical applications. Decarbonization demands an in-depth understanding of the variables influencing carbon emissions, precisely where the LMDI approach excels. The LMDI technique is a thorough and transparent method for breaking down variations in carbon emissions into their numerous underlying causes. LMDI enables analysts to pinpoint the factors contributing to emissions increase or reduction over time by segmenting the total emissions into population, GDP, energy intensity, and carbon intensity.

Therefore, the research needs to identify key drivers of emissions growth. LMDI can model different scenarios by altering the assumptions related to population growth, economic development, and technology adoption. These scenarios help stakeholders visualize the potential impacts of different policy choices and inform decision-making. The addicting LMDI decomposition approach was used in this investigation. One factor can be divided into several components under LMDI, and LMDI can quantify the effect of those components on the original factor. For Indonesia and ASEAN nations from 1971 to 2017, the author of this study may combine CO_2 into POP-effect, GDP-effect, EI-effect, and CO_2-effect components. The IEA provided data on CO_2 gas emissions, GDP, population, and primary energy consumption. The decomposed addictive LMDI model was used to get four aspects, population effect, GDP impact, energy intensity, and CO_2 intensity, to reflect the various consequences of increases in energy consumption. The following are the decomposition effect equations:

$$\Delta EC_{Total} = \left(\Sigma L\left(POP^{T}, POP^{0}\right) Ln\left(\frac{POP_{effect^{T}}}{POP_{effect^{0}}}\right)\right) + \left(\Sigma L\left(GDP^{t}, GDP^{0}\right) Ln\left(\frac{GDP_{effect^{T}}}{GDP_{effecr^{0}}}\right)\right) + \left(\Sigma L\left(EI^{T}, EI^{0}\right) Ln\left(\frac{PEC_{effect^{T}}}{PEC_{effect^{0}}}\right)\right) \left(\Sigma L\left(CO_2{}^{T}, CO_2{}^{0}\right) Ln\left(\frac{CO_{2effect^{T}}}{CO_{2effect^{0}}}\right)\right) \quad (1)$$

Where:

ΔEC_{Total}=Energy Consumption

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

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

$\Delta EI - effect = \left(\Sigma L\left(EI^{T}, EI^{0}\right) Ln\left(\frac{PEC_{effect^{T}}}{PEC_{effect^{0}}}\right)\right)$ was Energy Intensity

$\Delta CO2 - effect = \left(\Sigma L\left(CO_2{}^{T}, CO_2{}^{0}\right) Ln\left(\frac{CO_{2effect^{T}}}{CO_{2effect^{0}}}\right)\right)$ was CO_2 Intensity

According to Cansino et al. (2019), $\Delta E_{intensity}$ was a proxy for technological innovation or technological change, such as energy efficiency or renewable energy implementation. As a result, energy intensity might affect energy consumption and economic growth. Energy costs lowered by 1% for every 1% drop in energy intensity. In other words, the 1% energy savings that would ensue would equal the drop in energy intensity, or it may be expressed as follows: $\frac{ÄPEC}{PEC} 1_{GDP} = \frac{ÄEI}{EI}$. However, because the rebound effect also causes energy consumption to rise, the anticipated 1% reduction in energy consumption may not have happened. It might be said that the rebound effect caused the expected energy savings (EES) to differ from the actual energy savings (AES) (Sudarmaji, et al. 2022b; Sudarmaji, et al. 2022c). This study explores decomposition techniques and forecasting methods to understand better and project these trends.

Furthermore, the study aimed at forecasting energy demand using methods like VECM (Vector Error Correction Model). Such forecasting techniques provide valuable insights into future trends and help policymakers plan for sustainable development. These methods can help anticipate future energy demands, population growth, and environmental challenges. Governments can implement policies that promote sustainable development and reduce the carbon footprint by making informed projections. The long-run model panel data regression 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 were analyzed using the VECM. We connected our short- and long-run effects to the notable predictive framework on the effects of energy intensity (Cansino et al., 2019). Our econometric method emphasized us to estimate short-run effects relevant to the region. By reformulating Eq.(2) above as an ARDL(p, q., q) model. ARDL model as forecasting model for energy intensity "EI-effect," gross domestic effect "GDP-effect," population effect "POP-effect" and CO_2 emission effect "CO_2-effect," can be written as follows:

By focusing on impacts at various time horizons, we provide the groundwork for understanding the conflicting effects of energy intensity on population, GDP, and CO_2 intensity. The VECM was used to examine the results. According to Cansino et al. (2019) study on the impacts of energy intensity, we linked our short- and long-term results to this critical prediction framework. Our econometric approach placed a strong emphasis on estimating regionally appropriate short-run impacts. Eq. (2) may be rewritten as an ARDL (p, q., q) model. The ARDL model may be expressed as the following when used as a forecasting model for the energy intensity "EI-effect," gross domestic product "GDP-effect," population "POP-effect," and CO_2 emission "CO_2-effect:"

$$\text{EI} - \text{effect}_t = \alpha + + \varnothing \text{EI} - \text{effect}_{t-1} + \sum_{j=1}^{k} \beta_j \text{ X}_{j.t-1} + \sum_{j=1}^{q} \alpha_I \Delta\text{EIeffect}_{t-1} + \sum_{j=1}^{k} \sum_{i=0}^{q} \delta_{j,t} \Delta X_{j.t-1} + \varepsilon_t \quad (3)$$

$$\text{GDP} - \text{effect}_t = \alpha + + \varnothing \text{GDP} - \text{effect}_{t-1} + \sum_{j=1}^{k} \beta_j \text{ X}_{j.t-1} + \sum_{j=1}^{q} \alpha_I \Delta\text{GDPeffect}_{t-1} + \sum_{j=1}^{k} \sum_{i=0}^{q} \delta_{j,t} \Delta X_{j.t-1}. + \varepsilon_t \quad (4)$$

$$\mathrm{POP-effect_t} = \alpha + +\varnothing \mathrm{POP-effect}_{t-1} + \sum_{j=1}^{k} \beta_j\ \mathrm{X_{j.t-1}} + \sum_{j=1}^{q} \alpha_I \Delta \mathrm{CO_2 effect}_{t-1} + \sum_{j=1}^{k} \sum_{i=0}^{q} \delta_{j,t} \Delta X_{j.t-1} + \varepsilon_t \quad (5)$$

$$\mathrm{CO_2-effect_t} = \alpha + +\varnothing \mathrm{POP-effect}_{t-1} + \sum_{j=1}^{k} \beta_j\ \mathrm{X_{j.t-1}} + \sum_{j=1}^{q} \alpha_I \Delta \mathrm{CO_2 effect}_{t-1} + \sum_{j=1}^{k} \sum_{i=0}^{q} \delta_{j,t} \Delta X_{j.t-1} + \varepsilon_t \quad (6)$$

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 as:

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

The α and β parameters had a dimension N × R, where N was the coefficients, and R was the cointegration). The degree of cointegration indicates several long-term relationships between the Y_{-t} and the model we made. Cointegration can be said to be the main requirement of using VECM. Based on the decomposition analysis and VECM model, authors make some hypotheses about the impact of energy intensity variables on other variables such as GDP (economic growth), POP (population growth) and CO_2 (carbon emissions). In the Hypotheses, there is a long-term relationship between energy intensity, technology improvement, or energy efficiency on the other three variables.

4. RESULTS AND DISCUSSION

Energy efficiency is crucial to reduce energy use and the amount of CO_2 and other greenhouse gas emissions into the environment or decarbonization without compromising performance or comfort. Energy efficiency and decarbonization are vital strategies for sustainable energy development. Energy efficiency involves using less energy input to provide the same services by minimizing waste (Renewable Energy and Energy Efficiency Partnership, 2012). Decarbonization refers to reducing the carbon intensity of energy by transitioning from fossil fuels to low-carbon energy sources like renewables. While both contribute to sustainability, their approaches differ. Energy efficiency reduces environmental impacts by decreasing energy demand through better technologies and management.

In contrast, decarbonization focuses on changing the energy supply mix towards lower-carbon sources like solar, wind and nuclear power. Renewable Energy and Energy Efficiency Partnership (2012) gives examples of efficiency measures like upgrading motors, improving building insulation and installing efficient lighting. Decarbonization would involve increasing renewable power capacity and substituting natural gas for coal in power plants. Ultimately, energy efficiency and decarbonization are complementary strategies. Efficiency helps curb rising energy demand, while decarbonization cleans the energy supply. Pursuing both can enable providing energy services sustainably with minimal environmental harm. Renewable Energy and Energy Efficiency Partnership (2012) notes that efficiency makes energy resources go further, while renewables like solar support sustainable generation. Integrating efficiency and decarbonization through renewable energy, cleaner fossil fuels, and efficient end-use can facilitate the transition to a low-carbon energy future.

4.1. Descriptive Analysis

Table 1 below provides valuable insights into the dynamic nature of these Asian economies and their environmental challenges. They underscore the importance of sustainable development and effective policies to manage population growth, economic expansion, and environmental impact. As these countries continue to evolve, interpreting and managing such figures will remain crucial for their future prosperity and sustainability.

Table 1 shows that Indonesia saw a staggering population growth of 2182.8%. This is a remarkable increase, reflecting the country's demographic transition. Rapid population growth can pose challenges and opportunities, impacting the economy, infrastructure, and social services. Malaysia also experienced a substantial population increase of 1370.3% during the same period. This demographic shift likely played a pivotal role in shaping the country's economic landscape, including labour force dynamics and resource utilization. Thailand recorded an astonishing GDP growth of 3,003.7%. This phenomenal expansion signifies Thailand's robust economic development over the decades, making it one of the notable success stories in the region.

In contrast, Cambodia experienced an extraordinary 71.3% increase in GDP intensity. This indicates rapid economic growth and diversification, potentially fueled by foreign investments and increased exports. A stunning 864.1% rise in CO_2 intensity was seen in Vietnam. The difficulties Vietnam has in controlling its environmental effect as its economy grows are shown by this significant increase in carbon intensity. With a startling −398.9% drop, Singapore's CO_2 intensity remarkably declined-this remarkable decrease in carbon intensity results from Singapore's emphasis on sustainability and environmental legislation. During the same time frame, the Philippines had a massive drop in delta CO_2 of −557.2%, which indicates a considerable decrease in carbon emissions. This might mean the nation has advanced its use of greener energy sources or increased energy efficiency.

4.2. Decomposition Analysis

The complex interrelationship between economic growth, energy use, and carbon emissions is highlighted in Table 2. They also draw attention to significant variations in environmental effects over time, which various variables, such as changes in legislation, technological advancements, and adjustments in economic structures, may influence. Development that is ecologically conscious and sustainable must comprehend and handle these numbers.

The information in Table 2 above offers critical new perspectives on the trends in GDP changes, population growth, energy intensity, and carbon intensity over time. Carbon emissions significantly

Table 1: ASEAN CO_2 analysis

Year	Population Effects	GDP Effects	Intensity Effects	CO_2 Intensity	Delta CO_2	Country
1971-2017	7,758	(3,943)	10,099	(1,290)	12,624	Brunei
1971-2017	2,864	8,997	(1,903)	8,626	18,584	Cambodia
1971-2017	8,805	40,412	(24,879)	27,447	51,785	Myanmar
1971-2017	56,962	99,516	(24,648)	(50,360)	81,470	Singapore
1971-2017	103,812	116,683	(70,343)	55,239	205,391	Philippines
1971-2017	61,130	227,176	(47,489)	109,081	349,900	Vietnam
1971-2017	172,991	280,552	(164,401)	107,354	396,496	Malaysia
1971-2017	91,366	379,195	10,703	(25,240)	456,024	Thailand
1971-2017	275,564	649,784	(259,744)	276,298	941,902	Indonesia

Table 2: ASEAN population, GDP, energy intensity, carbon intensity over CO_2

No	Year	Delta CO_2	Population effects on CO_2		GDP effects on CO_2		Energy intensity effects on CO_2		Carbon intensity effects on CO_2	
1	1971-75	27,178	8,443	31.1%	13,506	49.7%	(8,420)	−31.0%	13,649	50.2%
2	1976-80	68,611	13,388	19.5%	30,795	44,9%	(11,152)	−16,3%	35,580	51,9%
3	1981-85	41,300	17,222	41.7%	16,615	40.2%	1,441	3.5%	6,022	14.6%
4	1986-90	102,272	20,621	20.2%	50,911	49.8%	11,899	11.6%	18,841	18.4%
5	1991-95	139,427	27,892	20.0%	97,644	70.0%	(30,454)	−21.8%	44,345	31.8%
6	1996-97	43,53	6,514	15.0%	14,182	32.6%	(5,801)	−13.3%	28,635	65.8%
7	1997-98	13,36	6,782	50.8%	(74,242)	−555.6%	56,858	425,5%	23,965	179.3%
8	1998-03	131,485	37,522	28.5%	62,169	47.3%	(1,635)	−1.2%	33,430	25.4%
9	2003-08	80,624	45,331	56.2%	139,482	173.0%	(111,451)	−138.2%	7,262	9.0%
10	2008-13	137,719	49,551	36.0%	162,889	118.3%	(107,578)	−78.1%	32,857	23.9%
11	2013-17	156,394	42,295	27.0%	135,835	86.9%	(53,450)	−34.2%	31,713	20.3%

increased between 1971 and 1975, with a Delta CO_2 of 27,178. This demonstrates a considerable increase in the environmental effect at this period. Population changes due to CO_2 between 1971 and 1975 had a significant impact, accounting for 31.1%. This suggests that a major factor in carbon emissions is population expansion. The exact period also saw significant GDP effects on CO_2, which helped to drive a 49.7% shift. This implies a direct link between rising carbon emissions and economic development. Between 1971 and 1975, the energy intensity over CO_2 fell by −31.0%. The decrease in carbon emissions per unit of energy consumed reflects efforts to increase energy efficiency. On the other hand, the carbon intensity effects on CO_2 grew by 50.2% during the same time, showing a considerable rise in carbon intensity per unit of GDP.

When comparing 1997 and 1998, there was a sharp and significant decrease in carbon emissions, with a Delta CO_2 of 13,360. This is notable and might be ascribed to certain occurrences or laws. The GDP impact on CO_2 increased astonishingly by 425.5% in 1997-1998. This is a striking departure from the prior pattern and could point to a change in the economic structure or policies of the nation. Carbon emissions increased significantly between 2003 and 2008, with a Delta CO_2 of 80,624. This shows that the environmental effect increased throughout this time. Significant efforts were made to increase energy efficiency and lower carbon emissions per unit of energy consumed between 2003 and 2008, as seen by the −138.2% drop in energy intensity over CO_2. From 2008 to 2013, there was a substantial decrease in carbon emissions, with a Delta CO_2 of −107,578. This might be attributed to policy changes, technological advancements, or economic shifts. The carbon intensity effects over CO_2 during 2013-17 increased by 20.3%, indicating a rise in carbon intensity per unit of GDP despite the overall decrease in carbon emissions.

4.3. Individual Country Analysis

In Figure 1 below, the factors contributing to the highest increase in Delta CO_2 varied across these countries. Population growth, economic development (GDP effects), and changes in carbon intensity (intensity effects and CO_2 intensity) were the primary drivers. However, the relative importance of these factors differed from one country to another. Understanding these dynamics is crucial for developing targeted policies to effectively manage and reduce carbon emissions. Figure 1 below shows that Brunei experienced a substantial increase in Delta CO_2 from 1971 to 2017. Population and intensity effects played significant roles, indicating that both population growth and changes in energy intensity were critical drivers of increased carbon emissions in Brunei. Delta CO_2 in Cambodia had a substantial increase throughout that time. GDP impacts and CO_2 intensity were the key contributions, demonstrating that economic development and changes in carbon intensity were the main reasons for escalating carbon emissions in Cambodia. The most incredible rise in Delta CO_2 occurred in Indonesia. Along with GDP impacts, population effects had a sizable influence, indicating that population expansion and quickening economic development were Indonesia's leading causes of rising carbon emissions (Sudarmaji et al., 2021).

Over the period, Malaysia's Delta CO_2 dramatically rose. Like Indonesia, Malaysia's population and GDP impacts were crucial, highlighting the impact of rising numbers of people and an expanding economy on carbon emissions. Delta CO_2 in Myanmar has risen. The main contributors were population impacts and CO_2 intensity, demonstrating that increases in CO_2 intensity and population expansion were crucial factors in Myanmar's rising carbon emissions. The Delta CO_2 increased significantly in the Philippines. Population effects, GDP effects, and CO_2 intensity all contributed considerably, indicating that the leading causes

Figure 1: Individual country analysis on delta CO_2

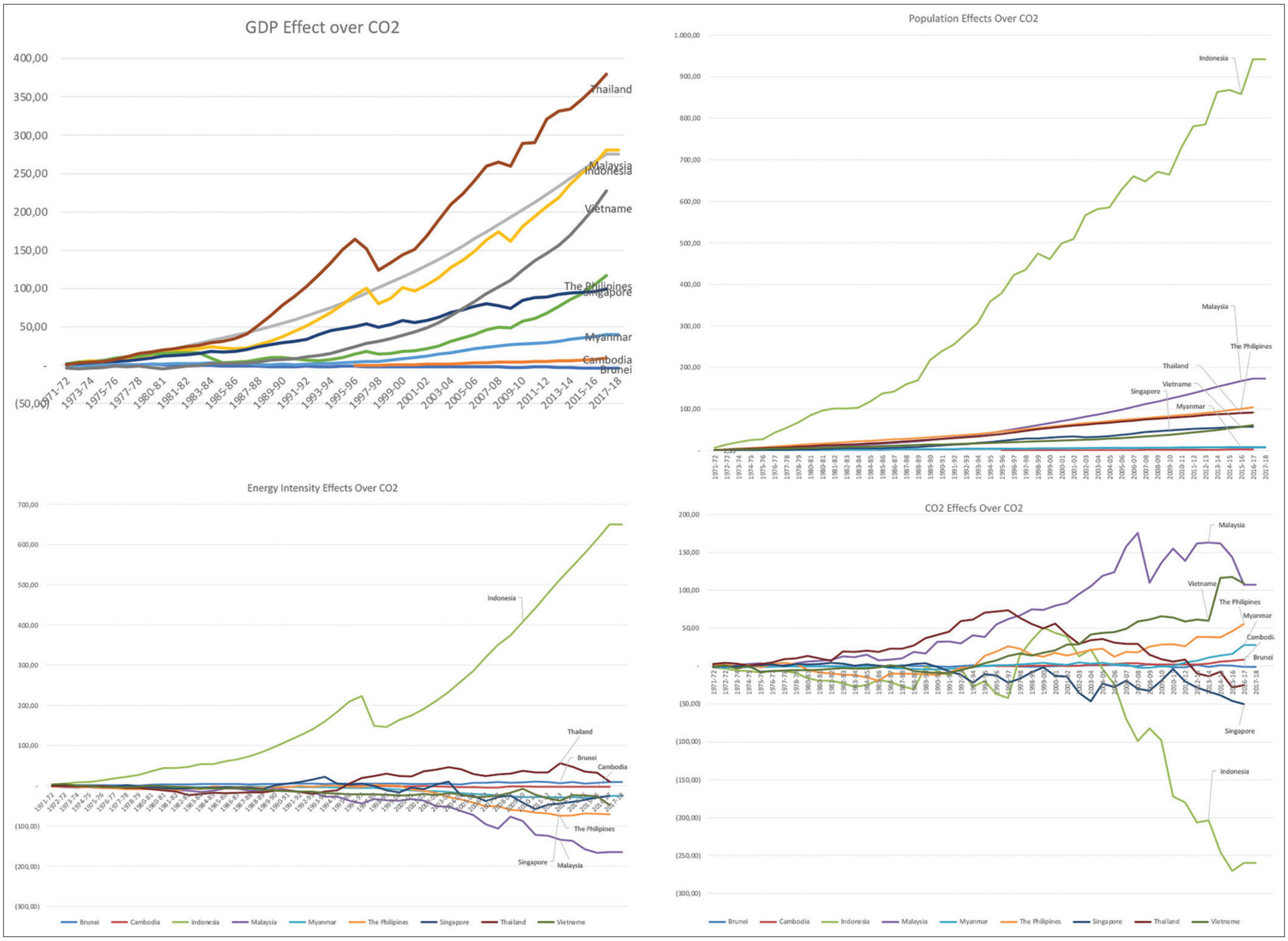
of carbon emissions in the Philippines were changes in carbon intensity, economic development, and population expansion. Delta CO_2 in Singapore significantly rose. GDP and intensity impacts both had a substantial impact, with the latter showing an increase in energy efficiency while the former increased emissions. Delta CO_2 levels in Thailand increased significantly, with GDP impacts being the main driver. Population impacts also contributed, underscoring that Thailand's fast economic expansion was the country's primary source of carbon emissions. Delta CO_2 in Vietnam substantially increased. Population effects and CO_2 intensity had a considerable impact, indicating that both population expansion and variations in carbon intensity considerably impacted Vietnam's carbon emissions.

For these Southeast Asian countries, the patterns in Figure 2 show steady economic expansion, which increases carbon emissions (Delta CO_2). A commitment to sustainable economic growth, including investments in clean energy, green technology, and environmentally friendly legislation, is required to address this problem. For these nations to achieve their goal of a greener and more sustainable future, they must strike a balance between economic success and environmental sustainability. Figure 2 below shows that Thailand had the highest increase in GDP Effects over CO_2. Thailand's GDP Effects have consistently grown, with occasional fluctuations. This sustained economic growth has contributed to a gradual increase in Delta CO_2, indicating the environmental consequences of economic expansion. To address this, Thailand should prioritize sustainable economic development by investing in green technologies, improving energy efficiency, and adopting policies that reduce carbon intensity. Malaysia had the second highest increase in GDP Effects over CO_2. Malaysia's GDP Effects have also demonstrated steady growth, with a few fluctuations along the way. The trend in Delta CO_2 aligns with the economic growth pattern, highlighting the connection between economic development and carbon emissions. Malaysia can work towards decoupling economic growth from carbon intensity by transitioning to cleaner energy sources and implementing eco-friendly industrial practices. In the meantime, Indonesia (3^{rd} highest increase in GDP Affects CO_2. Indonesia's GDP Effects have exhibited substantial growth, indicating significant economic expansion.

Figure 2 shows a clear link between rising populations and increasing CO_2 emissions per capita across Southeast Asia between 1971 and 2018. Countries like Indonesia and Malaysia experienced rapid population growth, with Indonesia's population doubling from 119 million to 264 million. Indonesia's per capita emissions climbed steeply from 0.59 tons in 1971 to 941.9 tons in 2018. Malaysia followed a similar trajectory as its population and emissions grew. This pattern demonstrates the environmental strain of larger populations and increasing industrialization and consumption. Sustainable development policies that support growing populations while curbing emissions growth will be essential for the region. The trend Population Effect highlights the correlation between population growth and rising per capita emissions in ASEAN countries. It ties population growth to industrialization and consumption as drivers of emissions. It concludes that sustainability policies can support development while mitigating emissions growth.

Carbon intensity LMDI is a method used to analyze and decompose changes in the carbon intensity of energy or economic activity.

Figure 2: GDP, population, energy intensity and CO_2 intensity over CO_2



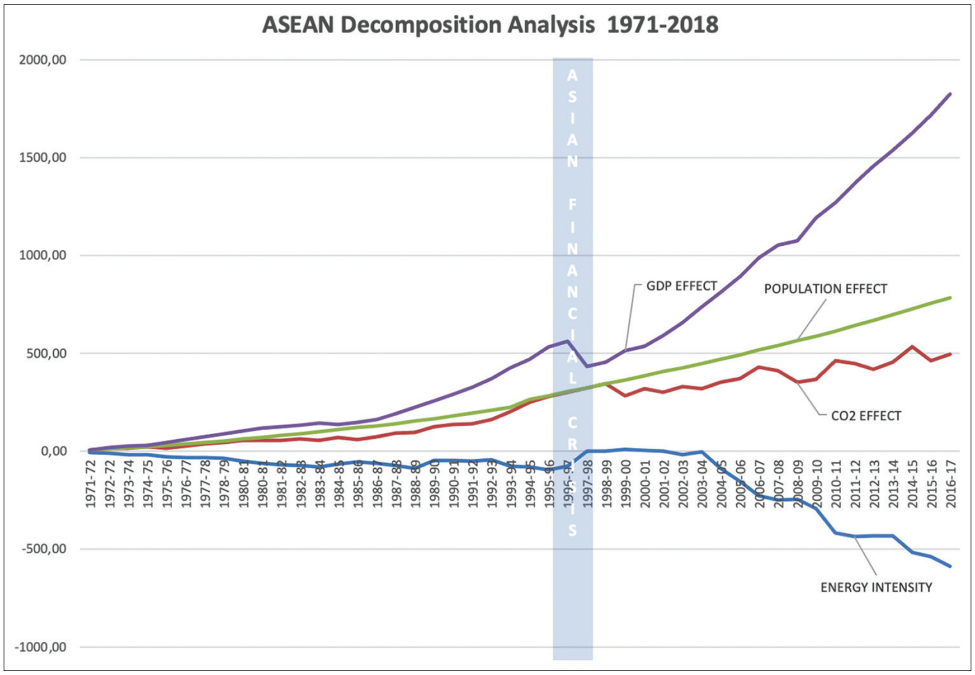
Carbon intensity measures the carbon dioxide (CO_2) emissions produced per unit of energy consumed or per unit of economic output, such as Gross Domestic Product (GDP). This method is beneficial for understanding how various factors influence changes in carbon intensity over time: activity Effect, Structural Effect and Intensity Effect. The Intensity Effect component measures changes in carbon intensity driven by improvements in energy efficiency, technological advancements, or changes in energy sources within the same sector. If industries become more energy-efficient or switch to lower-carbon energy sources, it can lead to a decrease in carbon intensity. Figure 2 shows Indonesia has dramatically shown a declining trend in CO_2 intensity over CO_2 emission as it increased hugely due to GDP and Population effects.

4.4. Energy Intensity as Decarbonized Pathways

Energy Intensity (technological innovations and energy efficiency) in energy consumption linked to energy policy, stakeholders have different interests in forming energy policy (EEFIG, 2015). With the high cost of capital-intensive alternative energy infrastructure (e.g., Solar panels, wind turbines), as experienced in recent years, this has become a significant economic problem for most countries, especially developing countries. On the other hand, the issue of climate change and carbon pricing create additional restrictions and exacerbate problems in developing countries' energy sectors. Its application has the potential to eliminate a product's competitiveness and decrease the gross domestic product (Diamond and Zodrow, 2018; Driscoll, 2020). At the same time, technologies to improve energy efficiency across all sectors can help moderate energy demand growth. Adopting these technologies alongside renewable power capacity can maximize emissions reductions. (Strbac et al., 2020) emphasizes the need for flexibility in the energy system to support a cost-effective transition to a lower-carbon system. (Ma et al., 2022) discusses the importance of low-carbon technologies, market mechanisms, and flexible resources in achieving low-carbon operation in integrated energy systems.

Figure 3 provides data on four factors for several years: Energy Intensity, CO_2 Intensity, Population Effect, and GDP Effect. The trend line highlights the complex interplay between energy consumption, economic growth, and environmental impact. The table showed that energy intensity initially improved but later fluctuated, and the CO_2 Intensity, Population Effect, and GDP Effect increased steadily. The table shows energy intensity decreased, especially from the early 1970s to the mid-1980s. This indicates that the economy became more energy-efficient during this period. However, after a brief increase, it declined until 1997-98. After that point, there was a fluctuating pattern with occasional increases, suggesting variations in energy efficiency. CO_2 Intensity represents the impact of energy consumption on

Figure 3: ASEAN Decomposition Over CO_2



carbon dioxide emissions, which contribute to climate change. The data showed a substantial increase in CO_2 Intensity over the years, indicating a rising carbon footprint. This trend is concerning from an environmental perspective, as it reflects increased emissions despite improvements in energy efficiency. Population Effect measures the impact of population growth on energy consumption. It demonstrated a consistent upward trend, indicating that energy consumption has also increased as the population has grown.

The trend underscores the importance of addressing energy efficiency and environmental concerns in the context of a growing population. GDP Effect represents the impact of economic growth on energy consumption. It displayed a clear upward trajectory, suggesting that as the economy grew, energy consumption also increased. This is a common trend in developing economies where industrialization and urbanization drive energy demand. Rising CO_2 emissions from fossil fuel combustion are driving dangerous climate change. While renewable energy is crucial, improving energy efficiency in all sectors offers significant untapped potential to reduce emissions. Most climate policy focuses heavily on scaling up renewable energy. However, enhanced energy efficiency's significant emission reduction potential is often overlooked. More research is needed on optimizing energy efficiency as a core decarbonization strategy.

Energy intensity measures how much energy is used to produce a unit of economic output, often expressed as energy consumption per unit of GDP (typically measured in terms of constant dollars or purchasing power parity). A higher energy intensity indicates that more energy is being used to generate economic value, which may be due to various factors. Indonesia has the most enormous contribution and contributor to CO_2 emissions among ASEAN countries. Efforts to reduce CO_2 emissions in Indonesia will be able to change the aggregate CO_2 emissions figures in the ASEAN region. When comparing Indonesia's energy intensity to other ASEAN (Association of Southeast Asian Nations) countries, several reasons could explain why it might be higher. The overall energy efficiency of a country's industrial and commercial sectors can vary. For Instance, Indonesia's industries are less energy-efficient than its ASEAN counterparts, which could result in higher energy intensity. The availability and quality of infrastructure, such as transportation and logistics networks, can influence energy use. Less efficient infrastructure can lead to higher energy consumption for transportation and distribution.

On the other hand, Government policies and technological advancements play a crucial role. Indonesia has not implemented energy efficiency measures or adopted energy-saving technologies to the same extent as other ASEAN countries; hence, it contributes to higher energy intensity. Population size and growth can also impact energy intensity. Indonesia's population is multiplying, which may increase energy demand for residential and commercial sectors. Under Energy Subsidies policies, Subsidized energy prices In Indonesia can lead to inefficient energy use, as consumers and industries may have less incentive to conserve energy. The presence of energy subsidies can contribute to higher energy intensity.

4.5. ASEAN's Energy Intensity Forecasting

Vector Error Correction Models (VECMs) are valuable tools in time series analysis, particularly for understanding the dynamics between variables that exhibit cointegration relationships. In this essay, we explore the results of a VECM analysis involving four critical variables: CO_2effect (carbon dioxide emissions), EIeffect (energy intensity), GDPeffect (economic growth), and POPeffect (population growth). The Error Correction Term (ECT) coefficients and the Speed of Adjustment are examined to decipher the short-term dynamics and long-term relationships among these variables. The first step was cointegration analysis. It is a vital tool in time series econometrics that allows authors to explore long-term relationships among variables.

Table 3: Cointegration analysis

Hypothesized No. of CE (s)	Eigenvalue	Cointegration rank test (Trace)			Cointegration rank test (Maximum Eigenvalue)		
		Trace statistic	0.05 Critical Value	Prob.**	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.477	353.622	47.856	0.000	223.232	27.584	0.000
At most 1 *	0.183	130.389	29.797	0.000	69.514	21.132	0.000
At most 2 *	0.143	60.876	15.495	0.000	53.238	14.265	0.000
At most 3 *	0.022	7.637	3.841	0.006	7.637	3.842	0.006

*denotes rejection of the hypothesis at the 0.05 level, **MacKinnon-Haug-Michelis (1999) P-values

Table 3, results for the "At most 2" hypothesis also indicate the presence of cointegration. Both statistics significantly exceed their critical values, leading to rejection of the null hypothesis. The table's results indicate the presence of cointegrating relationships among the variables being analyzed.

The next step was to provide insights into the temporal precedence of one variable in predicting another, shedding light on potential causal connections. The Granger causality tests provide valuable insights into the temporal causal relationships among the variables GDPEFFECT, EIEFFECT, POPEFFECT, and CO_2EFFECT. These results can inform authors about the potential directions of causality in economic, energy intensity, and population dynamics. Notably, economic and population growth appears to have significant causal effects on each other, while economic and population factors influence energy intensity. The low P-value (0.000) indicates strong evidence against the null hypothesis, suggesting that the variables do indeed granger cause at a significant level of 0.01 (*). These findings underscore the complexity of interrelationships in these critical domains and emphasize the importance of addressing them holistically Table 4.

Table 4: Granger casualty

Null Hypothesis	F-Statistic	Prob.
GDP did not Granger Cause Energy Intensity	16.714	0.000*
Energy Intensity did not Granger Cause GDP	1.255	0.286
Population did not Granger Cause Energy Intensity	13.005	0.000*
Energy Intensity did not Granger Cause Population	0.861	0.424
CO_2 Emission did not Granger Cause Energy Intensity	5.513	0.004*
Energy Intensity did not Granger Cause CO_2 Emission	2.153	0.118
Population did not Granger Cause GDP	32.260	0.000*
GDP did not Granger Cause Population	4.367	0.013**
CO_2 Emission did not Granger Cause GDP	0.808	0.446
GDP did not Granger Cause CO_2 Emission	19.714	0.000*
CO_2 Emission did not Granger Cause Population	7.066	0.001*
Population did not Granger Cause CO_2 Emission	11.485	0.000*

*significant level at the 0.01 level, **significant level at the 0.05 level

Analysis of Coefficients in the VECM in Table 5 showed that the coefficient of ECT in the CO_2 EFFECT(-1) equation indicates a significant long-term relationship between the CO_2 effect and the other variables in the model. The negative sign of the Speed of Adjustment (−1.459) suggests that deviations from the equilibrium are corrected at a rate of approximately 1.459% per period. The significance level of this relationship is very high (*), indicating a solid cointegration relationship. In the EI EFFECT(-1) equation, the coefficient of ECT is −0.249, implying a significant long-term relationship between environmental impact (EIeffect) and the other variables. The positive Speed of Adjustment (1.059) suggests that deviations from equilibrium are corrected at approximately 1.059% per period. This relationship is statistically significant (*). Meantime, the GDP EFFECT(-1) equation indicates a long-term relationship between economic growth (GDPeffect) and the other variables, with a coefficient of ECT of −0.067. The negative Speed of Adjustment (−0.181) suggests a gradual correction of deviations at approximately 0.181% per period. This relationship is statistically significant (*) at a 0.01 significance level.

At last, the PO PEFFECT(-1) equation highlights a significant long-term relationship between population growth (POPeffect) and the other variables, with a coefficient of ECT of −0.873. The positive Speed of Adjustment (0.009) suggests a correction rate of approximately 0.009% per period for deviations from equilibrium. This relationship is statistically significant (*) at a 0.01 significance level. The VECM analysis reveals cointegration relationships among these variables, signifying long-term connections. The Speed of Adjustment values provide insights into the rate at which deviations from equilibrium are corrected. The significance levels of the coefficients underscore the strength of these relationships, with many being highly significant at the 0.01 level (*). These findings are essential for authors interested in understanding the interplay between economic, environmental, and population factors and their implications for sustainability and policy planning.

Based on the result, the authors make hypotheses about the impact of EIEffect (energy intensity) on GDPEffect (economic growth), POPEffect (population growth) and CO_2Effect (carbon emissions):

- The Granger causality tests show that EIEffect is Granger caused by both GDPEffect and POPEffect. This suggests that economic and population growth changes precede and likely drive changes in energy intensity. As GDP grows, energy demand increases, potentially raising energy intensity. Population growth also drives energy demand.
- However, the VECM results show that EIEffect has a significant long-run relationship with the other variables. This implies that it conversely impacts them in the long run. Declines in energy intensity could restrain GDP and population growth over time by making energy use more efficient.
- The VECM results specifically show a long-run linkage between EIEffect and CO_2Effect. This suggests that reducing energy intensity can lower carbon emissions in the long term by curbing energy demand and facilitating decarbonization.

Table 5: VECM

Co Integration Equation	CO_2 effect			EIeffect			GDP effect			POPeffect		
	Coef of ECT	Coef of ECT	Speed of Adjustment	Coef of ECT	Coef of ECT	Speed of Adjustment	Coef of ECT	Coef of ECT	Speed of Adjustment	Coef of ECT	Coef of ECT	Speed of Adjustment
CO_2 EFFECT(-1)	1.000	−1.459	−1.459	1.000	−0,263	−0.264	1.000	0.012	0.012	1.000	−0.008	−0.008
		(−13.412)*			(−12.260)*			(2.315)**			(−2.899) *	
EI EFFECT(−1)	−0.249	1.059	−0.264	0.270	0.045	0.012	−14.826	0.098	−1.459	0.077	0.158	0.012
	(−3.946)*	(12.260)*		(1.197)	(2.314)**		(−15.162)*	(13.4124)*		(1.336)	(2.314)**	
GDP EFFECT(−1)	−0.067	−0.181	0.012	3.507	−0,002	−0.008	3.692	−0.0714	−0.264	−1.145	1.275	−1.459
	(−1.034)	(−2.314)*		(4.401)*	(−2.899)*		(4.388)*	(−12.260)		(−15.447)*	(13.412)*	
PO PEFFECT(−1)	−0.873	0.009	−0.008	−4.015	0.363	−1.459	12.949	−0.000	−0.008	0.285	−0.925	−0.264
	(−4.499)*	(2.899) *		(−15.780)*	(13.412)*		(5.705)*	(−2.899)*		(3.778)*	(−12.260)*	
Coefficient	0.504			−2.022			−7.465			−0.576		

* accepted Null hypothesis on 0.01 level, ** on 0.05 level

Based on these relationships, authors could expect policies and technologies that reduce energy intensity (EIEffect) to restrain GDP and population growth while lowering carbon emissions gradually. However, the short-term impacts may be small as economic and population factors appear to drive intensity changes. To forecast EIEffect, we could use the VECM model coefficients. The ECT coefficient −0.249 suggests past deviations from equilibrium correct at about 0.25% per period. Using the other coefficients with lagged EIEffect values and forecasts of GDP, population, and emissions could produce a reasonable EIEffect forecast, capturing the long-run equilibrium relationships. The short-term dynamics may be less accurate due to the other causal effects. Regular model re-estimation with new data would enhance forecasting power over time.

In other words, reductions in energy intensity could restrain GDP growth in the long run by making energy usage more efficient. If the same economic outputs can be produced with less energy input due to greater efficiency, it could dampen the growth in energy demand that previously fueled GDP growth. Similarly, lower energy intensity could gradually restrain population growth. More efficient energy use reduces resource pressures that can limit population growth, like electricity shortages. This releases such pressures and enables larger populations. If energy efficiency curbs electricity demand growth, it could remove an enabling factor for population growth. Declining energy intensity directly enables lower carbon emissions over time by reducing energy demand growth. With more economic output per unit of energy, less energy is needed for additional output. This means marginal economic growth does not require as much additional energy, limiting emissions growth. Energy efficiency gains also facilitate decarbonization of energy supplies by reducing overall demand, making it easier to transition from fossil fuels. With lower overall energy needs, clean energy sources do not need to scale as quickly to displace fossil fuels. These results suggest that, in the long run, reducing energy intensity can restrain GDP and population growth while directly lowering emissions through efficiency gains and enabling decarbonization. The effects may manifest gradually but could be meaningful over decades.

5. CONCLUSION

Rising CO_2 emissions linked to fossil fuel energy pose a critical threat, necessitating decarbonization policies worldwide. This is especially pressing in Southeast Asia's rapidly growing ASEAN bloc. ASEAN's economic ascent has increased prosperity but also energy demand and emissions. However, climate change risks from unconstrained emissions are unsustainable. Therefore, this research analyzed drivers of ASEAN emissions growth and reductions from 1971 to 2017 to inform strategic climate mitigation planning. The study employed the Kaya Index and Logarithmic Mean Divisia Index (LMDI) decomposition methods on data covering emissions, GDP, population, and energy use across nine major ASEAN economies. This allowed a detailed analysis of factors escalating or dampening emissions over time. The goal was to identify critical drivers for targeted policymaking for sustainable decarbonized development.

Results revealed that GDP growth and population increases are the primary drivers of escalating ASEAN emissions. Indonesia and Thailand saw substantial growth from economic and population expansion. Energy efficiency improvements provided a countervailing effect, reducing emissions growth initially before fluctuating impact. Meanwhile, carbon intensity per GDP increased emissions overall. These findings demonstrate the need for an integrated policy approach combining clean energy deployment, energy efficiency optimization, infrastructure planning, and low-carbon economic reform. Transitioning to affordable clean energy systems through renewable sources and efficiency gains, underpinned by proactive national leadership and regional coordination, can enable ASEAN to achieve sustainable development while mitigating climate change risks.

Further research should identify optimally tailored policy mixes for each ASEAN nation to maximize socio-economic progress and human welfare while meeting urgent emission reduction imperatives. As ASEAN strives to pioneer decarbonized development pathways, analysis of historical trends provides vital insights to inform national strategies and climate actions aligned with development objectives, resources, and capacities. Tackling the complex but pressing decarbonization challenge requires recognizing ASEAN's diversity.

This study significantly enhances our understanding of the dynamics driving ASEAN emissions growth and decline. The LMDI decomposition analysis provides a robust framework for pinpointing high-impact mitigation opportunities. By leveraging these insights into key factors and relationships, ASEAN policymakers can craft evidence-based integrated strategies to achieve prosperous, equitable and environmentally sustainable development. ASEAN has the potential to lead the developing world in pioneering innovative, equitable, low-carbon models if it seizes this opportunity.

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