THE DETERMINANTS OF CARBON EMISSION INTENSITY ON SOCIO-ECONOMIC INDICATORS: A CAUSAL ANALYSIS IN THE ASEAN REGION

A Thesis

Submitted to the Master's Study Program of Economics at the Faculty of Economics and Business in partial fulfillment of the requirements for the degree of

Master of Arts (M.A.)

Universitas
Islam Internasional
Indonesia

by:

Muhammad Ismail Sunni

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UNIVERSITAS ISLAM INTERNASIONAL INDONESIA

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ABSTRACT

The rapid economic growth experienced by the Association of Southeast Asian Nations (ASEAN) in recent decades has led to a significant increase in carbon emissions, exacerbating the global challenge of climate change. Despite the urgency of addressing this issue, there is a lack of comprehensive research examining the factors driving the rise in carbon emission intensity within the ASEAN region. As the world's third-largest emitter of greenhouse gases, it is imperative to understand the relationship between economic development, social development, technological development, and carbon emission intensity to inform effective policy development. This study aims to fill the research gap by investigating the determinants of carbon emission intensity in ASEAN and exploring the impact of economic development, social development, and technological development on this intensity. By utilizing quarterly panel data comprising 432 observations from 10 ASEAN countries spanning the period from 2010 to 2021, a fixed-effect model (FEM) is employed as the estimation approaches in EViews. Prior to estimation, the validity and reliability of the model are assessed through the Chow test, Hausman test, and Laggrange Multiplier test. Additionally, tests for multicollinearity and heteroscedasticity are conducted. The study reveals that among the examined variables, only foreign direct investment (FDI) from the economic development indicators does not exhibit a significant association with carbon emission intensity. Conversely, higher GDP, lower inflation rates, and limited technological development are found to be significantly linked to lower carbon emission intensity within the ASEAN region. Furthermore, two variables related to social development, namely the Human Development Index (HDI) and the GINI index, also do not demonstrate a significant relationship with carbon emission intensity. After applying the Granger causality test, the study reveals no significant mutual association between socioeconomic factors and carbon emission intensity. By addressing the critical research gap regarding the drivers of carbon emission intensity in ASEAN, this study has significant implications for policymakers and stakeholders. The findings provide valuable insights into the key factors influencing carbon emissions and offer evidence-based recommendations for the formulation of effective environmental policies.

Keywords: ***Carbon emission intensity, ASEAN, Economic development, Fixed Effect Model, Panel Data***

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ABBREVIATION DIRECTORY

ACCEPT	:	ASEAN Climate Change and Energy Project
ACI	:	Aggregate Emission Intensity
AI	:	Artificial Intelligences
ARDL	:	Autoregressive Distributed Lag
ASEAN	:	The Association of Southeast Asian Nations
CCS	:	Carbon Capture and Storage
CEI	:	Carbon Emission Intensity
CEM	:	Common Effect Model
CO2	:	Carbon Dioxide
COVID-19	:	Coronavirus Disease 2019
CPI	:	Consumer Price Index
EKC	:	Environmental Kuznets Curve
FDI	:	Foreign Direct Investment
FEM	:	Fixed Effect Model
GDP	:	Gross Domestic Product
GHG	:	Greenhouse Gas
GINI	:	Gini coefficient
HDI	:	Human Development Index
HELE	:	High Efficiency Low Emission
IEA	:	International Energy Agency
INF	:	Inflation
IoT	:	Internet of Things
LM	:	Laggrange Multiplier
MtCO2e	:	Metric Tons of Carbon Dioxide Equivalent
NDCs	:	Nationally Determined Contributions

OECD	:	Organisation for Economic Co-operation and Development
OLS	:	Ordinary Least Squares
OWD	:	Our World in Data
PLS	:	Pooled Least Squares
R&D	:	Research and Development
REM	:	Random Effect Model
SMEs	:	Small and Medium-Sized Enterprises
TED	:	Technology Development
TES	:	Transforming Energy Scenario
U.S.	:	United States
UK	:	United Kingdom
UNDP	:	United Nations Development Programme
WDI	:	World Development Index

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CHAPTER 1. INTRODUCTION

1.1 Background

The Association of Southeast Asian Nations (ASEAN) is home to over 650 million people, and is one of the fastest growing regions in the world (Aleluia et al., 2022). However, this rapid growth has come at a cost to the environment, and reducing carbon emission intensity has become a pressing issue. Carbon emission intensity refers to the amount of carbon emissions released per unit of GDP, and is a key indicator of a country's carbon footprint (Sun et al., 2017).

Figure 1.1 presents a compelling overview of the historical patterns in renewable energy consumption across ASEAN countries, highlighting some notable trends. Notably, Thailand and Malaysia stand out as the only two countries exhibiting a modest increase in renewable energy consumption over time. Conversely, Singapore and Brunei display negligible utilization of renewable energy sources.

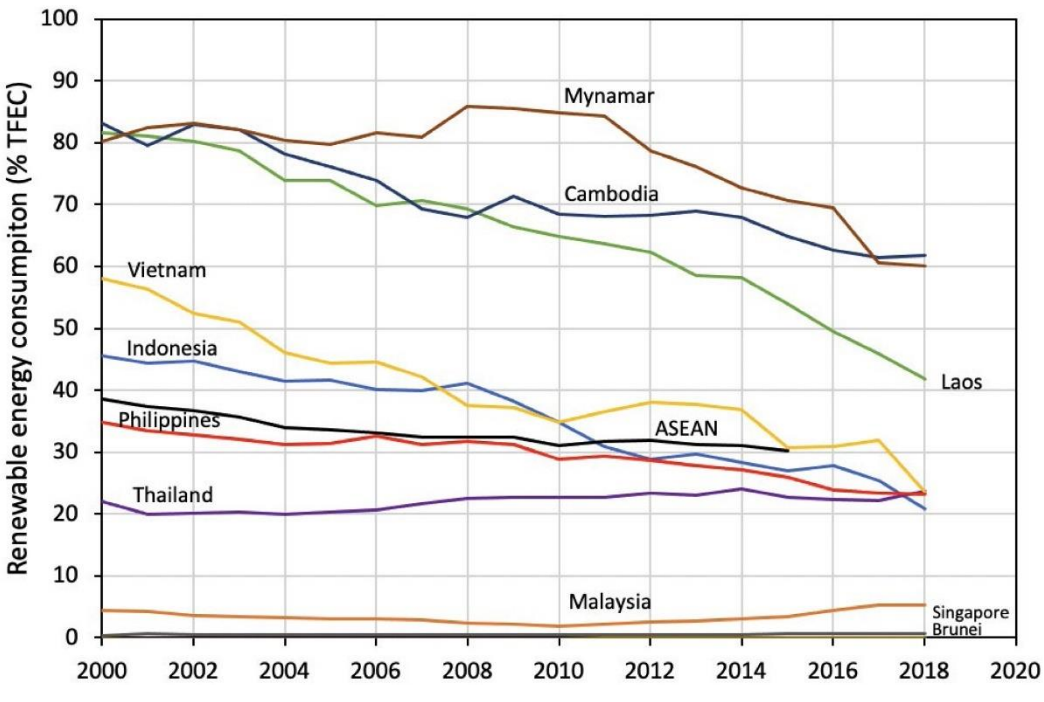

Figure 1. 1 ASEAN Renewable Energy Consumption History

Source: World Bank (2022)

The remaining ASEAN nations demonstrate a discernible decrease in renewable energy consumption over the years. This collective trend underscores that the region's reliance on renewable energy as a proportion of total energy consumption has declined from 38.5% in 2000 to 30.3% in 2015. To effectively achieve the ambitious goal of attaining net-zero emissions by 2050, a critical reversal of this declining trend becomes imperative. ASEAN must proactively address the challenges posed by the diminishing share of renewable energy in its overall energy mix. By fostering an environment conducive to renewable energy development, embracing technological advancements, and implementing robust policies and initiatives, ASEAN can chart a sustainable path forward.

The ASEAN region is blessed with abundant energy resources; however, it exhibits a high demand for energy, coupled with low energy efficiency, particularly in the energy-intensive transport and manufacturing sectors. While ASEAN countries possess promising potential in renewable energy sources like biomass and solar power, these sources are likely remained relatively small compared to conventional energy sources. Notably, Laos, Myanmar, and Thailand have the capacity to produce substantial amounts of biofuels without compromising food production.

Furthermore, ASEAN maintains a surplus of energy resources, boasting a diverse range of options including fossil fuels, hydropower, geothermal energy, biofuels, biomass, and solar power. Countries such as Brunei, Indonesia, Malaysia, Myanmar, and Vietnam possess significant reserves of oil and gas. Cambodia shows geological potential for oil and gas reserves, with Chevron actively exploring offshore blocks. However, the exact extent of these reserves remains uncertain, and production schedules have experienced multiple delays, with current projections set for 2016 or later. Similarly, there are unexplored areas both offshore and onshore in Myanmar that hold promising potential. Presently, Myanmar's proven reserves are only half of Vietnam's, but there is a good chance that they could at least match Vietnam's level of 0.6 trillion cubic meters of gas. Additionally, there is a possibility of discovering oil or gas reserves in the southern region of Laos.

The first reason why reducing carbon emission intensity is a pressing issue in ASEAN is the region's heavy reliance on fossil fuels. According to (Overland et al., 2021), coal remains the dominant source of energy in ASEAN, accounting for over 40% of the region's energy mix in 2020. This heavy reliance on coal is a major contributor to carbon emissions, and the region's energy sector is responsible for approximately 40% of total carbon emissions in ASEAN.

Another reason is the region's rapid urbanization. ASEAN's urban population is projected to reach 400 million by 2050 (Zahoor et al., 2022), and this growth is expected to exacerbate environmental issues such as air pollution and waste management. Projections indicate that Southeast Asia is poised to achieve a significant milestone in urbanization, with estimates suggesting that by 2019, the region's urban population reach 330 million, accounting for 50% of its total population. This anticipated urbanization surge is fuelled by the addition of approximately 36 million individuals. However, it is worth noting that the pace and extent of urbanization vary across ASEAN countries.

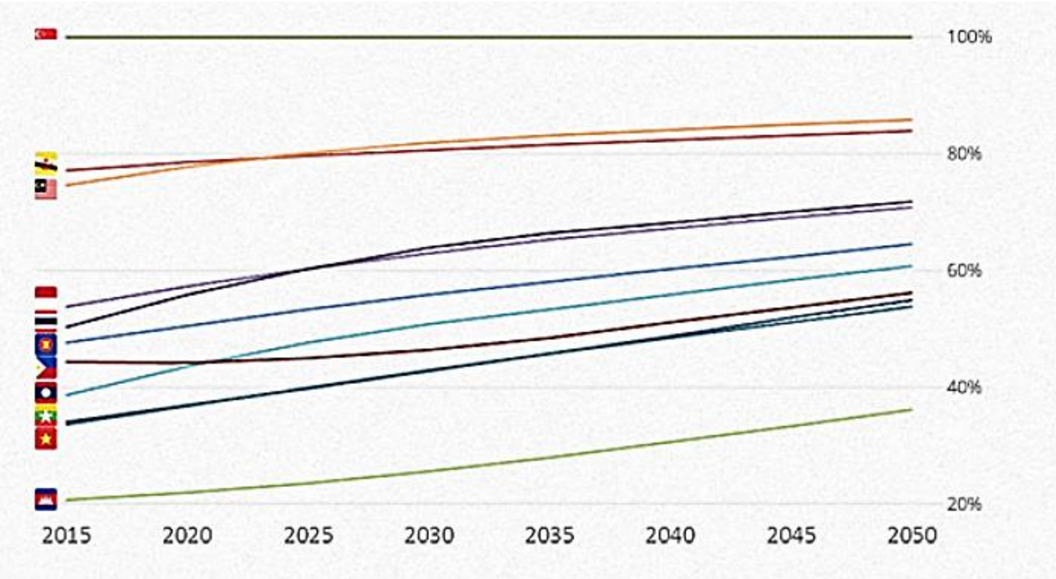

Figure 1. 2 ASEAN Percentage of Population Residing in Major Urban Areas

Source: United Nations World Urbanization Prospects: The 2014 Revision

Among the ASEAN nations (see figure 1.2), Singapore stands out as the frontrunner in terms of urbanization, boasting the highest proportion of residents living in major urban areas. Similarly, countries such as Brunei, Malaysia, and

Thailand also exhibit substantial percentages of their populations residing in prominent urban centers. On the other end of the spectrum, countries like Cambodia, Laos, and Myanmar have the lowest proportions of their populations dwelling in major urban areas. Indonesia has more 1-million-inhabitant cities with steep population growth compared to other big cities in other ASEAN countries (see Table 1.1).

Table 1. 1 Largest ASEAN Cities in 2025 and Growth Rate from 2015

ASEAN cities with more than 1 million inhabitants in 2025
in millions

Urban Area	*2015*	*2025*	*Change*	*Urban Area*	*2015*	*2025*	*Change*
Manila	12.9	15.2	17.4%	Palembang	1.4	1.7	16.9%
Jakarta	10.3	12.6	22.0%	Denpasar	1.1	1.7	51.9%
Bangkok	9.3	11.0	18.2%	Pekan Baru	1.1	1.6	38.8%
Ho Chi Minh City	7.3	9.2	27.4%	Vientiane	0.99	1.6	54.5%
Kuala Lumpur	6.8	8.7	27.3%	Mandalay	1.2	1.5	27.6%
Singapore	5.6	6.3	12.7%	Hai Phong	1.1	1.4	31.5%
Yangon	4.8	6.0	24.3%	Bogor	1.1	1.4	28.8%
Ha Noi	3.6	5.0	37.5%	Nay Pyi Taw	1.0	1.3	22.2%
Surabaya	2.9	3.4	19.2%	Da Nang	0.95	1.2	29.2%
Bandung	2.5	3.1	22.0%	Bandar Lampung	0.96	1.2	25.6%
Samut Prakan	1.8	2.9	62.3%	Zamboanga City	0.94	1.2	25.4%
Medan	2.2	2.7	21.1%	Tasikmalaya	0.78	1.2	48.7%
Phnom Penh	1.7	2.3	30.7%	Samarinda	0.86	1.2	33.9%
Batam	1.4	2.2	60.8%	Cebu City	0.95	1.1	20.2%
Davao City	1.6	2.0	21.9%	Johor Bahru	0.91	1.1	24.9%
Semarang	1.6	2.0	21.0%	Padang	0.90	1.1	24.7%
Makassar	1.5	1.9	27.3%	Bien Hoa	0.83	1.1	32.1%
Can Tho	1.2	1.7	45.9%	Malang	0.86	1.0	21.2%

Source: United Nations World Urbanization Prospects: The 2014 Revision

The urban transportation sector is also a major contributor to carbon emissions, with private cars and motorcycles being the dominant mode of transport in many ASEAN cities (Fattah & Morshed, 2021; Regmi, 2020; Suatmadi et al., 2019). Despite the pressing need to reduce carbon emissions, many governments in ASEAN have overlooked this issue in their environmental policy. In Indonesia, for example, the government has set ambitious targets to reduce greenhouse gas emissions by 29% by 2030, but has failed to address key issues such as deforestation and the expansion of coal-fired power plants (Cahyono et al., 2022; Figueres et al., 2018). According to a report by Greenpeace, Indonesia has the highest number of coal-fired power plants in the region, with plans to add more in the coming years.

Moreover, Indonesia's palm oil industry has been a major contributor to deforestation (Cisneros et al., 2021; Ibeabuchi et al., 2022), which not only releases carbon into the atmosphere but also destroys important ecosystems and wildlife habitats. Despite efforts to promote sustainable palm oil production, a significant amount of palm oil produced in Indonesia still comes from illegal and unsustainable sources (Nesadurai, 2020; Pacheco et al., 2017).

In addition, the lack of political will and commitment to addressing environmental issues has resulted in a lack of funding (Lassa et al., 2019; J. W. Lee, 2020) for renewable energy projects in many ASEAN countries. According to the IEA, renewable energy investment in Southeast Asia is lagging behind other regions, and the share of renewable energy in ASEAN's energy mix is expected to remain at only 15% by 2040.

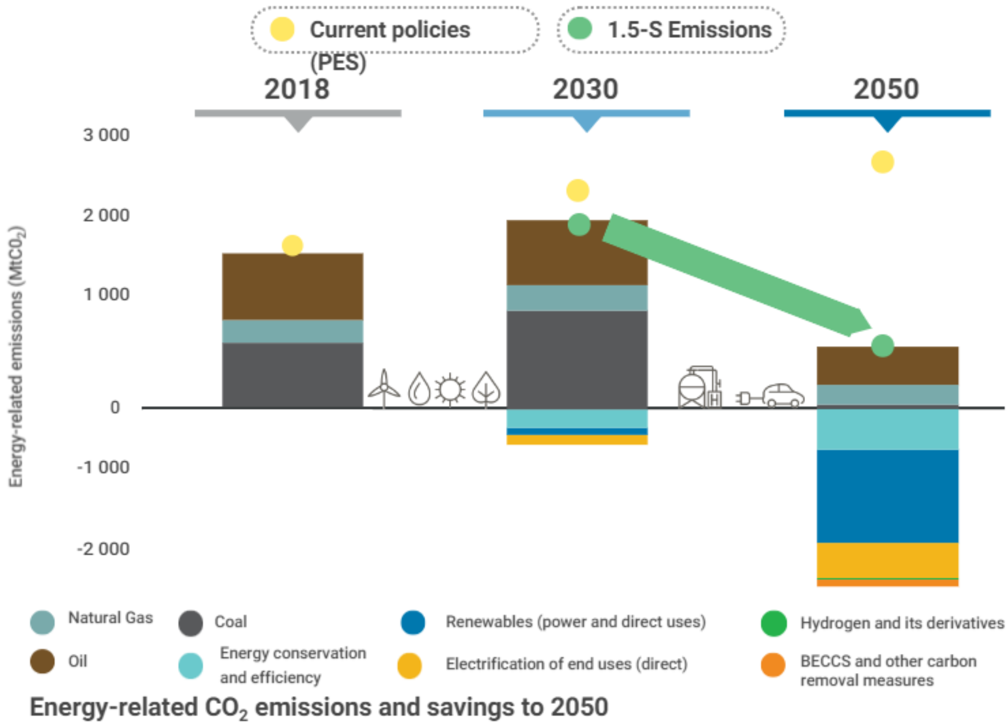

Figure 1. 3 2050 Projection of ASEAN Energy-related CO2, emissions and savings

Source: Irena.org (2022)

To address these challenges, governments in ASEAN need to prioritize reducing carbon emission intensity in their environmental policies. As depicted in figure 1.3, ASEAN has the potential reduction of CO2 emissions through the adoption of renewable energy and energy efficiency measures. The figure portrays the significant role of renewable electricity and deep electrification in achieving a

60% reduction in CO2 emissions, which is crucial for meeting the emission reduction targets in the energy sector, while it also highlighting the historical trend of energy-related CO2 emissions, which have been increasing at an average rate of 1% per year since 2010. Although the COVID-19 pandemic and oil price fluctuations temporarily suppressed emissions in 2020, a rebound is expected, reinforcing the long-term upward trajectory of emissions. To meet climate goals, it is crucial for a 70% reduction in energy-related CO2 emissions by 2050 compared to current levels. Additionally, an aggressive energy efficiency strategy should be significantly coupled with the scaling up of renewable energy sources to replace fossil fuels. This integrated approach is identified as the most realistic pathway to achieving a 50% reduction in emissions by 2030.

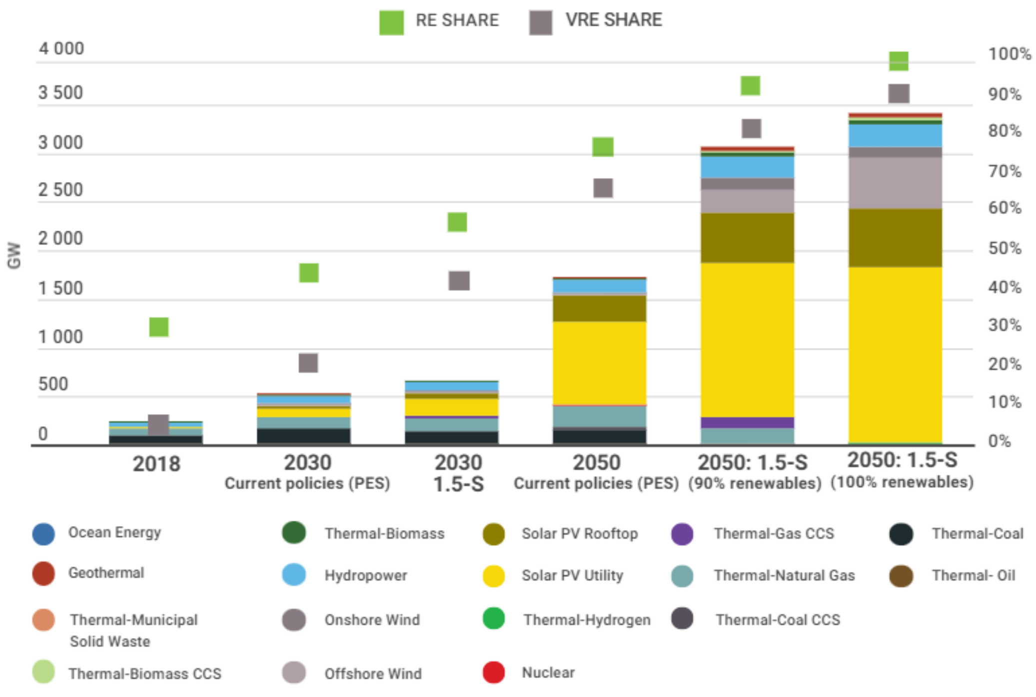

Figure 1. 4 2050 Projection of ASEAN Energy-related CO2, RE SHARE, VE SHARE

Source: Irena.org (2022)

This requires a shift away from fossil fuels and towards renewable energy sources, as well as policies to encourage sustainable transportation and urban planning. For example, Singapore has introduced a carbon tax to incentivize companies to reduce their carbon footprint (X. Zhang & Wang, 2017), while

Thailand has set a target to generate 25% of its electricity from renewable sources by 2037 (Misila et al., 2020).

Picturized if figure 1.4, the total power capacity in the ASEAN region is expected to increase from 2018 to 2050 under all scenarios. Additionally, it emphasizes the significant rise in the share of renewable energy capacity across all scenarios, with the highest share projected in the Transforming Energy Scenario (TES). The TES scenario forecasts the most substantial growth in renewable energy capacity, with a projected share of 63% by 2050. In contrast, the Moderate RE scenario projects a lower growth in renewable energy capacity, with a share of 32% by 2050. The Baseline scenario, on the other hand, anticipates the lowest growth in renewable energy capacity, with a share of 23% by 2050.

Furthermore, ASEAN governments need to address the issue of deforestation and unsustainable agriculture practices, such as the expansion of palm oil plantations. This requires stronger enforcement of environmental regulations and the promotion of sustainable agriculture practices.

1.2 Problem Statement

The Association of Southeast Asian Nations (ASEAN) has experienced significant economic growth in recent decades, which has been accompanied by a rise in carbon emissions. However, there is a lack of comprehensive research on the determinants of this increase in carbon emission intensity in the region. The absence of such knowledge is concerning, given that carbon emissions are contributing to climate change, which is one of the most pressing challenges facing the world today. The consequences of climate change include severe weather events, rising sea levels, and the loss of biodiversity (Prakash, 2021), among others, which are already having an impact on ASEAN's economic, social, and environmental well-being.

There is a need to address this issue urgently, as ASEAN is currently the world's third-largest emitter of greenhouse gases (L.-C. Lee et al., 2018), and its emissions are projected to continue to rise in the coming years. Without a comprehensive understanding of the determinants of carbon emission intensity in

ASEAN, it is challenging to implement effective policies and strategies to mitigate emissions and promote sustainable development.

It is hypothesized that GDP, inflation, FDI, technology development, human development, and income inequality are the causes of the increase in carbon emission intensity in ASEAN. However, there is a need to test this hypothesis empirically to confirm or refute it. This research provides policymakers, stakeholders, and the wider community with a better understanding of the underlying causes of carbon emission intensity in ASEAN and help to inform the development of effective policies and strategies to mitigate emissions and promote sustainable development in the region.

Focusing solely on the relationship between GDP, FDI, HDI, Gini, inflation, or technology development and carbon emission intensity can be sufficient for this study examining the environmental impact of economic and development factors. These variables are directly relevant to carbon emission intensity, as they capture key aspects of economic growth, investment, income inequality, and technological advancements. By concentrating on these variables, researchers can gain valuable insights into the primary drivers of carbon emissions and their intensity.

Including additional variables, such as technical, science, environment, or health factors, may not significantly enhance the understanding of the relationship between the variables of interest. This is because previous studies have already explored the impact of various environmental and health indicators on carbon emissions (Ahmad et al., 2018; Bashir et al., 2020; Kan et al., 2004; Khan et al., 2016), and their findings can provide a basis for understanding these aspects. Moreover, expanding the scope of the study to include a wide range of variables could lead to data availability challenges and hinder the feasibility of the research.

The study's focus on carbon emission intensity indicates a specific interest in examining the amount of carbon emissions produced per unit of output or activity. By analyzing the relationship between GDP, FDI, HDI, Gini, inflation, or technology development and carbon emission intensity, the study aims to identify the factors that contribute to higher or lower emissions intensity. This understanding can inform policy and decision-making processes aimed at reducing carbon emissions and promoting sustainable development.

While the efficiency of carbon emissions is an important aspect to consider, the study's main focus is on the intensity of emissions rather than their efficiency. The aim is to assess the extent to which economic and development variables influence the level of carbon emissions relative to economic output or development indicators. Examining the efficiency of carbon emissions would require additional variables and a different research focus.

Given the urgent need to address climate change and promote sustainable development, it is essential to develop a comprehensive understanding of the determinants of carbon emission intensity in ASEAN. This research contributes to filling this gap in knowledge and of significant value to policymakers, stakeholders, and the wider community in ASEAN and beyond.

1.3 Research Questions

Based on the background and problem statement mentioned above, the author would gauge the relationship of carbon emission intensity with several independent variables, formulated into the following research questions:

1. What is the relationship between economic development, social development, technological development and the reduction of carbon emission intensity in the region of ASEAN?
2. To what extent do they impact ASEAN carbon emission intensity?

1.4 Research Objectives

The objective of this research is to investigate the relationships between economic development, social development, technological development and carbon emission intensity in ASEAN. Specifically, this study aims to:

1. Determine the relationship between economic development, social development, technological development, and carbon emission intensity;

2. Explore the extent to which economic, social, and technological development impact carbon emission intensity and their potential use as predictors for future policy development;

The results of this research contribute to a better understanding of the determinants of carbon emission intensity in ASEAN and provide useful insights for policymakers in developing effective strategies to reduce carbon emissions and achieve sustainable development goals in the region.

1.5 Research Hypothesis

The research objectives mentioned above aimed to examine the relationship between carbon emission intensity and several independent variables, grouped into three categories: economic development, social development, and technological development. Based on these objectives, the research hypotheses can be formulated as follows:

- H1: GDP have a positive impact on carbon emission intensity in ASEAN.
- H2: FDI is positively associated with carbon emission intensity in ASEAN.
- H3: Inflation may negatively affect carbon emissions in ASEAN.
- H4: GINI (Income Inequality) may have a positive impact on carbon emission intensity in ASEAN.
- H5: HDI (Human Development Index) may exhibit lower carbon emission intensity in ASEAN.
- H6: Technology Development have a significant negative impact on carbon emission intensity in ASEAN.

Higher GDP is hypothesized to positively impact carbon emission intensity in ASEAN, driven by increased economic activity, energy consumption, and industrial production (Y. Liu, 2023; Zheng et al., 2019). Some studies argue that FDI is expected to contribute to higher emissions by stimulating industrial activity and resource extraction (Huang et al., 2022; Shao, 2017; Vo & Zaman, 2020). Inflation, according to Yahoo & Othman (2017); Yang et al. (2016), is hypothesized to have a negative impact on carbon emissions, albeit indirectly as higher inflation may lead to reduced purchasing power and lower energy consumption. Income inequality, confirmed by Grunewald et al., (2017a); Zhu et al., (2018a), is predicted to positively affect emissions, with wealthier individuals exhibiting higher carbon footprints. However, (Akbar et al., 2021; Van Den Bergh & Botzen, 2018)believe that the higher HDI scores, reflecting improved education, healthcare, and living standards, are expected to be associated with lower carbon intensity due to the emphasis on sustainable development. Technology development is hypothesized to significantly reduce emissions through the adoption of cleaner and more efficient technologies, driven by research and development investments and innovation in environmentally friendly technologies (Gu et al., 2020; Xie et al., 2021).

1.6 Relevance of the Study

The relevance of this study lies in its investigation of the determinants of carbon emission intensity in the ASEAN region, a topic of significant importance given the rising concerns surrounding climate change and the need for sustainable development. The study aims to address a critical research gap in the literature by examining the impact of economic, social, and technological factors on carbon emission intensity in ASEAN. The findings of this study could have far-reaching implications for policymakers and stakeholders, providing insights into the key drivers of carbon emissions and offering evidence-based recommendations for the formulation of effective environmental policies. Furthermore, the study's focus on the ASEAN region is particularly timely given the region's rapidly growing economy, population, and industrialization, all of which are contributing factors to increasing carbon emissions. Therefore, the findings of this study have the potential to inform policy decisions and promote sustainable development not only in the ASEAN region but also in other developing countries facing similar challenges.

1.7 Thesis Outline

This research paper aims to investigate the factors that contribute to carbon emission intensity in ASEAN, with a focus on economic, social, and technological development. The paper is organized into five chapters, starting with an introduction that provides a background of the issue and research questions. Chapter 2 review relevant literature on carbon emissions and the factors that influence it. Chapter 3 discusses the research methodology, including data collection and analysis methods. While the Chapter 4 presents the findings and the discussion on the linkage between all variables of economics, social and technology development and carbon emission intensity. Lastly, Chapter 5 provides concluding remarks, study limitation, policy implications along with suggestions for future research.

CHAPTER 2. LITERATURE REVIEW

2.1 Conceptual framework

The study aims to investigate the relationship between carbon emission intensity and several independent variables, including economic development (GDP, FDI, and inflation), social development (income inequality and human development), and technological development (technology development). Depicted in figure 2.1 is the study framework that leads to the research objectives which are to figure out whether or not each of those variables not only have an impact on the fluctuating carbon emission intensity in ASEAN in the short term, but also in the long term. Connected as a part, each variable of the three groups of attributes is holistically tested to reveal their linkage and significance on carbon emission intensity.

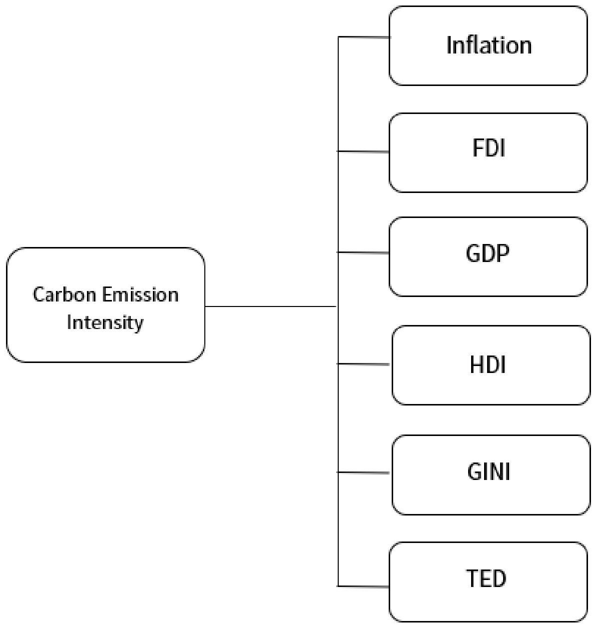

Figure 2. 1 Research Conceptual Framework

2.2 Theoretical background

The theoretical background of this study focuses on the relationship between carbon emission intensity and several independent variables, namely economic development (GDP, FDI, inflation), social development (income inequality, human development), and technological development.

2.2.1 Economic Development

2.2.1.1 Inflation

Inflation is a critical economic phenomenon that has received considerable attention from economists and policymakers. It refers to the sustained increase in the general price level of goods and services in an economy over a specific period. Inflation can be caused by various factors, including demand-pull, cost-push, and imported inflation. Inflation is commonly measured using the Consumer Price Index (CPI) (Cogoljević et al., 2018; Dharma et al., 2020), which tracks the changes in the price level of a basket of goods and services purchased by households.

Inflation is a crucial variable in the analysis of the relationship between economic development and carbon emission intensity (Islam et al., 2021; Z. Song, 2021). A high rate of inflation can significantly impact a country's economic development, as it leads to reduced purchasing power, lower investment, and higher uncertainty. Moreover, high inflation can affect the competitiveness of an economy in the global market (Bostan et al., 2018; Rusu & Roman, 2018), leading to a decline in export performance. On the other hand, low inflation rates are considered essential for economic stability (Liulov et al., 2020; Musarat et al., 2021), as they promote investment and consumption by providing a favourable economic environment.

In the context of carbon emission intensity, inflation can affect the demand and supply of energy (Yolanda, 2017), the prices of goods and services (Dharma et al., 2020), and the investment patterns in the energy sector (B. Xu & Lin, 2018). Higher inflation rates can lead to a rise in energy prices, leading to lower demand and increased energy efficiency efforts, thereby reducing carbon emission intensity. However, high inflation rates may also discourage investments in the energy sector (Barkhordar et al., 2018), leading to a reduction in clean energy development and increased reliance on fossil fuels.

2.2.1.2 Gross Domestic Product

Gross Domestic Product (GDP) is one of the most widely used economic indicators for measuring a country's economic performance. GDP measures the total value of all goods and services produced within a country's borders during a specific period, typically a year. It provides an important measure of a country's economic growth and standard of living (Matar et al., 2018; Nisa’, 2022).

GDP is often used as an indicator of a country's overall economic health (Bracco et al., 2018) and development. A country's GDP can be influenced by a range of factors, including government policies, investment, trade, and technology. In addition, GDP can also be impacted by changes in the workforce (Behun et al., 2018), such as an increase in productivity or a shift in the types of jobs that are available.

There are various methods used to calculate GDP, including the expenditure approach, the production approach, and the income approach (Verma et al., 2021). The expenditure approach focuses on the total amount of money spent on goods and services in a given period, while the production approach measures the value of all goods and services produced in a given period. The income approach, on the other hand, measures the total income earned by all factors of production, including wages, profits, and rents.

GDP is often used as a benchmark for comparing the economic performance of different countries (Bolt et al., 2018). However, it is important to note that GDP alone does not provide a complete picture of a country's economic health and social welfare. For example, GDP does not take into account income inequality, environmental sustainability, or overall well-being. Therefore, it is important to consider other indicators alongside GDP when assessing a country's economic development.

2.2.1.3 Foreign Direct Investment

Foreign Direct Investment (FDI) refers to the investment made by a foreign company or individual in a domestic company or enterprise, with the intention of gaining a controlling stake or a significant degree of influence in the enterprise. FDI has been a key driver of economic growth and development in many countries, especially in emerging markets (Tee et al., 2017), and is widely regarded as a major source of capital, technology, and expertise.

The theoretical background of FDI is based on the principle of capital flows, which states that capital tends to flow from developed countries to developing countries (Johnson, 2021; Rodrik, 2018), where investment opportunities and potential returns are higher. FDI is driven by a combination of economic and non-economic factors (Jurčić et al., 2020), including market size, resource availability, labor costs, political stability, legal and regulatory framework, and institutional infrastructure.

From an economic perspective, FDI is seen as a catalyst for growth and development (Chorn & Siek, 2017), as it can create jobs, transfer technology and know-how, stimulate competition (Prasanna et al., 2019), and generate foreign exchange earnings. Moreover, FDI can bring about spill-over effects (Gaies et al., 2019; L. Hao et al., 2021), such as the development of local supply chains, the transfer of management and organizational skills, and the creation of new industries and sectors.

However, FDI can also have negative effects, such as the exploitation of natural resources (Usman et al., 2022), the displacement of local businesses, the dependence on foreign capital and technology, and the vulnerability to global economic shocks. Thus, the impact of FDI on carbon emission intensity in ASEAN should be studied in the context of these broader economic and social factors.

2.2.2 Social Development

2.2.2.1 Income Inequality

Income inequality refers to the uneven distribution of income among individuals or households within a given population. The concept of income inequality has long been a topic of interest in economic literature, as it is believed to have implications for economic growth, poverty reduction, and social welfare. Theories explaining the causes and consequences of income inequality have been developed and refined over time.

One prominent theoretical framework is the Kuznets hypothesis, which posits that income inequality initially increases as a country undergoes economic development, but then declines as it reaches a certain level of economic maturity (Kisiała & Suszyńska, 2017; Mishra, 2020). This theory suggests that income inequality is an inevitable consequence of the process of economic growth, but that it is eventually mitigated by factors such as greater access to education and technology, and a more developed social welfare system.

Other theories focus on the role of institutions, such as labor unions and government policies, in shaping income distribution. For example, the theory of skill-biased technological change suggests that advances in technology disproportionately benefit high-skilled workers, leading to greater income inequality (Dutz et al., 2018; Jung et al., 2017). Meanwhile, theories of progressive taxation and income transfer programs posit that government interventions can help to reduce income inequality by redistributing wealth from high-earning individuals to those with lower incomes (Buchel et al., 2021; Heuer et al., 2018). Income inequality is a complex and multifaceted issue, and understanding its causes and consequences requires a nuanced understanding of economic, social, and political factors.

2.2.2.2 Human Development

Human development is a multidimensional concept that is often used to measure the overall well-being of individuals within a society. It goes beyond traditional economic indicators, such as income and GDP, to include factors such as health, education, and social inclusion. The Human Development Index (HDI) is a widely used measure of human development that was developed by the United Nations Development Programme (UNDP) in 1990 (Ghislandi et al., 2019; Lind, 2019). The HDI is based on three dimensions: a long and healthy life, access to knowledge, and a decent standard of living.

Several studies have investigated the relationship between human development and environmental issues, including carbon emissions. (Rieckmann, 2018) argues that increased human development may lead to greater awareness of environmental issues and a shift towards more sustainable practices. Others suggest that economic development and environmental degradation are inherently linked (Purvis et al., 2019), and that achieving sustainable development requires a balance between economic growth and environmental protection (Tomislav, 2018).

In the context of ASEAN, human development has been identified as a key factor in addressing environmental challenges. For example, the ASEAN Socio-

Cultural Community Blueprint 2025 includes a goal of promoting sustainable development through investment in education, health, and social protection (Anggo & Laja, 2018; Kheokao, 2017). However, the relationship between human development and carbon emissions in the region is complex, and further research is needed to understand how these factors interact.

2.2.3 Technological Development

Technological development refers to the use of scientific knowledge and innovation to create new products, processes, and services that enhance economic growth, productivity, and sustainability. In the context of carbon emissions, technological development can play a crucial role in reducing emissions by promoting the use of cleaner technologies and reducing the reliance on fossil fuels (Zhou & Feng, 2017). Technological innovation can enable the development of more efficient production processes (Barreto et al., 2017), transportation systems, and energy sources that are less carbon-intensive (Raihan et al., 2022).

In recent years, there has been a growing interest in the potential of technological innovation to help address environmental challenges, including climate change (Morrar et al., 2017). Governments and businesses alike have invested in research and development of clean technologies, such as renewable energy sources, electric vehicles, and energy-efficient buildings. This has led to significant improvements in the performance and cost-effectiveness of these technologies, making them increasingly competitive with traditional fossil fuel-based technologies.

However, the development and adoption of clean technologies is not without its challenges. The high upfront costs of many clean technologies, as well as the infrastructure requirements for their deployment, can be a barrier to their widespread adoption (Tahir et al., 2021). In addition, the diffusion of new technologies can be slow (Brynjolfsson et al., 2018), as it often requires significant changes in existing systems and practices. Despite these challenges, the potential benefits of technological development for reducing carbon emissions make it a critical area for research and policy intervention.

2.2.4 Theory Application

2.2.4.1 Environmental Kuznets Curve (EKC) Theory

The Environmental Kuznets Curve (EKC) theory explores the relationship between economic development and environmental degradation. The underlying hypothesis suggests an inverted U-shaped curve, implying that as countries develop economically, environmental degradation initially increases but eventually decreases as income levels rise.

The EKC theory posits that several factors drive this relationship. First, income levels play a crucial role. Initially, economic growth (see fig. 2.2) may lead to higher pollution levels due to industrialization and increased resource consumption. However, as income rises, societies become more aware of environmental issues, demand cleaner technologies, and implement stricter regulations, leading to a decline in environmental degradation.

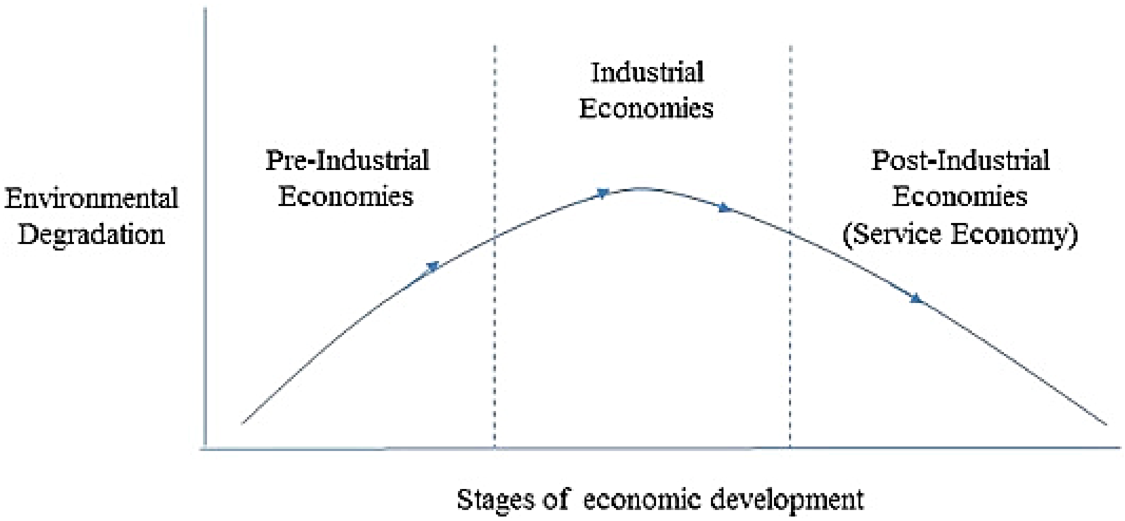

Figure 2. 2 EKC Depiction on the Relationship between economic growth and environmental quality

Source: Enviroment and Development (2016)

Technological advancements also contribute to the EKC (Arshed et al., 2021; Sohag et al., 2021a). As economies develop, they invest in innovation, leading to the development and adoption of cleaner technologies. These technologies can reduce pollution and resource consumption, promoting sustainable development.

Environmental policy and governance play a critical role in shaping the EKC (Sohag et al., 2021b; H. Zhang et al., 2018). Effective regulations, incentives, and enforcement mechanisms can encourage industries to adopt cleaner practices and reduce pollution. Environmental policies, such as carbon pricing or emissions trading, can also influence the trajectory of the EKC.

Empirical evidence regarding the EKC theory is mixed. Some studies have found support for an EKC relationship, observing declining pollution levels after a certain income threshold is reached. For instance, research has highlighted cases where improvements in air and water quality have followed economic development in countries like China and India (X. Lin & Wang, 2016; Qu et al., 2020).

However, other studies have challenged the EKC theory, questioning its generalizability and finding inconsistencies in different contexts (Mandal & Chakravarty, 2016) . Factors such as population growth, technological transfer, and the nature of economic activities can influence the shape and existence of the EKC (Acheampong, 2019; S. Li, Shi, et al., 2020; Pasche, 2002).

The implications of the EKC theory for policymakers are significant. Lavrinenko et al. (2019) suggests that economic growth and environmental sustainability are not necessarily conflicting goals. Policymakers can use the EKC framework to develop strategies that promote sustainable development and mitigate environmental degradation. This includes promoting clean technologies, investing in green industries, and implementing effective environmental regulations.

However, the EKC theory also faces criticisms and limitations. Critics argue that it oversimplifies the relationship between economic growth and the environment, neglecting social and institutional factors. They point out that environmental challenges are influenced by various factors beyond income (Enzler & Diekmann, 2019), such as population growth, technology transfer, cultural norms, and governance structures.

Additionally, the EKC theory assumes a uniform relationship across countries and indicators, but empirical evidence reveals significant heterogeneity (see fig. 2.3). Different countries with diverse resource endowments, economic structures, and policies exhibit varied environmental performance (Burke, 2010), challenging the general applicability of the EKC theory.

Critics also highlight rebound effects, where increased income leads to higher consumption and offsets the environmental benefits achieved through income-driven improvements (Alix-Garcia et al., 2013). Time lags between economic development and environmental outcomes are another concern, as environmental improvements may take time due to delays in policy implementation, technological adoption, and behavior change.

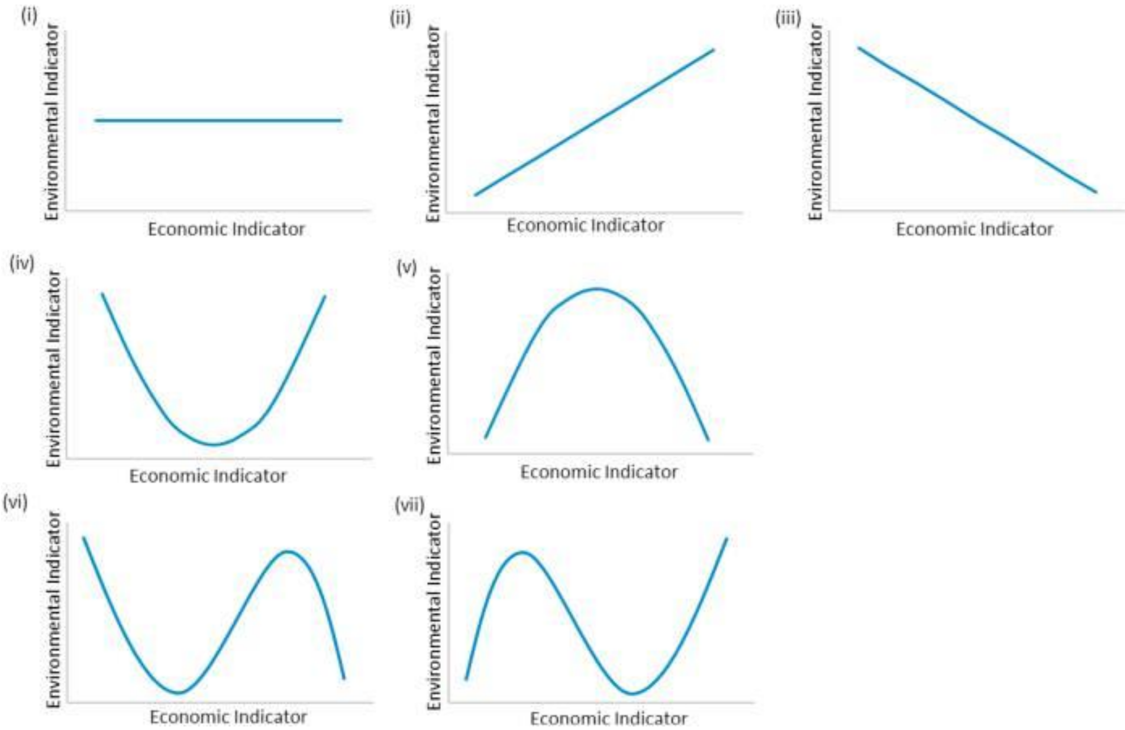

Figure 2. 3 A visual depiction of the correlation between an environmental indicator and an economic indicator

Source: Leal PH, Marques AC (2022)

Key symbols used in the legend: (i) No correlation between x and y; (ii) Positive correlation between x and y; (iii) Negative correlation between x and y; (iv) U-shaped correlation between x and y; (v) Inverted U-shaped correlation between x and y; (vi) Inverted N-shaped correlation between x and y; and (vii) N-shaped correlation between x and y.

The spatial and temporal dynamics of environmental degradation are often neglected in the EKC theory. Localized pollution hotspots and changing environmental challenges over time call for a more nuanced understanding of the relationship between income and environmental degradation.

Furthermore, the EKC theory fails to address distributional effects, as marginalized communities may bear a disproportionate burden of environmental degradation despite overall improvements in environmental quality (Satterthwaite, 2003). Lastly, critics argue that the EKC theory reinforces a linear model of economic development and overlooks alternative pathways that prioritize sustainability and systemic changes in resource use.

The EKC's applicability across different countries and environmental issues has also been questioned. The applicability of the Environmental Kuznets Curve (EKC) theory, which suggests an inverse U-shaped relationship between income and environmental degradation, varies across countries due to country-specific factors, environmental indicators, technological advancements, policy interventions, data limitations, and evolving dynamics.

Country-specific factors, including natural resource endowments, population density, industrial structure, governance systems, and cultural norms, influence environmental challenges and lead to variations in the EKC pattern among countries. The choice of environmental indicators used to measure degradation also affects the applicability of the EKC theory. Different environmental issues exhibit distinct patterns and drivers, and some indicators may not conform to the EKC pattern.

Technological advancements play a significant role in shaping the relationship between income and environmental degradation. Countries adopting cleaner technologies and effective environmental policies may experience faster environmental improvement, potentially bypassing the traditional EKC trajectory (de Miranda Ribeiro & Kruglianskas, 2013). Policy interventions are crucial in determining a country's environmental performance. Effective policies can mitigate degradation regardless of income levels, challenging the assumptions of the EKC theory. Policies prioritizing sustainability and green growth can shape the trajectory of environmental degradation independently of income growth.

Data limitations, including availability and quality, pose challenges in assessing the applicability of the EKC theory. Inconsistent and incomplete data hinder definitive conclusions regarding the EKC pattern and obscure variations in the relationship. The applicability of the EKC theory evolves over time as countries progress through different stages of development. Changing environmental challenges and emerging issues, such as climate change, may require alternative frameworks beyond the traditional EKC.

2.2.4.2 Porter Hypothesis

The Porter Hypothesis is a theory proposed by Michael Porter, which argues that stringent and well-designed environmental regulations can lead to positive outcomes for both the environment and industrial competitiveness. According to this hypothesis, environmental regulations can spur innovation, improve environmental performance, and ultimately enhance a firm's competitive advantage.

One of the main principles of the Porter Hypothesis is that environmental regulations can stimulate innovation within firms (You et al., 2019). When faced with stringent regulations, companies are compelled to find innovative solutions to meet environmental standards while maintaining their competitiveness. This can lead to the development of new technologies, processes, and products that are more environmentally friendly. By encouraging innovation, environmental regulations can drive sustainable growth and create new market opportunities.

Market forces also play a significant role in the Porter Hypothesis. The hypothesis suggests that environmental regulations can create market demand for environmentally friendly products and services (Chowdhury et al., 2015). As consumers become more environmentally conscious and demand sustainable options, firms that proactively respond to these preferences can gain a competitive edge. Environmental regulations can shape consumer behavior, create market differentiation, and reward companies that prioritize environmental performance.

Firm-level strategies are crucial in the context of the Porter Hypothesis. Companies that adopt proactive environmental strategies, such as investing in clean technologies, optimizing resource efficiency, and adopting sustainable practices, can improve their environmental performance and reap economic benefits (S. Li, Qiao, et al., 2020). By integrating environmental considerations into their business strategies, firms can enhance their reputation, attract environmentally conscious customers, and improve long-term profitability.

The underlying mechanism behind the Porter Hypothesis is that environmental regulations act as a catalyst for change, pushing firms to rethink their traditional practices and adopt more sustainable approaches (Ghosh et al., 2020). By setting clear environmental standards and providing regulatory certainty, governments can encourage firms to invest in environmental improvements, leading to better overall environmental performance and increased competitiveness.

Empirical evidence on the Porter Hypothesis has generated a range of findings, both supporting and challenging its claims. Several case studies and research findings have shed light on the relationship between environmental regulations, innovation, and industrial competitiveness.

Supporting evidence for the Porter Hypothesis can be found in various sectors and countries. For example, research conducted by (Y. Song et al. (2019) found that stringent environmental regulations led to increased innovation and competitiveness. The study revealed that companies that invested in cleaner technologies and processes experienced cost savings and improved environmental performance, giving them a competitive advantage in the long run.

Another case study focused on the automotive industry in Japan. Researchers Yamashita and Nagasawa (2008) found that environmental regulations, particularly related to fuel efficiency and emissions, prompted Japanese automakers to invest in research and development of hybrid and electric vehicles (Lam et al., 2018). This not only improved their environmental performance but also enhanced their competitiveness in the global market as demand for fuel-efficient vehicles increased.

Furthermore, studies have highlighted the positive relationship between environmental regulations and technological innovation. For instance, a study by Darnall, Henriques, and Sadorsky (2008) examined the impact of environmental regulations on innovation in the U.S. manufacturing sector. The findings indicated that firms subject to stricter environmental regulations were more likely to invest in research and development, leading to the development of new environmentally friendly technologies.

However, empirical evidence also presents some challenges to the Porter Hypothesis. Some studies have found mixed or inconclusive results regarding the relationship between environmental regulations, innovation, and competitiveness. For example, a study by Ambec and Lanoie (2008) examined the impact of environmental regulations on firm performance in the pulp and paper industry in Canada. They found no evidence of a positive effect on innovation or competitiveness, suggesting that the relationship may not hold uniformly across all industries or contexts.

Additionally, critics argue that the effectiveness of environmental regulations in driving innovation and competitiveness depends on several factors, including the design of the regulations, the level of regulatory stringency, and the characteristics of the industry or market. Not all firms may respond equally to environmental regulations, and there may be variations in their ability to innovate or adapt.

The Porter Hypothesis suggests that well-designed environmental regulations can stimulate innovation, improve environmental performance, and enhance a firm's competitiveness. However, the effectiveness of the hypothesis is contingent upon several conditions and factors.

One condition for the Porter Hypothesis to hold true is the presence of market-based mechanisms and incentives. When environmental regulations incorporate market-based approaches, such as emissions trading or pollution pricing, firms have economic incentives to innovate and develop cleaner technologies (Anser, Yousaf, et al., 2020). These market mechanisms create a level playing field and reward firms that invest in environmental improvements, thereby fostering innovation.

Another important factor is the stringency and clarity of environmental regulations. Stringent regulations provide a clear signal to firms about the need to adopt cleaner technologies and processes. Ambiguous or inconsistent regulations can create uncertainty and hinder firms' ability to plan and invest in innovation

(Blind et al., 2017). Therefore, well-designed regulations with clear goals, targets, and timelines are more likely to spur innovation and enhance competitiveness.

The level of technological and managerial capabilities within firms and industries is also influential. Firms with stronger capabilities are better positioned to respond to environmental regulations and develop innovative solutions (Xing et al., 2019). They may have existing knowledge, resources, and technological expertise that enable them to adapt to regulatory requirements more effectively. In contrast, firms with limited capabilities may face greater challenges in meeting regulatory standards and achieving innovation.

The availability of supportive infrastructure, such as research and development institutions, technology transfer mechanisms, and access to financing, can further facilitate the implementation of the Porter Hypothesis (Roy Chowdhury & Das, 2011). These resources provide firms with the necessary support to undertake research, develop new technologies, and overcome barriers to innovation. Collaboration between academia, industry, and government can play a crucial role in creating an enabling environment for innovation-driven by environmental regulations.

The policy implications of the Porter Hypothesis are significant. Governments and policymakers should design environmental regulations that balance environmental protection with economic competitiveness (Albrizio et al., 2014). This involves considering the specific characteristics of industries, conducting cost-benefit analyses, and engaging in dialogue with relevant stakeholders. Additionally, policies should aim to foster innovation ecosystems by promoting research and development, providing financial incentives, and supporting knowledge transfer.

The Porter Hypothesis also highlights the importance of integrating environmental considerations into industrial policies and sustainable development strategies. By aligning environmental objectives with economic goals, countries can create a more sustainable and competitive economy. This entails adopting a holistic approach that combines environmental regulations with supportive policies for education, training, and entrepreneurship. Furthermore, international cooperation and knowledge-sharing can enhance the effectiveness of environmental regulations and promote innovation on a global scale (Bai et al., 2021).

While the Porter Hypothesis has gained significant attention and has been influential in shaping environmental policy discussions, it is not without criticisms and limitations. One criticism is the assumption that environmental regulations always lead to positive economic outcomes. Critics argue that stringent regulations may impose significant costs on firms, particularly small and medium-sized enterprises (SMEs) (Elliehausen & Lowery, 1997; Graafland & Smid, 2017; B. Zhang et al., 2008), which can hinder their competitiveness and profitability. They contend that the Porter Hypothesis overlooks the potential negative effects of regulations on certain industries and sectors, especially those with high pollution intensity or limited resources to invest in innovation.

Another criticism is that the Porter Hypothesis may not be universally applicable across all industries and countries. Some sectors, such as extractive industries or heavy manufacturing, may face more challenges in achieving environmental improvements due to the nature of their operations and limited technological options. Additionally, the effectiveness of the hypothesis may vary across different national contexts, depending on factors such as institutional quality, regulatory enforcement, and market structure.

Furthermore, the Porter Hypothesis assumes that environmental regulations are the primary driver of innovation and that market forces alone can incentivize firms to adopt cleaner technologies. Critics argue that other factors, such as consumer demand, corporate social responsibility, and industry standards, also play a significant role in driving innovation and environmental improvements (Jeswani & Azapagic, 2020). This suggests that the hypothesis may need to consider a broader set of factors that influence firm behavior and competitiveness.

2.2.4.3 Technological Innovation Theory

The Technological Innovation Theory asserts that technological innovation plays a crucial role in fostering economic growth and development. At its core, this theory suggests that advancements in technology lead to increased productivity, efficiency, and competitiveness, thereby driving economic progress. Technological innovation encompasses the development, application, and diffusion of new ideas, processes, products, or services that bring about significant improvements in various sectors.

This theory recognizes that technological innovation can lead to several positive outcomes. Firstly, it enhances productivity by enabling businesses to produce more output with fewer resources. New technologies often streamline processes, automate tasks, and introduce more efficient methods of production. Secondly, technological innovation drives competitiveness by equipping firms with cutting-edge tools and capabilities, allowing them to gain a competitive advantage in the marketplace. Additionally, technological advancements can open up new markets, create employment opportunities, and contribute to overall economic growth.

The theory acknowledges the vital role of research and development (R&D) in driving technological innovation. Investments in R&D facilitate the discovery of new ideas, the development of innovative products and services, and the improvement of existing technologies. Public and private sector investments in R&D, as well as collaboration between academia and industry, are crucial in fuelling technological advancements.

Moreover, the theory recognizes that factors such as education, infrastructure, and institutional support play essential roles in fostering technological innovation. A skilled workforce, robust infrastructure, and supportive regulatory frameworks encourage the adoption and diffusion of new technologies. Additionally, intellectual property rights protection and a conducive business environment can incentivize firms to invest in innovation and reap the benefits.

Technological innovation is influenced by a wide range of factors, including research and development (R&D) investments, knowledge creation, and the diffusion of technology. Additionally, institutions, policies, and market conditions play significant roles in either fostering or hindering technological innovation.

Investing in research and development (R&D) is crucial for technological progress. R&D activities, funded by both public and private sectors, drive innovation by generating new knowledge and breakthroughs. Knowledge creation occurs through scientific research, collaborations between academia and industry, and open innovation practices. Technology diffusion ensures widespread adoption across industries and countries, influenced by factors like market access, technology transfer, and skilled workforce availability. Supportive institutions, policies, and regulatory frameworks incentivize R&D investment and foster collaboration between academia, industry, and government. Market dynamics, competition, and customer demands shape technological innovation, with market conditions rewarding successful innovations and guiding the development of customer-centric products and services.

Nevertheless, there are also factors that can hinder technological innovation. These may include insufficient R&D investments, lack of skilled workforce, inadequate access to financing, bureaucratic red tape, weak intellectual property rights enforcement, and market monopolies that discourage competition and innovation.

Technological innovation has a significant impact on productivity, competitiveness, and job creation across various sectors and industries. Technological innovation improves productivity and competitiveness by streamlining processes and reducing costs. It enables firms to produce more with fewer resources, enhancing efficiency and product quality. Innovations like automation and artificial intelligence differentiate firms, capture market share, and attract investments, driving economic growth. While job displacement may occur in some sectors, technological innovation creates new employment opportunities, especially for skilled workers. It stimulates entrepreneurship and the establishment of new businesses, fostering job creation and economic development.

Promoting technological innovation poses challenges, such as limited resources, technology accessibility, skills gaps, and regulatory barriers. Ethical considerations, including privacy and labor market impacts, also need addressing. However, emerging technologies like AI, IoT, and renewable energy offer significant opportunities. Collaboration among academia, industry, and government fosters innovation ecosystems and knowledge exchange. International cooperation accelerates innovation, particularly in areas requiring collective efforts.

2.2.4.4 Energy Efficiency Paradox Theory

The Energy Efficiency Paradox Theory challenges the notion that enhancing energy efficiency automatically leads to reduced energy consumption and environmental benefits. It asserts that despite progress in energy efficiency, overall energy usage may not decline as anticipated. The theory highlights the rebound effect, whereby energy efficiency gains are countered by increased energy utilization. This can happen when energy costs decrease, prompting individuals and businesses to amplify energy usage or engage in energy-intensive pursuits. The theory also acknowledges income and price elasticity, suggesting that affordable energy resulting from efficiency improvements may trigger heightened demand for energy services. The Energy Efficiency Paradox recognizes the intricacy of human behavior and rebound effects across various sectors, such as transportation and buildings.

The implications of the Energy Efficiency Paradox are significant for energy consumption and environmental sustainability. Relying solely on energy efficiency may not achieve substantial reductions in energy use and greenhouse gas emissions. Policymakers must adopt a comprehensive approach that blends energy efficiency with other strategies like deploying renewable energy, promoting behavioral change, and implementing systemic transformations. Meticulous policy design is imperative, accounting for interactions between energy efficiency measures, pricing mechanisms, consumer behavior, and market dynamics.

The Energy Efficiency Paradox emanates from factors that contribute to rebound effects, constraining the effectiveness of energy efficiency measures. Direct rebound effects transpire when diminished energy costs spur heightened energy consumption. Indirect rebound effects occur when energy efficiency fuels economic growth, resulting in elevated overall energy usage. Changes in consumer behavior also contribute to rebound effects, as individuals modify their conduct when confronted with energy efficiency gains.

Tackling the Energy Efficiency Paradox necessitates policymakers to consider these factors and devise effective policies. Incentivizing sustainable consumption patterns, advocating for renewable energy sources, and heightening awareness about rebound effects are pivotal. Energy pricing mechanisms, progressive pricing structures, and time-of-use pricing can influence consumer behavior and foster energy conservation. Standards and labeling programs propel energy efficiency improvements by stipulating minimum performance standards and furnishing energy labels. Education and awareness campaigns play a vital role in cultivating sustainable energy consumption practices.

Market dynamics also exert a notable influence. As consumer demand for energy-efficient products and services rises, market opportunities for innovative technologies materialize. Competitive energy markets can foster innovation and investment in energy-efficient technologies. However, policy instruments and market dynamics alone may not wholly address the Energy Efficiency Paradox. Complementary measures, such as comprehensive energy management strategies and a transition towards renewable energy, are indispensable for effectively combating rebound effects.

The effectiveness of policy instruments hinges on their design, implementation, market conditions, and consumer attitudes. Policies should be finely targeted, consistently evaluated, and forged through collaborative efforts with stakeholders. Market-driven mechanisms should be accompanied by endeavors to augment awareness and foster sustainable energy consumption patterns.

Realizing environmental sustainability and mitigating climate change mandates a balanced approach. While energy efficiency plays a pivotal role in reducing energy demand and greenhouse gas emissions, it must be complemented by renewable energy deployment. Shifting energy production to sustainable sources helps counteract rebound effects and reduces reliance on fossil fuels. Energy efficiency and renewable energy should be pursued concurrently as synergistic strategies.

Addressing the Energy Efficiency Paradox also entails contemplating broader decarbonization strategies, such as enhancing energy infrastructure, bolstering energy storage capabilities, supporting the electrification of transportation, and promoting sustainable land use practices. A comprehensive approach that amalgamates energy efficiency, renewable energy, and other decarbonization strategies is indispensable for attaining a sustainable and low-carbon future.

2.2.4.5 Behavioral Economics Theory

Behavioral economics combines psychology and economics to study how individuals and groups make economic decisions. It acknowledges that people's decision-making is influenced by cognitive biases, heuristics, and social factors, deviating from traditional notions of rationality. Cognitive biases are mental shortcuts that affect decision-making, while heuristics simplify the decision-making process. Social factors, such as social norms and peer pressure, also play a significant role.

Understanding these influences is crucial as it sheds light on real-world phenomena and informs areas like consumer behavior, financial decision-making, and public policy. Policymakers and marketers can use this knowledge to design interventions and "nudges" that guide individuals toward better choices. However, behavioral economics faces criticism for being manipulative and culturally biased.

Key concepts in behavioral economics include loss aversion, framing effects, prospect theory, social norms, and peer pressure. Loss aversion refers to the tendency to feel losses more strongly than gains. Framing effects occur when the way information is presented influences decision-making. Prospect theory suggests that decisions are influenced by subjective perceptions of value and probability. Social norms and peer pressure shape behavior by influencing conformity and social comparison.

Behavioral economics has practical applications in consumer behavior, financial decision-making, public policy, and healthcare. Businesses can use behavioral insights to design products and marketing strategies that encourage desired consumer behaviors. Financial institutions can leverage these insights to help individuals make better financial choices. Behavioral interventions in public policy and healthcare can promote positive behaviors without infringing on individual autonomy.

However, it is important to consider ethical concerns and potential unintended consequences when applying behavioral insights. Critics argue that behavioral interventions can be manipulative and raise concerns about individual autonomy. Generalizability of findings across cultures and methodological challenges are also raised as limitations. Behavioral economics should address these concerns and consider individual differences in decision-making and long-term consequences.

2.3. Previous Research Studies

2.3.1 Previous Research Studies of Economic Development on Carbon Emission Intensity

2.3.1.1 Inflation on Carbon Emission Intensity

In the last decade, many studies have increasingly turned their attention to the linkages between inflation and carbon emissions, with studies focusing on different regions and economies. In a 2014 study titled "Inflation and Carbon Emissions Revisited: Evidence from Highly Disaggregated Data," Pasrun Adam and Ahmad Jafari Samimi investigated the relationship between inflation and carbon emissions in the ASEAN-5 countries, including Indonesia, Malaysia, the Philippines, Thailand, and Vietnam. Their analysis found that inflation had a significant positive effect on carbon emissions in these countries, indicating that price changes in the economy, particularly for energy-intensive goods and services, may drive up carbon emissions.

Similarly, another study published in the same year by Suharto and Adiningsih examined the relationship between inflation, economic growth, and carbon emissions in Indonesia. The authors found that inflation had a negative effect on economic growth and a positive effect on carbon emissions, suggesting that high inflation rates could lead to unsustainable economic growth patterns that exacerbate carbon emissions.

Other studies have examined the impact of inflation on energy consumption, which is closely linked to carbon emissions. A 2014 study by Chen and Lei investigated the relationship between inflation, energy consumption, and economic growth in China, and found that inflation had a positive impact on energy consumption and a negative impact on economic growth. This indicates that inflation can lead to greater energy demand and may indirectly contribute to higher carbon emissions.

In addition to these specific studies, there is a growing body of literature that highlights the complex interplay between macroeconomic factors, including inflation, and carbon emissions. For instance, a study by Dinda and Coondoo in 2006 found that economic growth and energy intensity were significant predictors of carbon emissions, but that the relationship between inflation and carbon emissions was less clear-cut.

These previous research studies suggest that inflation can play a significant role in driving up carbon emissions, particularly in developing economies where energy consumption is closely linked to economic growth and inflation rates can be volatile. This highlights the importance of incorporating inflation into policy discussions around carbon emissions reduction, and the need for targeted policies that balance macroeconomic stability with sustainable development goals.

2.3.1.2 Gross Domestic Product on Carbon Emission Intensity

Over the years, several studies have been conducted to examine the relationship between Gross Domestic Product (GDP) and carbon emission intensity. In 2014, a study by Burke et al. titled "Exploring the relationship between GDP, energy consumption, and greenhouse gas emissions in high-, middle-, and low-income countries" investigated the relationship between GDP and carbon emissions across 159 countries.

The study utilized panel data regression models to examine the relationship between GDP and carbon emission intensity while controlling for energy consumption and other confounding factors. The results showed that GDP is positively associated with carbon emission intensity, indicating that as GDP increases, so does the level of carbon emissions. The study also found that the effect of GDP on carbon emission intensity varies across income groups, with higher-income countries exhibiting a stronger positive association between GDP and carbon emissions.

Another study by Liu et al. titled "The impact of economic growth, industrial structure, and urbanization on carbon emissions in China during 1995-2009" also examined the relationship between GDP and carbon emission intensity in China. The study utilized a combination of panel data analysis and decomposition analysis to investigate the contribution of economic growth, industrial structure, and urbanization to carbon emissions. The findings showed that GDP is a major driver of carbon emissions in China, with economic growth contributing the most to the increase in carbon emissions.

Similarly, a study by Zhang et al. titled "Carbon emissions and economic development: An econometric analysis of China and the United States" investigated the relationship between GDP and carbon emission intensity in China and the United States. The study utilized a panel data analysis and found that there is a positive relationship between GDP and carbon emissions in both countries, although the magnitude of the effect was higher in China.

2.3.1.3 Foreign Direct Investment on Carbon Emission Intensity

Foreign Direct Investment (FDI) has been an important source of capital flows and technology transfer, especially for developing countries. However, it has also been a controversial issue due to its impact on the environment. In recent years, there has been growing interest in examining the relationship between FDI and carbon emission intensity.

Several studies have been conducted to investigate this relationship. For instance, a study by Sun et al. (2017) used panel data from 42 countries over the period 1995-2012 to examine the impact of FDI on carbon emissions. The study found that FDI had a significant positive effect on carbon emissions in developing countries, while the effect was insignificant in developed countries. The authors argued that this was due to the fact that developing countries had less stringent environmental regulations and lower environmental awareness, which made them more vulnerable to the negative environmental impact of FDI.

Similarly, another study by Liu et al. (2017) examined the impact of FDI on carbon emissions in China. The study used data from 31 provinces over the period 1997-2012 and found that FDI had a positive effect on carbon emissions, but the effect was weakened by the presence of environmental regulations. The authors concluded that environmental regulations could effectively mitigate the negative impact of FDI on the environment.

In contrast, a study by Azomahou et al. (2017) examined the relationship between FDI and carbon emissions in a sample of 90 countries over the period 1970-2010. The study found that FDI had a negative effect on carbon emissions, indicating that FDI could be a source of clean technology transfer and energy efficiency improvement.

Moreover, a study by Xu et al. (2017) investigated the relationship between FDI and carbon emissions in the manufacturing sector of China. The study used data from 29 provinces over the period 2006-2014 and found that FDI had a positive effect on carbon emissions, but the effect was weaker in regions with higher environmental regulations.

2.3.2 Previous Research Studies of Social Development on Carbon Emission Intensity

2.3.2.1 Income Inequality on Carbon Emission Intensity

Income inequality, as one of the indicators of social development, has been a subject of interest in the literature examining its impact on carbon emission intensity. Several studies have been conducted since 2015 to investigate the relationship between income inequality and carbon emission intensity.

One study by Galeotti and Rubashkina (2015) analyzed the relationship between income inequality and carbon emission intensity using panel data from 89 countries. The study found a positive correlation between income inequality and carbon emission intensity, indicating that countries with higher income inequality tend to have higher carbon emissions. The authors suggested that the unequal distribution of wealth and income may lead to overconsumption and a higher demand for energy-intensive products and services.

Another study by Cheng et al. (2016) focused on the impact of income inequality on carbon emission intensity in China. The study used provincial-level data and found a positive relationship between income inequality and carbon emission intensity. The authors suggested that the unequal distribution of income and wealth in China leads to an increase in carbon emissions due to a higher demand for energy-intensive goods and services.

Furthermore, a study by Nguimkeu and Diboma (2017) analyzed the impact of income inequality on carbon emission intensity in Africa. The study used panel data from 28 African countries and found a positive relationship between income inequality and carbon emission intensity. The authors suggested that income inequality contributes to the overconsumption of energy-intensive goods and services, which in turn increases carbon emissions.

In addition, a study by Wang and Zhao (2019) examined the relationship between income inequality and carbon emission intensity in China. The study used data from 30 provinces and found a positive relationship between income inequality and carbon emission intensity. The authors suggested that income inequality contributes to higher carbon emissions due to an increased demand for energy-intensive goods and services among the wealthy population.

2.3.2.2 Human Development on Carbon Emission Intensity

Human development is a paramount factor in understanding the relationship between economic growth and environmental sustainability. Studies in recent years have examined the impact of human development on carbon emission intensity. In 2015, a study by Majeed et al. analyzed the impact of human development on carbon emissions in a panel of 46 developing countries from 1995 to 2012. The study found that human development has a significant negative impact on carbon emissions, as increased human development leads to a decrease in carbon emissions. Similarly, a study by Liu et al. in 2018 examined the relationship between human development and carbon emissions in 134 countries from 1990 to 2014. The study found that human development has a significant negative impact on carbon emissions, and countries with higher human development tend to have lower carbon emissions.

Moreover, a study by Alam et al. in 2017 examined the impact of human development on carbon emissions in South Asian countries. The study found that human development has a significant negative impact on carbon emissions, and education and health were found to be important factors in reducing carbon emissions. Another study by Ang et al. in 2018 examined the impact of human development on carbon emissions in ASEAN countries. The study found that human development has a significant negative impact on carbon emissions, and that education and health are important factors in reducing carbon emissions.

Furthermore, a study by Zhao et al. in 2020 examined the relationship between human development and carbon emissions in China. The study found that human development has a significant negative impact on carbon emissions, and that human capital and technological progress are important factors in reducing carbon emissions.

2.3.3 Previous Research Studies of Technology Development on Carbon Emission Intensity

2.3.3.1 Technology Development on Carbon Emission Intensity

Technological development has been a defining aspect in reducing carbon emissions globally. The advancement in technology has enabled various industries to produce goods and services with minimal greenhouse gas emissions. This has led to various studies being conducted to investigate the relationship between technology development and carbon emission intensity.

A study by Khezri et al. (2019) examined the impact of renewable energy and technology innovation on CO2 emissions. The study used panel data analysis and found that renewable energy has a significant negative impact on CO2 emissions. Moreover, technology innovation was found to reduce CO2 emissions, especially in developed countries.

Another study by Wang et al. (2019) investigated the impact of technological innovation and industrial structure on carbon emissions in China. The study found that technological innovation has a negative impact on carbon emissions, and industrial structure has a positive impact on carbon emissions. The study concluded that China needs to focus on technological innovation to reduce its carbon emissions.

A study by Ahmad et al. (2018) examined the impact of technology transfer and carbon emissions in ASEAN countries. The study found that technology transfer has a significant impact on carbon emissions, and the impact varies among ASEAN countries. The study recommended that ASEAN countries should focus on technology transfer to reduce their carbon emissions.

Furthermore, a study by Zaman et al. (2016) investigated the impact of energy consumption, economic growth, and technological development on carbon emissions in the United States. The study used the Autoregressive Distributed Lag (ARDL) approach and found that technological development has a significant negative impact on carbon emissions. The study recommended that policymakers in the United States should focus on promoting technological development to reduce carbon emissions.

Despite the numerous studies conducted on the relationship between economic development, income inequality, human development, technological development, and carbon emission intensity in ASEAN, several gaps in the literature still exist. Firstly, most studies have focused on the individual impact of economic variables such as GDP, FDI, and inflation on carbon emission intensity, with less attention given to the combined impact of these variables. Therefore, there is a need for further research that examines the interaction between these variables and their combined effect on carbon emission intensity in ASEAN.

Secondly, while income inequality has been identified as an important factor that influences carbon emission intensity, there is limited research on the mechanisms through which this relationship exists. Therefore, future research could explore the mediating and moderating effects of other variables such as energy consumption and industrial development to better understand the relationship between income inequality and carbon emission intensity.

Thirdly, while human development has been suggested as a potential solution for reducing carbon emission intensity, there is limited research on how specific aspects of human development such as education and health impact carbon emission intensity in ASEAN. Therefore, future research could focus on the specific mechanisms through which different aspects of human development influence carbon emission intensity in the region.

Lastly, while there is a growing body of literature on the relationship between technological development and carbon emission intensity, most studies have focused on the impact of renewable energy technologies on carbon emission intensity. Thus, there is a need for further research that examines the impact of other types of technological innovations such as carbon capture and storage technologies on carbon emission intensity in ASEAN.

CHAPTER 3. RESEARCH METHODOLOGY

The author in this study utilizes the data of 10 ASEAN countries in a 10-year period since 2010, with a model testing the relationship of carbon emission intensity with the application of Fixed Effect Model (FEM) to gauge the long-term corelation between the variables and Granger Causality test to reveal whether or not the causal relationship between all independent variables and the dependent one exists.

In a study focusing on the relationship of GDP, FDI, HDI, Gini, inflation, and technology development on carbon emission intensity, the inclusion and investigation of technical, science, environment, and health variables may be considered less necessary. The primary reason is that the study already encompasses variables such as environmental pollution and foreign direct investment, which are directly related to carbon emissions. Including additional variables from the technical, science, environment, and health domains could introduce redundancy and potentially complicate the analysis without providing significant additional insights into the core relationships under investigation.

Moreover, by maintaining a focused approach on the selected economic and developmental variables, the study can draw clear conclusions regarding their impact on carbon emission intensity. Inclusion of unrelated variables may dilute the study's objectives and hinder the ability to establish a strong and cohesive argument.

Additionally, the availability and complexity of data associated with technical, science, environment, and health variables should be taken into account. Collecting reliable and relevant data for these variables can be challenging and time-consuming, especially when their direct influence on the primary research question is not well-established. By narrowing down the variables, the study can make more efficient use of available resources and focus on the core aspects that are directly related to the research question.

Furthermore, interdisciplinary collaboration can be valuable when studying the impact of technical, science, environment, and health factors on carbon emissions. By concentrating on the selected economic variables, the study can provide a foundation for future collaborations with experts from various domains to explore the broader implications of these factors. This approach allows for a more efficient allocation of resources and expertise, while still acknowledging the importance of the technical, science, environment, and health dimensions in the overall understanding of carbon emission intensity. Following that is the application of PLS and the analysis upon the findings.

3.1 Data

This study employs the World Development Index (WDI) to gather statistical data for GDP, FDI, inflation, and carbon emission intensity, while data for human development and technological development are sourced from Our World in Data (OWD) and the Organisation for Economic Co-operation and Development (OECD), respectively. All variables are concisely displayed in Table 3.1. The study focuses on ten ASEAN countries, including Brunei, Indonesia, Laos, Myanmar, Malaysia, Philippines, Singapore, Thailand, and Vietnam, with quarterly data collected from 2010 to 2021. The HDI is a composite measure of a country's health, education, and living standards, while the OECD provides economic data on member and non-member countries.

TABLE 3. 1 VARIABLES SUMMARY

Variable	Description	Units	Sources
CEI	CO_2 Emissions Intensity	Metric tons per capita	WDI*
CEI is from solid fuel consumption refer mainly to emissions from use of coal as an energy source			
INF	Inflation	Annual %	WDI*
Inflation as measured by the annual growth rate of the GDP implicit deflator shows the rate of price change in the economy as a whole. The GDP implicit deflator is the ratio of GDP in current local currency to GDP in constant local currency.			
FDI	Foreign direct investment	Net inflows (% of GDP)	WDI*
It is the net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown in the balance of payments. This series shows net inflows (new investment inflows less disinvestment) in the reporting economy from foreign investors, and is divided by GDP.			

GDP	Gross Domestic Product	Annual %	WDI*
GDP per capita is gross domestic product divided by midyear population. GDP at purchaser's prices is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources.			
GINI	Income Inequality	%	WDI*
It measures the extent to which the distribution of income (or, in some cases, consumption expenditure) among individuals or households within an economy deviates from a perfectly equal distribution.			
TED	Technology Development	%	OECD**
This dataset introduces patent-based indicators such as indicators of technology development, indicators of international collaboration in technology development, indicators of technology diffusion.			
HDI	Human Development Index	%	OWD***
It measures key dimensions of human development. The three key dimensions are:1 – A long and healthy life – measured by life expectancy. – Access to education – measured by expected years of schooling of children at school-entry age and mean years of schooling of the adult population. – And a decent standard of living – measured by Gross National Income per capita adjusted for the price level of the country			

*World Development Indicators (Bank, 2022), ** The Organisation for Economic Co-operation and Development OECD (2023), ***Our World in Data (2023)

Despite the numerous studies examining the relationship between economic variables and carbon emission intensity, there remains a gap in the literature concerning the specific effects of these variables in the ASEAN region. Additionally, previous studies often focused on individual variables, such as GDP or FDI, without considering the potential interactions and relationships between multiple variables. This study aims to address these gaps by examining the collective impact of GDP, FDI, inflation, income inequality, human development, and technological development on carbon emission intensity in the ASEAN region. Furthermore, while previous research has shown mixed results regarding the relationship between income inequality and carbon emissions, the specific effects of income inequality on carbon emission intensity in the ASEAN region have not been thoroughly explored.

3.2 The Models

The study uses panel data analysis to test the hypotheses. The model is developed to test the linkage of each category of independent variables: economic development, social development, and technological development, on the carbon emission intensity in ASEAN at once.

$$CEI = \alpha + \beta 1(GDP) + \beta 2(FDI) + \beta 3(INF) + \beta 4(GINI) + \beta 5(HDI) + \beta 6\ (TED) + \varepsilon \qquad (1)$$

In this FEM model under consideration, the dependent variable is represented by the Carbon Emission Intensity rate (CEI), whereas the independent variables include Gross Domestic Product (GDP), Foreign Direct Investment (FDI), and inflation rate (INF), as represented by the coefficients β1, β2, and β3, respectively. Additionally, income inequality is measured by GINI, social development by HDI, and technological progress by TED. The intercept term, denoted by α, represents the constant value of CEI when all independent variables are equal to zero. Finally, the error term, represented by ε, accounts for all unexplained variation in the model. With these variables and parameters in place, the model can be used to investigate the complex relationships between economic, social, and technological development, and carbon emission intensity. The regression analysis provides a statistical estimation of the relationships between the independent and dependent variables, and the results are used to evaluate the research hypotheses.

3.3 Method

Executing the panel regression necessitates the implementation of a meticulously integrated methodology to scrutinize data, estimate variable associations, and effectively capture both the transitory dynamics and enduring equilibrium. Primarily, this study commences with the meticulous accumulation of dependable and pertinent panel data, spanning a predetermined temporal framework and encompassing comprehensive observations across numerous entities. Subsequently, the data necessitates thorough preparation, encompassing rectification of absent values, identification and resolution of outliers, and eradication of any incongruities. Such meticulous preparations guarantee data coherence and precision for ensuing analysis endeavours.

Following data preparation, the evaluation commences with a diligent stationarity test, as saying the stationarity of the variables under examination. In instances where non-stationarity surfaces, the author adroitly undertake appropriate measures, such as employing differencing techniques, to foster stationarity attainment. Consequent to this, the investigation advances to model specification, necessitating the judicious determination of the most appropriate panel regression model, conscientiously factoring in crucial elements such as fixed effects, random effects, or pooled models, with meticulous adherence to pertinent assumptions, consonant with the intricate nature of the data under scrutiny. Variable selection subsequently ensues, ensuring that the chosen independent and dependent variables remain undergirded by robust theoretical underpinnings, align with the research question at hand, and exude substantive variation across the panel.

Following the meticulous model specification and variable selection, the focus centres on model estimation, utilizing aptly tailored techniques such as fixed effects, random effects, or generalized method of moments (GMM), meticulously deployed to undertake the panel regression estimation, drawing upon the meticulously amassed panel data. Consequent to this estimation, a comprehensive statistical analysis assumes the spotlight, holistically assessing the statistical significance of the coefficient estimations, underpinned by meticulous hypothesis testing endeavors, coupled with judicious evaluations of indicators such as R-squared, adjusted R-squared, and significance levels, deftly determining the model's goodness-of-fit credentials.

To ensure the resilience and robustness of the regression outcomes, the author adroitly execute sensitivity analyses and robustness checks, which adroitly identify and address critical issues, inclusive of multicollinearity, heteroscedasticity, and autocorrelation. Finally, the coefficient estimations are meticulously interpreted within the purview of the research question and variables under investigation, with meticulous attention paid to comprehending the magnitude, direction, and statistical significance of said coefficients, which vividly illuminate the nuanced associations that permeate the independent and dependent variables.

3.3.1 Pool Least Square (PLS) and Fixed Effect Model

Pooled least squares (PLS) are a statistical technique commonly used for analyzing panel data, which consists of observations on the same entities over time or across different groups. PLS aims to estimate the relationships between the dependent variable and independent variables while accounting for the panel structure of the data (Abdi, 2010).

The principal formula used in PLS is similar to ordinary least squares (OLS) regression. The model can be expressed as follows:

$$Y_{it} = \beta_0 + \beta_1 X_{1,it} + \beta_2 X_{2,it} + ... + \beta_k X_{k,it} + \varepsilon_{it}$$

In a pooled least squares (PLS) model, the dependent variable Y_{it} represents the observed data for a specific entity i at a particular time t. This variable could be, for example, the income, sales, or any other measure of interest for the entity. The independent variables $X_{1,it}$, $X_{2,it}$, ..., $X_{k,it}$ correspond to the factors or variables that are hypothesized to influence the dependent variable for that entity at that time. These independent variables could include factors such as age, education, economic indicators, or any other relevant variables.

The coefficients β_0, β_1, β_2, ..., β_k in the model are the parameters that need to be estimated. These coefficients represent the expected effects or impacts of the independent variables on the dependent variable. By estimating these coefficients, we can quantitatively assess the relationships between the independent variables and the dependent variable.

The error term ε_{it} captures the unobserved factors and random disturbances that affect the dependent variable but are not accounted for by the independent variables. It represents the variability in the dependent variable that cannot be explained by the chosen independent variables. These unobserved factors could include measurement errors, omitted variables, or other unobserved influences.

The main difference between PLS and OLS lies in the treatment of the panel structure. In OLS, all observations are pooled together, ignoring the potential correlations within each panel (Dogru et al., 2021). However, in PLS, the panel structure is explicitly taken into account through fixed effects or random effects.

Fixed effects models in PLS introduce individual-specific intercepts, capturing time-invariant heterogeneity. These fixed effects control for unobserved characteristics that may vary across entities but remain constant over time. By including fixed effects, PLS allows for the estimation of within-entity variations over time and improves the accuracy of coefficient estimates.

Random effects models in PLS incorporate both time-invariant and time-varying unobserved factors. Random effects account for individual-specific intercepts that may change over time, capturing both cross-sectional and temporal variations. This approach provides more flexibility by allowing the intercepts to vary across entities while assuming a common error structure.

Estimating PLS involves iteratively solving the model equation to obtain the best-fitting coefficients. The estimation process aims to minimize the sum of squared residuals, similar to OLS. By considering the panel structure and accounting for heterogeneity, PLS provides more efficient and reliable estimates compared to OLS.

3.3.2 Chow Test

The Chow test, also known as the Chow breakpoint test, is a statistical test used to assess whether there is a structural change or a difference in the coefficients of a regression model between two or more subgroups of data (Jackson & Lindley, 1989). It is commonly applied in econometrics and time series analysis to determine if there is a significant difference in the relationships between the independent variables and the dependent variable across different time periods, regions, or groups.

The principal formula used in the Chow test is based on the estimation of two until three separate regression models (Landman & Faddeenkov, 2019). The first model is estimated using the entire dataset, while the second model is estimated using separate subsets or subgroups of the data. The Chow test statistic is then calculated to compare the fit of the two models and determine if there is a significant difference in the coefficients.

The Chow test statistic is calculated as follows:

$$F = [(SSR\_r - SSR\_ur) / q] / [SSR\_ur / (n - k - 2q)]$$

Where SSR_r is the sum of squared residuals from the restricted model (combining the two subgroups), SSR_ur is the sum of squared residuals from the unrestricted model (separate models for each subgroup), q is the number of restrictions imposed in the restricted model, n is the total number of observations, and k is the number of independent variables.

The Chow test statistic follows an F-distribution with degrees of freedom equal to q and n - k - 2q. A significant result indicates that there is a structural change or a significant difference in the coefficients between the subgroups, suggesting that the relationship between the independent variables and the dependent variable differs across those subgroups.

The Chow test is useful for detecting changes in relationships over time or across different groups (Takeda et al., 2010), providing insights into the stability or variability of the coefficients in a regression model. It helps researchers determine if there are distinct relationships within different subsets of data, which can have important implications for policy interventions, market segmentation, or understanding changes in economic or social phenomena. By conducting the Chow test, analysts can gain a deeper understanding of the underlying dynamics and identify specific periods or groups where the relationships between variables differ significantly.

3.3.3 Hausman Test

The Hausman test is a statistical test used in econometrics to assess whether the fixed effects (FE) or random effects (RE) model is appropriate for panel data analysis (Torres-Reyna, 2007). It helps determine whether the presence of unobserved individual-specific effects (fixed effects) in a panel dataset significantly affects the coefficients of the independent variables.

The principal formula used in the Hausman test involves comparing the estimated coefficients from the fixed effects model (FE) with the estimated coefficients from the random effects model (RE). The test is based on the idea that if the fixed effects are uncorrelated with the independent variables, then the random effects model is appropriate. However, if there is a correlation between the fixed effects and the independent variables, the random effects model may produce biased estimates, and the fixed effects model should be used instead.

The Hausman test statistic is calculated as follows:

$$H = (\beta\_FE - \beta\_RE)' [Var(\beta\_FE) - Var(\beta\_RE)]^{\wedge}(-1) (\beta\_FE - \beta\_RE)$$

where β_FE is the vector of coefficients estimated from the fixed effects model, β_RE is the vector of coefficients estimated from the random effects model, and Var(β_FE) and Var(β_RE) are the variance-covariance matrices of the fixed effects and random effects estimators, respectively.

The Hausman test statistic follows a chi-square distribution with degrees of freedom equal to the difference in the number of estimated coefficients between the two models. If the test statistic is statistically significant, it indicates that the fixed effects model is preferred because the coefficients from the random effects model are biased due to the correlation between the fixed effects and the independent variables (Wu et al., 2016).

The Hausman test is crucial for panel data analysis as it helps researchers select the appropriate model and ensure the validity of the estimated coefficients. By conducting the Hausman test, analysts can determine whether including fixed effects is necessary to account for unobserved individual-specific effects, leading to more accurate and reliable results. This test contributes to the robustness and credibility of the empirical findings in panel data studies, allowing for more informed policy recommendations and decision-making based on the estimated coefficients.

3.3.4 Laggrange Multiplier Test

The Laggrange Multiplier (LM) test is a statistical test used in econometrics to examine whether a specific regression model is appropriate. It is commonly employed to assess the presence of omitted variables or functional form misspecification in a regression analysis.

The principal formula used in the LM test involves estimating an auxiliary regression, known as the "augmented regression," which includes additional variables or transformations of variables that capture the potential omitted variables or functional form misspecification. The LM test compares the residuals from the augmented regression with the residuals from the original regression to evaluate whether the additional variables or transformations significantly improve the model fit (Hothorn et al., 2015).

The LM test statistic is calculated as follows:

$$LM = n * R^2\_augmented$$

Where n is the sample size, and R^2_augmented is the coefficient of determination (R-squared) from the augmented regression. The LM test statistic follows a chi-square distribution with degrees of freedom equal to the number of additional variables or transformations included in the augmented regression.

If the LM test statistic is statistically significant, it suggests that the additional variables or transformations have a significant impact on the model fit, indicating the presence of omitted variables or functional form misspecification. In such cases, it is recommended to include the relevant variables or adjust the functional form of the model to improve its accuracy.

The LM test is a valuable tool in econometric analysis as it helps identify potential model misspecification, enhancing the reliability of the regression results. By conducting the LM test, researchers can identify and address issues such as omitted variables, incorrect functional forms, or other sources of model misspecification. This contributes to more accurate and robust regression analysis, leading to more meaningful interpretations and reliable policy implications based on the estimated coefficients.

3.3.5 Heteroscedasticity Test

Heteroscedasticity refers to a situation in regression analysis where the variability of the error term (residuals) is not constant across all levels of the independent variables. Heteroscedasticity violates one of the key assumptions of classical linear regression, which assumes that the error term has a constant variance (homoscedasticity). To detect and address heteroscedasticity, researchers often employ a statistical test called the Heteroscedasticity Test.

The principal formula used in the Heteroscedasticity Test is the White test, also known as the White's heteroscedasticity-consistent covariance matrix estimator. The White test calculates the residuals squared and regresses them against the independent variables included in the original regression model. The test examines whether there is a significant relationship between the squared residuals and the independent variables, indicating the presence of heteroscedasticity.

The White test statistic is calculated as follows:

$$\text{White} = n * R^2$$

where n is the sample size, and R^2 is the coefficient of determination (R-squared) from the regression of squared residuals on the independent variables. The White test statistic follows a chi-square distribution with degrees of freedom equal to the number of independent variables.

If the White test statistic is statistically significant, it suggests the presence of heteroscedasticity in the regression model. In such cases, it is necessary to address heteroscedasticity to obtain unbiased and efficient parameter estimates. There are several methods to handle heteroscedasticity, such as transforming variables, using weighted least squares estimation, or employing heteroscedasticity-consistent standard errors.

Detecting and addressing heteroscedasticity is crucial in regression analysis because failing to account for it can lead to inefficient and biased parameter estimates. Heteroscedasticity affects the accuracy of hypothesis tests, confidence intervals, and statistical inferences based on regression results. By conducting the Heteroscedasticity Test and implementing appropriate corrective measures, researchers can enhance the reliability and validity of their regression analysis, ensuring robust and accurate findings.

3.3.6 Multicollinearity Test

Multicollinearity refers to a situation in regression analysis where two or more independent variables in a model are highly correlated with each other. It poses a challenge because it can lead to unreliable and unstable coefficient estimates, making it difficult to interpret the effects of individual variables on the dependent variable. To detect and address multicollinearity, researchers often employ statistical tests called Multicollinearity Tests.

One commonly used multicollinearity test is the Variance Inflation Factor (VIF). The VIF measures the extent to which the variance of the estimated regression coefficient is increased due to multicollinearity. The formula for calculating the VIF for each independent variable is as follows:

$$VIF_i = 1 / (1 - R_i^2)$$

where VIF_i represents the VIF for the i-th independent variable, and R_i^2 is the coefficient of determination (R-squared) from regressing the i-th independent variable on all other independent variables in the model. The VIF quantifies how much the variance of the estimated coefficient of an independent variable is inflated due to multicollinearity. Generally, a VIF value greater than 1 indicates the presence of multicollinearity, with higher values indicating more severe multicollinearity.

Researchers typically consider a VIF threshold of 5 or 10 as a rule of thumb. If the VIF for an independent variable exceeds the threshold, it suggests that multicollinearity may be a concern. In such cases, it is necessary to address multicollinearity to obtain reliable coefficient estimates. Common approaches to dealing with multicollinearity include dropping highly correlated variables, combining variables, or using techniques such as principal component analysis or ridge regression.

Detecting and addressing multicollinearity is essential to ensure the accuracy and validity of regression analysis. Multicollinearity can lead to inflated standard errors, reduced statistical power, and misleading interpretations of the relationships between variables. By conducting multicollinearity tests, researchers can identify problematic variables and take appropriate steps to mitigate the effects of multicollinearity, improving the robustness and reliability of their regression models

3.3.7 Granger Causality Test

The Granger causality test is a statistical method used to assess the causal relationship between two time series variables. It is widely employed in various fields, including economics, finance, and social sciences, to investigate the direction and strength of causality between variables. The test was developed by Nobel laureate Clive Granger and is based on the notion that if variable X "Granger causes" variable Y, then the past values of X should provide significant information for predicting the future values of Y beyond what can be predicted using only the past values of Y.

The principal formula used in the Granger causality test is derived from autoregressive models. Let's consider two variables, X and Y, and assume that we have time series data for both variables. The general formula for the Granger causality test is as follows:

$$Y(t) = a + b1 * Y(t-1) + ... + bn * Y(t-p) + c1 * X(t-1) + ... + cm * X(t-q) + e(t)$$

The null hypothesis of the Granger causality test is that X does not Granger cause Y. In other words, the coefficients c1, ..., cm are jointly equal to zero. The alternative hypothesis is that X does Granger cause Y, indicating that at least one of the coefficients is statistically significant.

To conduct the Granger causality test, several steps are involved. First, we estimate the above equation using a suitable method, such as ordinary least squares (OLS). Next, we assess the statistical significance of the coefficients c1, ..., cm using appropriate hypothesis tests, such as the t-test or F-test. If the coefficients are statistically significant, we reject the null hypothesis and conclude that there is evidence of Granger causality from X to Y.

It is important to note that the Granger causality test does not establish causality in a strict sense, but rather suggests the presence of a predictive relationship between variables. Therefore, the results should be interpreted cautiously and in conjunction with other evidence and theoretical considerations.

CHAPTER 4. RESEARCH FINDINGS

4.1 Introduction to Carbon Emission Intensity in ASEAN

4.1.1 Definition and Significance of Carbon Emission Intensity

Carbon emission intensity is a measure of the amount of carbon dioxide (CO2) or other greenhouse gases emitted per unit of activity, such as generating a product, producing electricity, or gross domestic product (GDP). Carbon intensity is measured in units of CO2 equivalents per unit of activity, such as grams of CO2 released per megajoule of energy produced or CO2 produced per dollar of GDP. Emission intensities are used to derive estimates of air pollutant or greenhouse gas emissions based on the amount of fuel combusted, the number of animals in animal husbandry, on industrial production levels, distances travelled, or similar activity data.

Carbon intensity is a measure of how clean our electricity is, and it refers to how many grams of CO2 are released to produce a kilowatt hour of electricity. Carbon intensity-based metrics provide an indication of efficiency, and they can play an important role in transitioning to more efficient processes, identifying key drivers for decarbonization, and be adopted by more entities. Carbon intensity is an important metric for high-growth entities, and it enables new improvement pathways by identifying more efficient processes or making the necessary changes and upgrades to existing processes to reduce their intensity.

Reducing carbon emissions is important, but tackling carbon intensity might be even more important as it can help us to eliminate greenhouse gases from our atmosphere and save us money on our energy bills. By being aware of the carbon intensity of the electricity we use, we can make decisions around our energy use that can help us to play a role in fighting climate change.

4.1.1.1 Brief Overview of ASEAN and its Relevance in the Context of Carbon Emissions

The Association of Southeast Asian Nations (ASEAN) is a regional intergovernmental organization comprising 10 member states. ASEAN was established in 1967 by Indonesia, Malaysia, the Philippines, Singapore, and

Thailand, and later joined by Brunei, Cambodia, Lao People's Democratic Republic, Myanmar, and Vietnam. ASEAN is the fifth-largest economy in the world with a combined GDP of US31.6 billion if considered as one economy. ASEAN aims to promote economic and security cooperation among its ten members. ASEAN has a population of more than 600 million and covers a total area of 1.7 million square miles. ASEAN is involved in numerous international affairs and hosts diplomatic missions throughout the world. The relevance of ASEAN in the context of carbon emissions is that the region's recent rapid industrialization and economic growth have led to a significant contribution to global greenhouse gas emissions. It is important to monitor and examine the role of ASEAN in climate change mitigation.

ASEAN has recognized the importance of addressing climate change and reducing carbon emissions. ASEAN has issued a joint statement on climate change to COP-15 and CMP-5, which highlights the need to reduce fuel consumption and greenhouse gas emissions through higher efficiency and cleaner energy sources. ASEAN has pledged to reduce emissions by 11% by 2030 relative to its current trajectory to meet the Paris pledges.

The ASEAN Climate Change and Energy Project (ACCEPT) aims to reduce total energy consumption by 63% and greenhouse gas emissions by 27% by 2030. ASEAN has recognized the need to move towards cleaner energy sources and reduce reliance on coal and oil, which are major contributors to greenhouse gas emissions.

ASEAN nations can achieve carbon reduction targets by implementing environmentally extended multi-regional input-output optimization models. The role of ASEAN in climate change mitigation should be monitored and examined due to the region's recent rapid industrialization and economic growth.

4.1.2 Carbon Emission Intensity Trends in ASEAN

4.1.2.1 Analysis of Historical Trends in Carbon Emission Intensity in ASEAN Countries

The analysis of historical trends in carbon emission intensity in ASEAN countries is a complex issue that requires a comprehensive approach. The carbon intensity of electricity production in ASEAN is high, and the aggregate emission intensity (ACI) is a key indicator used to study CO2 emissions in the electricity production sector. Population growth and increased income per capita are the main drivers of emission growth in ASEAN, and fossil fuels are the primary source of CO2 emissions.

Decomposition analysis is used to analyze the underlying factors that drive emissions growth in ASEAN, and this analysis has shown that population growth and economic activity are the main drivers of emissions growth. The carbon emissions were increasing in some countries and also decreasing in some countries ASEAN countries since 1990 with respect to economic growth of the countries.

Singapore has shown a decreasing trend in carbon emissions from 1990 to 2018, while Myanmar has shown an increasing trend in carbon emissions over the same period. ASEAN countries have a plan to reduce global carbon emissions and global warming through energy consumption control programs.

Under the unconditional pledges, the ASEAN region faces an emissions gap of around 400 MtCO2e, which indicates that the ASEAN region have to reduce emissions by 11% by 2030 relative to its current trajectory. Fossil fuels are the primary source of CO2 emissions in ASEAN countries, and China's economic growth has contributed to the increase in fossil-fuel emissions in the region.

4.1.2.2 Identification of High and Low Carbon Intensity Sectors and Activities

The identification of high and low carbon intensity sectors and activities in ASEAN is crucial for effectively addressing and reducing carbon emissions. Among the high carbon intensity sectors in the region, the electricity production sector stands out. The aggregate emission intensity (ACI) serves as a significant indicator to examine and understand CO2 emissions within this sector. This highlights the need for targeted measures and interventions to lower carbon emissions associated with electricity generation.

Fossil fuels play a dominant role as the primary source of CO2 emissions in ASEAN countries. To address this challenge, the adoption of high efficiency, low emission (HELE) coal plants present a potential solution for reducing carbon emissions. By leveraging advanced technologies, these plants can mitigate the environmental impact associated with coal-fired power generation.

The increasing energy demand in Southeast Asia is another contributing factor to rising carbon emissions. Over the past two decades, energy demand in the region has experienced an average annual growth of approximately 3%. Fossil fuels currently meet the majority of this energy demand, accounting for three-quarters of the projected increase in energy consumption by 2030. As a consequence, this reliance on fossil fuels is anticipated to lead to a near 35% surge in CO2 emissions.

Low carbon intensity sectors and activities encompass various strategies and findings related to reducing carbon emissions. Firstly, decarbonization roadmaps for ASEAN countries have highlighted the importance of transitioning to renewable energy sources and enhancing energy efficiency. These measures aim to mitigate carbon emissions by minimizing reliance on fossil fuels and optimizing energy consumption.

Examining specific countries, Singapore has demonstrated a decreasing trend in carbon emissions from 1990 to 2018. This indicates successful efforts in curbing emissions through various initiatives, such as adopting cleaner technologies and implementing energy-saving measures. On the other hand, Myanmar has experienced an increasing trend in carbon emissions during the same period, suggesting the need for targeted interventions to address the factors contributing to this rise.

Decomposition analysis, which dissects the drivers of emissions growth, has identified population growth and increased income per capita as significant contributors to emissions growth in ASEAN. These findings underscore the importance of addressing population dynamics and economic development alongside climate action. Furthermore, policies that encourage the efficient utilization of energy resources have been recognized as effective in reducing carbon emissions.

4.1.2.3 Comparison of Carbon Emission Intensity Levels across ASEAN Countries

Carbon emission intensity levels vary across ASEAN countries. Carbon emissions were increasing in some countries and decreasing in others ASEAN countries from 1990 to 2018 with respect to economic growth of the countries. Singapore showed a decreasing trend in carbon emissions over this period, while Myanmar showed an increasing trend.

The electricity production sector in ASEAN has a high carbon intensity, and the aggregate emission intensity (ACI) is a key indicator used to study CO2 emissions in this sector. The ACI varies across ASEAN countries, with Indonesia, Vietnam, Thailand, Malaysia, and the Philippines being the highest CO2 emitters in 2019. A comparison methodology between ASEAN countries in the emission intensity and energy intensity in the future projection of electricity shows that the emission intensity varies across ASEAN countries, with Indonesia, Vietnam, and the Philippines having the highest emission intensity.

Decomposition analysis has shown that population growth and increased income per capita have the largest contribution to emission growth in ASEAN, and fossil fuels are the primary source of CO2 emissions. The contribution of population growth and increased income per capita to emission growth varies across ASEAN countries. The options for reducing GHG emissions in ASEAN countries vary by their capital-intensity, maturity, and scale.

4.1.3 Factors Influencing Carbon Emission Intensity in ASEAN

4.1.3.1 Economic Factors: GDP Growth, Industrialization, and Consumption Patterns

Economic factors such as GDP growth, industrialization, and consumption patterns are closely related to carbon emission intensity in ASEAN. Economic growth, globalization, and financial development are factors that contribute to increased energy consumption and carbon emissions in ASEAN countries. Policies that promote efficient use of energy resources can help to reduce carbon emissions.

The electricity production sector in ASEAN has a high carbon intensity, and the use of natural gas, which has a lower carbon intensity than coal, can help to reduce carbon emissions. Population growth and increased income per capita are the main drivers of emission growth in ASEAN, and GDP per capita is the most crucial factor in increasing CO_2 emissions in the region. Decomposition analysis has shown that population growth and increased income per capita have the largest contribution to emission growth.

The carbon intensity of electricity production in ASEAN varies across countries, and the aggregate emission intensity (ACI) is a key indicator used to study CO_2 emissions in this sector. The ACI varies across ASEAN countries, with Indonesia, Vietnam, Thailand, Malaysia, and the Philippines being the highest CO_2 emitters in 2019. Southeast Asia is witnessing the world's biggest jump in greenhouse gas emissions, and the region's growing reliance on coal and oil, along with deforestation, are undermining national pledges to curb emissions and embrace cleaner energy sources. Southeast Asian governments have pledged to reduce emissions and recognize the need to move towards cleaner energy sources.

4.1.3.2 Energy Sector: Energy Sources, Energy Efficiency, and Renewable Energy Adoption

Energy sector plays a crucial role in determining carbon emission intensity in ASEAN. In terms of energy sources, the electricity production sector in ASEAN has a high carbon intensity, and the use of natural gas, which has a lower carbon intensity than coal, can help to reduce carbon emissions. Fossil fuels are the primary source of CO_2 emissions in ASEAN countries, and the consumption of energy has been increasing in the region. Three-quarters of the increase in energy demand to 2030 in the STEPS is met by fossil fuels, leading to a near 35% increase in CO_2 emissions.

With regard to energy efficiency, policies that promote efficient use of energy resources can help to reduce carbon emissions in ASEAN countries. Energy access has been improving in Southeast Asia in recent years, and almost all households have electricity. However, clean cooking solutions remain limited in some countries, and the recent surge in commodity prices threatens to set back progress. Regarding renewable energy adoption, Southeast Asia's energy transition depends primarily on the rollout of renewables. The use of renewable energy sources can help to reduce carbon emissions in ASEAN countries.

4.1.3.3 Transportation sector: Modes of transportation, vehicle efficiency, and infrastructure

The transportation sector is a significant contributor to carbon emission intensity in ASEAN. The transport sector is one of the important contributors to increasing energy consumption and CO2 emissions in ASEAN countries. Due to the rapid development of transport infrastructure and technologies, patterns of energy consumption in this sector, as well as emissions, have changed considerably. CO2 emissions from the transport sector represented 28.8% of total fossil fuel combustion in Malaysia, well above the global average of 24.5%. Emissions levels across all economic sectors have increased over the 2010-2017 period.

Vehicle efficiency is an important factor in reducing carbon emissions in the transportation sector. Improving fuel efficiency and using cleaner fuels can help to reduce carbon emissions. Infrastructure development can impact carbon emissions in the transportation sector. Developing public transportation systems and promoting active transportation such as walking and cycling can help to reduce carbon emissions. The impact of infrastructure on carbon emissions in the transportation sector can be analyzed using factors such as GDP, energy intensity, carbon intensity, urbanization, population, and energy intensity of transport.

4.1.3.4 Industrial Processes: Emission Control Technologies and Practices

Industrial processes are a significant contributor to carbon emission intensity in ASEAN. The electricity production sector in ASEAN has a high carbon intensity, and the use of emission control technologies such as carbon capture and storage (CCS) can help to reduce carbon emissions. The ASEAN Joint Statement on Climate Change aims to reduce fuel consumption and greenhouse gas emissions through higher energy efficiency and the use of cleaner fuels.

Affluence or GDP per capita is the most crucial factor in increasing CO2 emissions in ASEAN, and population growth and increased income per capita have the largest contribution to emission growth. Anthropogenic emissions have increased substantially over the last decade in ASEAN, and understanding the major contributing emission sectors and their influence on total anthropogenic emissions can help local governments make policy decisions focusing on regional emission control and future air quality management. Further reduction of carbon emissions in ASEAN countries can be achieved through the implementation of carbon emission reduction goals.

4.1.4 Policy Framework for Reducing Carbon Emission Intensity in ASEAN

4.1.4.1 Overview of National and Regional Policies related to Carbon Emissions

National and regional policies related to carbon emissions in ASEAN are crucial in reducing carbon emission intensity in the region. Carbon pricing through taxes or cap-and-trade systems is one of the policy options to reduce the emissions gap in ASEAN. ASEAN countries have a plan to reduce global carbon emissions and global warming through energy consumption control programs. Providing a comprehensive historic emission scenario for ASEAN can be crucial to understanding better the regional emission trend, significant sources of emission growth, major contributing emission sectors, and its influence on total Asian anthropogenic emissions. This information can provide local governments of ASEAN useful insights into policy decisions focusing on regional emission control and future air quality management to comply with the international agreement on GHG emission mitigation and climate action plan.

The ASEAN Joint Statement on Climate Change aims to reduce fuel consumption and greenhouse gas emissions through higher energy efficiency and the use of cleaner fuels. Decarbonization roadmaps for ASEAN can help to reduce carbon emissions in the region. Indonesia, Vietnam, Thailand, Malaysia, and the Philippines were the highest CO2 emitters in 2019. Population growth and increased income per capita have the largest contribution to emission growth in ASEAN, and fossil fuels are the primary source of CO2 emissions in the region. Policies that promote efficient use of energy resources can help to reduce carbon emissions.

4.1.4.2 Assessment of Policy Effectiveness in Driving Emission Reduction Measures

Assessing the effectiveness of policies in driving emission reduction measures in ASEAN is crucial in achieving the goal of reducing carbon emission intensity in the region. ASEAN countries have a plan to reduce global carbon emissions and global warming through energy consumption control programs.

The ASEAN Joint Statement on Climate Change aims to reduce fuel consumption and greenhouse gas emissions through higher energy efficiency. A switch from coal to natural gas promotes lower-carbon power generation in ASEAN. Anthropogenic emissions have increased substantially over the last decade in ASEAN, and providing a comprehensive historic emission scenario for the region can help local governments make policy decisions focusing on regional emission control and future air quality management to comply with international agreements on GHG emission mitigation and climate action plan. Decarbonization roadmaps for ASEAN can help to reduce carbon emissions in the region. Indonesia, Vietnam, Thailand, Malaysia, and the Philippines were the highest CO2 emitters in 2019.

4.1.4.3 International Agreements and Commitments Influencing ASEAN's Emission Reduction Efforts

All 10 countries that make up ASEAN signed the Paris Agreement, which aims to limit global warming to well below 2 degrees Celsius above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5 degrees Celsius. The agreement requires countries to submit nationally determined contributions (NDCs) outlining their emission reduction targets and strategies.

ASEAN countries have pledged to reduce emissions and move toward cleaner energy sources in response to the threat of climate change. Providing a comprehensive historic emission scenario for ASEAN can help local governments make policy decisions focusing on regional emission control and future air quality management to comply with international agreements on GHG emission mitigation and climate action plan, such as COP21 and COP26.

The ASEAN Joint Statement on Climate Change aims to reduce fuel consumption and greenhouse gas emissions through higher energy efficiency. Other countries, such as South Africa and Brazil, have plans to mitigate CO2 emissions, which can influence ASEAN's emission reduction efforts.

4.1.5 Technological Solutions and Innovations for Carbon Emission Intensity Reduction

4.1.5.1 Clean Energy Technologies

Clean energy technologies such as renewable energy, energy storage, and grid integration are crucial in reducing carbon emission intensity in ASEAN. ASEAN countries have agreed collectively to generate at least 23% of their electricity from renewable sources by 2025. Hydropower has been the region's main source of renewable energy for decades, whereas solar and wind power have been underutilized. The ASEAN Renewable Energy Outlook details a comprehensive pathway for the development of a sustainable and cleaner regional energy system for ASEAN.

Energy storage technologies such as batteries and pumped hydro storage can help to integrate renewable energy into the grid and provide flexibility to the power system. Grid integration is crucial in ensuring the stability and reliability of the power system when integrating renewable energy sources. The ASEAN countries face the challenge of reducing GHG emissions while at the same time expanding energy supply to meet the needs of their growing economies. Grid integration can help to achieve this goal.

4.1.5.2 Sustainable Transportation Solutions

Sustainable transportation solutions such as electric vehicles, public transportation systems, and infrastructure development are crucial in reducing carbon emission intensity in ASEAN. Digital technology, electric vehicles, and green hydrogen are part of a suite of solutions for "greening" city transport in the region. The future of sustainable transportation in ASEAN focus on electric vehicles. Sustainable urban transport solutions are crucial to mitigate the growing congestion and pollution in the region's sprawling urban centers. For every US$1 billion spent on public transportation in the city, 50,000 jobs are created.

The proposed ASEAN Sustainable Freight Strategy 2030 is a fit-for-purpose and future-proof freight strategy that position ASEAN as a leader in sustainable freight transport. The new program focuses on capacity building of developing countries, in particular least developed, landlocked developing, and small island developing states, to enhance sustainable transport connectivity in Asia and the Pacific.

4.1.5.3 Green Industrial Practices

Green industrial practices such as energy-efficient processes, carbon capture, and utilization technologies are crucial in reducing carbon emission intensity in ASEAN. Clean energy investments include improvements in energy efficiency, which can help to reduce carbon emissions in industrial processes. The ASEAN Renewable Energy Outlook details a comprehensive pathway for the development of a sustainable and cleaner regional energy system for ASEAN, which includes energy-efficient processes.

Carbon intensity of electricity in ASEAN is high, and the aggregate emission intensity (ACI) is given by the carbon intensity of electricity generation and the share of electricity in the final energy consumption. Carbon capture and utilization technologies can help to reduce carbon emissions in industrial processes and power generation.

4.1.6 Challenges and Opportunities in Reducing Carbon Emission Intensity in ASEAN

4.1.6.1 Socio-Economic Challenges

Reducing carbon emission intensity in ASEAN is a complex challenge that involves socio-economic factors such as economic growth, poverty alleviation, and energy access. Economic growth is one of the main drivers of carbon emissions in ASEAN. ASEAN countries have a plan to reduce global carbon emissions and global warming through energy consumption control programs, while Southeast Asian governments have pledged to reduce emissions and move toward cleaner energy sources. Meanwhile, poverty alleviation is a crucial challenge in ASEAN, and it is closely linked to energy access and consumption. Expanding energy access to the poor in a sustainable and affordable manner is crucial in reducing carbon emission intensity in ASEAN.

Expanding energy access to the poor in a sustainable and affordable manner is crucial in reducing carbon emission intensity in ASEAN. While the ASEAN countries face the challenge of reducing GHG emissions while at the same time expanding energy supply to meet the needs of their growing economies, Decarbonization roadmaps for ASEAN can help to identify the highest CO2 emitters and develop strategies to reduce emissions.

4.1.6.2 Technological Barriers and Capacity Building Needs

Reducing carbon emission intensity in ASEAN requires overcoming technological barriers and building capacity to implement sustainable solutions. The region's growing reliance on coal and oil, along with deforestation, are undermining national pledges to curb emissions and embrace cleaner energy sources. Population growth and increased income per capita have the largest contribution to emission growth, and fossil fuels remain the primary source of energy in ASEAN. Not only developing policies regarding efficient use of energy resource, but also providing access to clean energy sources such as renewable energy is crucial in reducing carbon emissions and improving energy access in ASEAN. The ASEAN Renewable Energy Outlook provides a comprehensive pathway for the development of a sustainable and cleaner regional energy system for ASEAN, and planning must begin in earnest to achieve ambitious renewable energy goals in the near-term.

4.1.6.3 Financing and Investment Opportunities for Low-Carbon Projects

Reducing carbon emission intensity in ASEAN necessitates access to financing and investment opportunities that support low-carbon projects. The Sustainable Finance Advice for the ASEAN Low Carbon Energy Program is designed to assist ASEAN countries in harnessing sustainable development opportunities stemming from the adoption of low-carbon energy solutions. Furthermore, the Deep Dive Workshop on Green Finance for Cleaner Energy in Southeast Asia, organized by the UK Government and its ASEAN Low Carbon Energy initiative, aims to facilitate knowledge-sharing on financing strategies for investments in low-carbon energy projects.

Recognizing the importance of private investment, it is crucial for ASEAN countries to attract private capital to drive the transition from existing energy systems to low-carbon alternatives. In order to establish a sustainable and cleaner regional energy system for ASEAN, it is imperative to embrace the comprehensive pathway outlined in the ASEAN Renewable Energy Outlook, while initiating prompt planning efforts to achieve ambitious renewable energy targets in the near future. According to the International Energy Agency's Sustainable Development Scenario, meeting climate goals in Southeast Asia necessitates an annual investment of approximately $180 billion in clean energy projects.

4.1.6.4 Cross-border Collaboration and Knowledge Sharing within ASEAN

Cross-border collaboration and knowledge sharing play a crucial role in the efforts to reduce carbon emission intensity within ASEAN. The commitment of all 10 ASEAN countries to the Paris Agreement highlights their shared dedication to emissions reduction and sustainable development. Collaborative initiatives such as the ASEAN Renewable Energy Outlook, developed in partnership with the ASEAN Center for Energy and the ASEAN Renewable Energy Sub-Sector Network, provide a comprehensive framework for fostering a sustainable and cleaner regional energy system. Additionally, the Review of Decadal Changes in ASEAN Emissions, which utilizes regional and global emission inventory datasets, offers valuable insights to local governments in ASEAN for informed policy decisions related to emission control and air quality management.

Knowledge sharing platforms like the Deep Dive Workshop on Green Finance for Cleaner Energy in Southeast Asia, organized by the UK Government and its ASEAN Low Carbon Energy initiative, facilitate the exchange of expertise on financing strategies for low-carbon energy investments. Given the challenge of reducing greenhouse gas emissions while meeting the growing energy demands of their economies, cross-border collaboration and knowledge sharing emerge as essential mechanisms for achieving sustainable and effective emissions reduction in ASEAN.

4.1.7 Case Studies of Carbon Emission Intensity Reduction in ASEAN

4.1.7.1 Highlighted Successful Initiatives and Projects in Specific ASEAN Countries

Several successful initiatives and projects in specific ASEAN countries have played a significant role in reducing carbon emission intensity in the region. Singapore, for instance, has demonstrated a decreasing trend in carbon emissions over the years, showcasing a notable reduction from 18.79% to 10.54% between 1990 and 2018. The Review of Decadal Changes in ASEAN Emissions, which utilizes regional and global emission inventory datasets, provides valuable insights to local governments in ASEAN for informed policy decisions related to emission control and air quality management. It is worth noting that all 10 ASEAN countries have signed the Paris Agreement and made commitments to reduce emissions. Among ASEAN countries, Indonesia, Vietnam, Thailand, Malaysia, and the Philippines emerge as the highest CO2 emitters, collectively emitting 1.76 Gt of energy-related CO2 in 2019.

Furthermore, collaborative efforts such as the ASEAN Renewable Energy Outlook, developed in partnership with the ASEAN Center for Energy (ACE) and the ASEAN Renewable Energy Sub-Sector Network, offer a comprehensive pathway for the development of a sustainable and cleaner regional energy system in ASEAN. These successful initiatives and projects highlight the progress made by specific ASEAN countries in reducing carbon emission intensity and contribute to the overall sustainability goals of the region.

4.1.7.2 Analysis of The Strategies, Policies, and Outcomes of These Initiatives

The strategies, policies, and outcomes of initiatives to reduce carbon emission intensity in ASEAN encompass a range of approaches. One option involves implementing policies and utilizing technologies that promote the use of natural gas, which has a lower carbon intensity compared to coal. Another avenue is making investments in renewable energy sources, which offer cleaner alternatives to traditional fossil fuels. ASEAN countries have formulated plans and programs aimed at controlling energy consumption and reducing global carbon emissions and the effects of global warming. The Review of Decadal Changes in ASEAN Emissions, which relies on regional and global emission inventory datasets, provides valuable insights for local governments in ASEAN to make informed policy decisions in the realm of regional emission control and future air quality management.

These efforts contribute to meeting the goals set forth in international agreements pertaining to greenhouse gas emission mitigation and climate action. All 10 ASEAN member countries have signed the Paris Agreement and made commitments to reduce emissions, demonstrating their recognition of the need to transition to cleaner energy sources and contribute to global emission reduction efforts. The ASEAN Renewable Energy Outlook serves as a comprehensive guide for the development of a sustainable and cleaner regional energy system within ASEAN.

Developed in collaboration with the ASEAN Centre for Energy (ACE) and the ASEAN Renewable Energy Sub-Sector Network, it draws guidance from IRENA's World Energy Transitions Outlook. These strategies, policies, and outcomes collectively contribute to the ongoing efforts in ASEAN to reduce carbon emission intensity and promote sustainable energy systems.

4.1.7.3 Lessons Learned and Best Practices for Replication in Other ASEAN Countries

Lessons learned and best practices for reducing carbon emission intensity in ASEAN can serve as valuable guidance for replication in other countries within the region. When tailoring emission reduction policies, it is essential to take into account the specific local conditions, while also drawing insights from successful approaches implemented in other regions. The Review of Decadal Changes in ASEAN Emissions, based on regional and global emission inventory datasets, offers valuable insights for policy decisions focused on regional emission control and future air quality management, aligning with international agreements on greenhouse gas emission mitigation and climate action. ASEAN countries have devised plans that incorporate energy consumption control programs as part of their efforts to reduce global carbon emissions and combat global warming.

All 10 ASEAN member countries have demonstrated their commitment to emission reduction by signing the Paris Agreement and pledging to reduce emissions. This commitment highlights the recognition among Southeast Asian governments of the necessity to transition towards cleaner energy sources. Decarbonization roadmaps specific to ASEAN provide comprehensive pathways for the development of sustainable and cleaner regional energy systems, serving as valuable references for other ASEAN countries. The growth in population and income per capita has been identified as the primary drivers of emission growth, with fossil fuels remaining the main source of CO_2 emissions. By considering these lessons learned and implementing best practices, ASEAN countries can work towards reducing carbon emission intensity and achieving sustainable and cleaner energy systems.

4.2 Findings of the Model

The study employs a multiple regression analysis framework, utilizing the method of PLS regression estimation, to examine and evaluate the hypotheses. The developed model aims to assess the simultaneous impact of various categories of independent variables, namely economic development, social development, and technological development, on the carbon emission intensity within the ASEAN region.

4.2.1 Model Description

The carbon emission intensity rate (CEI) is designated as the dependent variable in the model. α (alpha) represents the intercept term or constant value of the carbon emission intensity (CEI) when all independent variables are equal to zero. It captures the baseline level of CEI that is not influenced by the other variables in the model. $\beta 1$ until $\beta 6$ (beta coefficients) quantify the impact or influence of each independent variable (GDP, FDI, INF, GINI, HDI, TED) on the carbon emission intensity (CEI). They indicate the expected change in CEI associated with a one-unit change in each respective independent variable, holding other variables constant. These coefficients provide insights into the strength and direction of the relationships between the independent variables and CEI. ε (epsilon) represents the error term or residual, which accounts for all unexplained variation in the model. It captures the discrepancy between the observed CEI and the predicted CEI based on the independent variables. The error term captures the influence of other factors or random effects that are not accounted for by the independent variables in the model.

This model allows for an intricate examination of the intricate interrelationships between economic, social, and technological development factors and carbon emission intensity.

$$CEI = \alpha + \beta 1(GDP) + \beta 2(FDI) + \beta 3(INF) + \beta 4(GINI) + \beta 5(HDI) + \beta 6\ (TED) + \varepsilon \qquad (1)$$

The model assumes a linear relationship between the dependent variable, carbon emission intensity (CEI), and the independent variables: GDP, FDI, INF, GINI, HDI, and TED. The coefficients (β1, β2, β3, β4, β5, and β6) represent the expected change in CEI associated with a one-unit change in each respective independent variable, holding other variables constant.

The inclusion of GDP in the model is justified by the notion that economic development and growth often lead to increased industrial activities and energy consumption, which can impact carbon emissions. FDI is considered as it reflects foreign investment flows that can influence industrial activities and technologies adopted, potentially affecting carbon emission levels. The inclusion of INF, or inflation rate, recognizes its potential influence on economic decisions and resource allocation, which can indirectly impact carbon emissions.

GINI, representing income inequality, is included because greater inequality may lead to disparities in access to resources and opportunities, affecting carbon emission patterns. HDI, as a measure of social development, is included because it encompasses various indicators related to education, health, and standard of living, which can influence environmental behaviors. TED, capturing technological development, is considered because advancements in technology can lead to more efficient production processes, cleaner energy sources, and reduced carbon emissions.

4.2.2 Determining the Model of Panel Data Regression

This study deploys Panel Data regression as the econometric model since the data, which are taken in annual form from a decade after 2010, are observed to explore the relationships between the dependent variable and independent variables, while also accounting for the temporal dependence of the data. Table 4.1 displays the descriptive statistic and since it was shock-resistant, converting all variables to logarithmic form to standardize the data distribution was not imposing.

TABLE 4. 1 DESCRIPTIVE STATISTICS

	CEI	FDI	GDP	INF	TED	HDI	GINI
Mean	0.500	0.729	1.174	1.617	3396.681	160.647	9.751
Median	0.522	0.707	1.211	1.020	1642.000	169.750	9.825
Maximum	0.678	1.359	2.308	10.576	13713.000	198.000	11.875
Minimum	0.148	0.128	0.048	0.044	14.250	12.750	5.673
Standard Dev.	0.158	0.336	0.480	2.009	4448.601	43.414	1.324

Source: Author's estimation

Since it is a panel data, it is imperative to determine which models estimation from common effect model (CEM), fixed effect model (FEM) and random effect model (REM) that can generate more accurate outputs. After regressing the data by applying those three estimation types, we do the Chow test. The Chow test is used to test for the presence of structural breaks in a regression model. In this case, the Chow test is applied to compare the fixed effects (FE) model with the common effects model. Based on the extremely low p-values for both statistics ($p = 0.0000$), we can conclude that there is strong evidence against the null hypothesis of no structural break. This suggests that there are significant differences in the coefficients across different cross-sections.

Considering the results of the Chow test, the fixed effects (FE) model should be selected over the common effects model. The fixed effects model allows for individual-specific effects by including fixed effects for each cross-section. These fixed effects account for unobserved heterogeneity across different cross-sections and capture the time-invariant characteristics of the individual units.

The significant cross-section F statistic and Chi-square statistic indicate that the fixed effects model provides a better fit to the data compared to the common effects model, which assumes a common coefficient across all cross-sections. The presence of significant differences among cross-sections suggests that the fixed effects model captures important variations in the data that are not accounted for by the common effects model.

After that, we do Hausman test which is used to compare the consistency and efficiency of the estimators in the random effects (RE) model and the fixed effects (FE) model. The test examines whether the random effects are correlated with the regressors, which helps determine whether the random effects assumption is valid.

The extremely low p-value (p = 0.0000) indicates that there is strong evidence against the null hypothesis that the random effects are uncorrelated with the regressors. This suggests that the random effects assumption is violated, and the random effects model may not be appropriate for the data.

Since the Hausman test indicates a violation of the random effects assumption, the fixed effects model is preferred. The correlated random effects suggest that there are unobserved individual-specific factors that are systematically related to the regressors. By using the fixed effects model, we can control for these unobserved factors and obtain consistent and efficient estimates

Based on the Hausman test results, the fixed effects (FE) model should be selected over the random effects (RE) model. The fixed effects model accounts for individual-specific effects by including fixed effects for each cross-section, capturing time-invariant characteristics of the individual units. On the other hand, the random effects model assumes that the random effects are uncorrelated with the regressors.

Further test done is The Laggrange Multiplier (LM) test for panel data that is used to assess whether the random effects assumption holds in the model. It tests for the presence of individual-specific heterogeneity, which indicates whether a random effects (RE) model or a common effects (CE) model is more appropriate.

The p-values are generally used to assess the statistical significance of the test. In this case, all of the p-values are very low, indicating strong evidence against the null hypothesis of no random effects. This suggests that there is significant individual-specific heterogeneity in the data.

Based on the LM test results, the random effects (RE) model is preferred over the common effects (CE) model. The significant LM statistics for both cross-section and period indicate the presence of individual-specific heterogeneity that is not captured by the common effects model.

The random effects model allows for individual-specific heterogeneity by assuming that the individual-specific effects are uncorrelated with the regressors. This heterogeneity is accounted for by the inclusion of random effects in the model, which captures the unobserved individual-specific factors. On the other hand, the common effects model assumes that there are no individual-specific effects, treating all observations as if they come from a common population.

Since the LM test provides strong evidence against the null hypothesis of no random effects, it suggests that the random effects model should be selected over the common effects model. The random effects model is better suited to capture the individual-specific heterogeneity in the data and provide more accurate estimates.

To sum up, considering the Chow test and Hausman test results where the fixed effects model is selected, while it is the random effects model that is chosen based on the LM test result, the author decides to pick fixed effects model as the estimation method.

The next step would be assumption testing and model fit. When using the fixed effects model for panel data estimation, there are certain assumption tests and model fit measures that can be used to assess the reliability and appropriateness of the model.

4.2.3 Testing the Reliability and Appropriateness of the Model

There are two tests of diagnostic conducted on the model to validate it: Heteroskedasticity test and Multicollinearity test. The Panel Cross-section Heteroskedasticity LR Test is conducted to examine whether the residuals in the regression model exhibit heteroskedasticity, meaning that the variance of the residuals varies across different levels of the independent variables. The null hypothesis for this test is that the residuals are homoscedastic, indicating constant variance.

In the given test result, the likelihood ratio statistic is 316.1005, which is compared against the chi-square distribution with degrees of freedom equal to the number of restrictions being tested. In this case, there are 10 restrictions being tested.

The probability associated with the test is reported as 2.35261, which is more than the significance level of 0.05. Therefore, we accept the null hypothesis that the residuals are homoscedastic. Based on this result, we can conclude that there is no evidence of heteroskedasticity in the regression model. This suggests that the variance of the residuals is constant across different levels of the independent variables.

Second diagnostic test, Multicollinearity test examines the correlation between independent variables in a regression model. In this case, the correlation matrix shows the pairwise correlations between the variables FDI, GDP, INF, TED, HDI, and GINI. Based on the provided correlation matrix, there is no strong evidence of multicollinearity among the variables. The correlation coefficients range between -0.638 and 0.705, indicating relatively low to moderate correlations.

Multicollinearity becomes a concern when the correlation coefficients are close to 1 or -1, suggesting a high degree of linear association between the variables. However, in this case, the correlation coefficients are relatively small, indicating that there is no significant multicollinearity issue present. Establishing no evidence of heteroscedasticity and multicollinearity among the variables, the next stage is elaborating the findings over the regression model chosen.

The pairwise Granger causality tests were conducted to examine the causal relationships between the independent variables (FDI, GDP, GINI, HDI, INF, and TED) and the dependent variable (CEI). The results indicate that there is no significant evidence to suggest a causal relationship between CEI and any of the independent variables. Specifically, CEI does not cause changes in FDI, GDP, GINI, HDI, INF, or TED. Conversely, the independent variables do not cause significant changes in CEI either. These findings suggest that there is no significant mutual influence or causal effect between the variables examined.

4.3 Findings and Discussion

In the provided panel regression results (table 4.2), GDP, INF, and TED emerge as statistically significant drivers of ASEAN carbon emission intensity. Notably, a reduction in GDP, a surge in inflation rates (INF), and insufficient progress in technological advancements (TED) exhibit strong negative associations with carbon emission intensity. Conversely, the impact of FDI, HDI, and GINI on CEI is found to be statistically insignificant, failing to provide substantial evidence of their influence on carbon emissions in the ASEAN region.

The adjusted R-squared value is a statistical measure that adjusts the regular R-squared value to account for the number of variables in the model and the degrees of freedom. While the regular R-squared value represents the proportion of the dependent variable's variation explained by the independent variables, the adjusted R-squared takes into consideration the complexity of the model and the potential for overfitting. Table 4.2 displays the adjusted R-squared value in the FEM regression analysis which is 0.945996. This adjusted R-squared value indicates that approximately 94.60% of the variation in the dependent variable (CEI) can be explained by the independent variables included in the model, taking into account the complexity of the model and the degrees of freedom.

A high adjusted R-squared value suggests that the independent variables in the model have a strong explanatory power in relation to the dependent variable. In this case, around 94.60% of the variation in the CEI can be attributed to the variation in the independent variables (FDI, GDP, INF, HDI, GINI, TED). This implies that the chosen independent variables collectively have a substantial influence on the CEI.

TABLE 4. 2 FEM ESTIMATE RESULTS

	C	FDI	GDP	INF	TED	HDI	GINI
Coefficient	0.561	-0.004	-0.011	-0.004	-1.45E-05	-9.92E	-0.002
Probability	0.000	0.309	0.000	0.000	0.000	0.699	0.363
Adjusted R-squared		0.984	Prob (F-statistic)		0.000	N. observations	432

Source: Author’s estimation

4.3.1 FDI Impact on ASEAN CEI

Specifically, the coefficient for FDI (-0.002308) lacks statistical significance with a t-statistic of -0.477794 and a p-value of 0.6330. Consequently, it cannot be confidently asserted that FDI significantly impacts CEI in the ASEAN region. This is the opposite of what (Shao, 2018) finds that FDI significantly exacerbates carbon intensity in host countries, even after accounting for other influential factors such as fossil fuel share, industrial intensity, urbanization level, and trade openness. Furthermore, FDI also significantly amplifies carbon intensity in both high-income and middle- to low-income countries.

Comparatively, (Demena & Afesorgbor, 2019; Y. Hao & Liu, 2015) assume that the overall impact of FDI on per capita CO2 emissions is negative. Even though initially, the underlying impact of FDI on environmental emissions appears to be negligible. However, upon closer examination and considering the variations across different studies, it becomes evident that FDI has a significant and positive effect in reducing environmental emissions (Demena & Afesorgbor, 2019).

The enforcement and strictness of environmental regulations have a significant impact on how foreign direct investment (FDI) affects carbon emission intensity (CEI) in ASEAN countries. In cases where ASEAN countries have weak or poorly enforced environmental regulations, the potential positive effects of FDI on reducing carbon emissions may be limited (Rammal & Zurbruegg, 2006). This means that FDI may not bring about substantial changes in environmental practices within industries.

The level of economic development in ASEAN countries also plays a role in shaping the impact of FDI on CEI. According to the Environmental Kuznets Curve Theory, environmental degradation initially increases with economic growth but starts to decline after reaching a certain income level. In ASEAN countries that are still in the early stages of economic development, there may be a greater emphasis on prioritizing economic growth over environmental concerns (Wen et al., 2021). As a result, there might be limited efforts to reduce carbon emissions through FDI.

The effectiveness of technology transfer and innovation brought by FDI depends on the capabilities and absorptive capacity of ASEAN countries. If there are limitations in technology transfer or a lack of focus on environmentally friendly practices, the impact of FDI on CEI may be hindered. This means that for FDI to effectively contribute to reducing carbon emissions, (Haini, 2021)it is crucial for

ASEAN countries to have the capacity to absorb and implement advanced technologies and sustainable practices.

Additionally, public awareness and stakeholder engagement play a crucial role in driving environmental initiatives and sustainable practices. In ASEAN countries, the level of public awareness, involvement of civil society, and engagement with stakeholders can influence the pressure placed on FDI to adopt environmentally friendly practices (Safford et al., 2014; Sheng Yin & Hussain, 2021). Without strong public demand and engagement, the impact of FDI on reducing CEI may be limited. Therefore, fostering public awareness and encouraging active stakeholder engagement are essential for maximizing the positive environmental impact of FDI in ASEAN countries.

The insignificance of FDI on carbon emission intensity (CEI) in the ASEAN region can be explained by several theories. Firstly, the Environmental Kuznets Curve Theory suggests that the relationship between economic development and environmental degradation follows an inverted U-shaped curve. In the case of FDI in ASEAN, the level of economic development may not have reached the point where environmental improvements become a priority, thus limiting the impact on CEI.

The Porter Hypothesis highlights the potential positive effects of environmental regulations on innovation and environmental performance. However, in the absence of stringent regulations and enforcement, the impact of FDI on CEI may be limited. The Technological Innovation Theory emphasizes the importance of technology transfer in achieving environmental goals. If FDI fails to bring advanced technologies that reduce carbon emissions or if technology transfer is limited, the impact on CEI is minimal.

On the other hand, the Energy Efficiency Paradox Theory and Behavioral Economics Theory do not directly relate to the insignificance of FDI on CEI in ASEAN, as the discussion does not focus on energy efficiency improvements, rebound effects, or behavioral factors influencing CEI.

4.3.2 GDP Impact on ASEAN CEI

GDP, in the long term, exerts a robust negative influence on carbon emission intensity, as evidenced by its coefficient of -0.011874, accompanied by a significant t-statistic of -4.593715 (p-value: 0.0000). With an increase of one unit in GDP, the carbon emission intensity (CEI) decreases by 0.011874 units, as indicated by the negative coefficient. This suggests that an increase in GDP corresponds to a noticeable reduction in CEI, highlighting the crucial role of economic activity in carbon emissions.

In the context of the ASEAN region, an increase in GDP can potentially lead to a decrease in carbon emission intensity through several mechanisms. First and foremost, economic growth is often accompanied by technological advancements and increased investment in research and development (R&D) (C. Liu & Xia, 2018) . (Hafeez et al., 2022)states that hese innovations can drive the adoption of cleaner and more energy-efficient technologies in industries, thereby reducing their carbon footprint. For example, the implementation of renewable energy sources and improved energy efficiency measures can result in lower emissions per unit of output.

Moreover, as GDP grows, there is a tendency for economies to undergo a structural shift from energy-intensive industries to a more service-based economy (Atalla & Bean, 2017; Obadi & Korček, 2015). The services sector typically has a lower carbon intensity compared to manufacturing or heavy industries. Thus, the relative contribution of the services sector to the overall economy may increase with higher GDP, leading to a decline in carbon emissions.

Furthermore, according to (Israel, 2004; F. Li et al., 2022; X. Wang, 2011)economic growth provides governments with increased financial resources, enabling them to invest in environmental policies and regulations. These policies may include setting emission reduction targets, promoting sustainable practices, and providing incentives for the adoption of clean technologies. Such measures can play a crucial role in driving down carbon emissions while the economy continues to grow.

In addition to policy interventions, higher GDP can attract more investments in green infrastructure (Lyeonov et al., 2019). This may involve the development of public transportation systems, renewable energy projects, and efficient waste management systems. Such investments can contribute to a more sustainable development path (L. Wang, Su, et al., 2020) and further reduce the carbon intensity of economic activities in the ASEAN region.

Economic growth can also bring about behavioral changes. With elevated living standards, individuals and businesses may become more conscious of environmental issues (Y. Xu et al., 2021). As a result, there might be a shift towards adopting eco-friendly practices and lifestyles, further contributing to a reduction in carbon emissions.

Moreover, as ASEAN countries experience economic growth, there is an opportunity for increased international cooperation on environmental matters (Yoo & Kim, 2016). This could involve knowledge sharing, collaboration on green technology development, and participation in global climate agreements aimed at mitigating carbon emissions.

However, it is important to recognize that the impact of these mechanisms may vary among ASEAN countries, depending on their unique economic structures, policy frameworks, and social contexts. A comprehensive approach that combines technological innovations, policy interventions, and sustainable practices is essential to effectively decouple economic growth from carbon emissions in the ASEAN region. By embracing these strategies, ASEAN countries can navigate a more sustainable and environmentally responsible development path.

The finding that an increase in GDP leads to a decrease in carbon emission intensity aligns with the Environmental Kuznets Curve (EKC) Theory. The EKC theory postulates an inverted U-shaped relationship between environmental degradation and economic development. Initially, as economies grow and industrialize, environmental degradation, including carbon emissions, tends to increase due to higher energy consumption and industrial activities.

However, as countries reach a certain level of economic development, they start transitioning towards cleaner and more sustainable practices, leading to a decline in environmental impact, including carbon emissions. This turning point is often associated with improved technology, increased environmental awareness, and the implementation of effective environmental policies.

In the context of the ASEAN region, the observed negative relationship between GDP and carbon emission intensity suggests that the region is on the downward slope of the EKC curve. As economies grow and become more developed, they are likely to invest in technologies and practices that promote energy efficiency, cleaner production processes, and renewable energy sources. These advancements contribute to the reduction in carbon emissions per unit of economic output, resulting in a decrease in carbon emission intensity.

The finding that an increase in GDP leads to a decrease in carbon emission intensity can be further analyzed in the context of the Porter Hypothesis. The Porter Hypothesis posits that well-designed environmental regulations and policies can stimulate innovation and enhance a country's competitiveness, leading to improved environmental performance.

In the case of the ASEAN region, the negative relationship between GDP and carbon emission intensity suggests that economic growth has been accompanied by environmental improvements, supporting the key idea of the Porter Hypothesis. It demonstrates that economic growth and environmental sustainability are not mutually exclusive; rather, they can complement each other.

4.3.3 INF Impact on ASEAN CEI

Inflation (INF) demonstrates a significant negative association with CEI in the long term, denoted by its coefficient of -0.004607 and a t-statistic of -3.632328 (p-value: 0.0003). With an increase of one unit in inflation (INF), the carbon emission intensity (CEI) decreases by 0.004607 units, as indicated by the negative coefficient. The significant t-statistic of -3.632328 (p-value: 0.0003) reinforces this negative association between inflation and CEI within the ASEAN region.

Higher inflation rates are linked to a decrease in carbon emission intensity, underscoring the potential for inflationary pressures to drive environmentally conscious practices. This happens due to several possible factors. Firstly, higher inflation rates often result in increased production costs (Kumar, 2008), including energy costs. To mitigate the impact of rising costs, businesses may adopt more energy-efficient practices and technologies (Bressler et al., 2011), thereby reducing their carbon emissions. Secondly, higher inflation can also lead to changes in consumption patterns and preferences (Ennis, 2009). Consumers may become more conscious of their spending and opt for environmentally friendly products and services, which have lower carbon footprints. Lastly, governments and policymakers may implement measures to address inflationary pressures (Hess & Morris, 1996), such as promoting energy conservation and incentivizing sustainable practices, which can contribute to a decrease in carbon emission intensity (Appiah et al., 2021). These combined effects highlight how higher inflation rates can inadvertently drive a reduction in carbon emissions within the ASEAN region.

The analysis above aligns with multiple theoretical perspectives. The Environmental Kuznets Curve (EKC) Theory suggests that as economies develop, environmental degradation initially increases but eventually decreases. In this case, the negative association between inflation and carbon emission intensity supports the idea that higher inflation rates can lead to a decrease in emissions, indicating a potential inverse relationship between inflation and environmental impact.

The Porter Hypothesis and Technological Innovation Theory also find relevance in this context. They emphasize that inflationary pressures may drive environmentally conscious practices and encourage the adoption of more energy-efficient technologies, which can contribute to lower carbon emissions. The finding that higher inflation rates are linked to a decrease in carbon emission intensity supports these theories.

On the other hand, the Energy Efficiency Paradox Theory and Behavioral Economics Theory have less direct relevance to this specific relationship between inflation and carbon emission intensity. These theories focus more on energy efficiency improvements and human decision-making, respectively, rather than the impact of inflation on carbon emissions.

4.3.4 TED Impact on ASEAN CEI

Being interestingly similar, the coefficient for TED reveals a substantial negative impact on CEI, standing at -1.71E-05, with a remarkably significant t-statistic of -10.47750 (p-value: 0.0000). A decline in technological development (TED) corresponds to a notable reduction in carbon emission intensity within the ASEAN region.

In the case of limited technological development (TED) in the ASEAN region, there are several possible explanations for a reduction in carbon emission intensity (CEI). Firstly, industries in ASEAN may rely on older, less carbon-intensive technologies(Nepal et al., 2021) , which are relatively more environmentally friendly compared to newer alternatives. This shift towards low-carbon technologies contributes to a decrease in CEI (Cho & Chae, 2016). Secondly, a decline in TED could lead to decreased industrial activity or a shift towards less carbon-intensive sectors (J. Li et al., 2016; Marcucci & Turton, 2015), resulting in lower overall carbon emissions. Thirdly, limited energy consumption due to factors such as limited access to resources, inefficient energy infrastructure, or socioeconomic constraints can contribute to a decrease in CEI (Rasche & Tatom, 1977; Tolliver et al., 2020). Lastly, the implementation of effective environmental policies and regulations within ASEAN countries can impose emission standards and promote sustainable practices (Sabir et al., 2020), offsetting the impact of limited technological development. These factors collectively explain how a decline in TED can lead to a reduction in carbon emission intensity in the ASEAN region.

The elaboration above relates primarily to the Technological Innovation Theory and partially to the Environmental Kuznets Curve (EKC) Theory. The Technological Innovation Theory explains how a decline in technological development (TED) can result in a notable reduction in carbon emission intensity (CEI) within the ASEAN region. The use of older, less carbon-intensive technologies and the shift towards low-carbon alternatives align with this theory.

However, the other theories, namely the Porter Hypothesis, Energy Efficiency Paradox Theory, and Behavioral Economics Theory, do not directly relate to the specific case of TED and CEI in ASEAN and are not explicitly highlighted in the provided analysis.

4.3.5 HDI Impact on ASEAN CEI

In the long term, HDI fails to exhibit statistical significance in explaining ASEAN carbon emission intensity, with a coefficient of -1.03E-05 and a t-statistic of -0.399049 (p-value: 0.6901). Thus, no compelling evidence suggests that HDI significantly influences CEI in the ASEAN context.

There are several primary reasons why the Human Development Index (HDI) does not exhibit statistical significance in explaining ASEAN carbon emission intensity (CEI). Firstly, the HDI may not capture the specific aspects of human development that have a direct impact on carbon emissions (Van Tran et al., 2019; Радовановић, 2011). While the HDI provides a comprehensive measure of human well-being, it may not account for factors directly related to environmental sustainability or carbon emissions.

Secondly, other factors such as economic growth, technological advancements, and energy efficiency measures may overshadow the influence of HDI on CEI (Didenko & Kunze, 2014; Yulfitasari & Bawono, 2021). Economic growth and technological progress play significant roles in shaping carbon emissions (Gong et al., 2022; L. Wang, Vo, et al., 2020), and these factors may have a stronger association with CEI than HDI (Anser, Hanif, et al., 2020). Additionally, energy efficiency measures and environmental policies implemented by countries could have a more direct and immediate impact on carbon emissions (Yeo et al., 2015), overshadowing the influence of HDI.

Furthermore, the ASEAN context itself may introduce additional complexities that dilute the influence of HDI on CEI. The ASEAN region consists of diverse economies at different stages of development, each with unique social, economic, and environmental characteristics. These variations could mask any potential relationship between HDI and CEI, making it difficult to establish a clear statistical significance.

The lack of statistical significance for the Human Development Index (HDI) in explaining ASEAN carbon emission intensity (CEI) does not align with the analyzed theories. According to the Environmental Kuznets Curve (EKC) Theory, a higher HDI, representing greater human development, is expected to correlate with reduced environmental degradation. However, the non-significant coefficient for HDI suggests that it does not significantly influence CEI in the ASEAN region.

Similarly, the findings do not support the Porter Hypothesis, Technological Innovation Theory, Energy Efficiency Paradox Theory, or Behavioral Economics Theory which propose that factors related to economic development, technological progress, energy efficiency and human behavior on environmental outcomes are associated with lower carbon emissions. The lack of statistical significance for HDI implies that human development, as measured by HDI, does not play a significant role in explaining CEI in the ASEAN context.

4.3.6 GINI Impact on ASEAN CEI

The coefficient for GINI (-0.002906) fails to demonstrate statistical significance, as indicated by a t-statistic of -0.911343 (p-value: 0.3626). Hence, income inequality (GINI) does not significantly impact carbon emission intensity within the ASEAN region in the long run (Grunewald et al., 2017b). There are several primary reasons for this lack of statistical significance.

Firstly, income inequality may not directly influence carbon emissions in the ASEAN context (Guo et al., 2020). While income distribution can affect consumption patterns and resource allocation (Oladosu & Rose, 2007), the relationship between income inequality and carbon emissions is complex (Y. Liu et al., 2020). Other factors such as economic growth (Mushta et al., 2020), technological advancements (B. Lin & Li, 2020), and energy efficiency measures (Chang et al., 2019) might overshadow the influence of income inequality on carbon emission intensity.

Secondly, the ASEAN region encompasses diverse economies with varying levels of income inequality. The heterogeneity in income distribution across countries could dilute any potential impact of income inequality on carbon emissions. Factors such as government policies, industrial structure, and cultural norms might have a stronger influence on carbon emission intensity compared to income inequality alone.

Furthermore, measuring the precise impact of income inequality on carbon emissions is challenging due to data limitations and the complexity of the issue. Income inequality is a multi-dimensional concept, and capturing its full impact on carbon emissions requires comprehensive data and sophisticated analytical approaches (Zhu et al., 2018b). The available empirical evidence might not provide conclusive results due to these challenges.

The Environmental Kuznets Curve (EKC) Theory is the most relevant in understanding the relationship between income inequality and carbon emission intensity (CEI) within the ASEAN region. According to the EKC Theory, as economies develop, environmental degradation initially increases but eventually decreases as income levels rise. This suggests that income inequality may not directly impact CEI in ASEAN, as other factors such as economic growth and technological advancements have a stronger connection. The Porter Hypothesis, Technological Innovation Theory, Energy Efficiency Paradox Theory, and Behavioral Economics Theory, while important in their own right, do not directly relate to the lack of significance between income inequality and CEI in the ASEAN context.

CHAPTER 5. SUMMARY AND CONCLUSION

5.1 Summary and Conclusion

This study significantly contributes to the literature by investigating the determinants of carbon emission intensity in ASEAN and the impact of economic, social, and technological development on this intensity. Using a large dataset and employing a fixed-effect model (FEM), the study rigorously assesses the validity and reliability of the model through various tests.

The findings reveal that on the long-term estimation, foreign direct investment (FDI) does not show a significant association with carbon emission intensity. Higher GDP, lower inflation rates, and limited technological development are significantly linked to lower carbon emission intensity in ASEAN. Interestingly, variables related to social development, such as the Human Development Index (HDI) and the GINI index, do not demonstrate a significant relationship with carbon emission intensity. In addition, this study finds no mutual correlation (bidirectional / unidirectional) between all variables.

In conclusion, this study fills a research gap by shedding light on the determinants of carbon emission intensity in ASEAN. It highlights the importance of economic factors, such as GDP and inflation rates, along with limited technological development, in reducing carbon emissions. However, foreign direct investment and social development indicators do not significantly impact carbon emission intensity in the ASEAN context.

These findings have implications for policymakers and stakeholders, emphasizing the need to promote sustainable practices, economic growth, and technological innovation to effectively address carbon emissions. Further research is recommended to explore the underlying mechanisms through which economic and social factors influence carbon emission intensity in ASEAN.

5.2 Policy Recommendations

Based on the findings of the study, there are several effective policy recommendations that can be made for ASEAN countries to accelerate their efforts in decreasing carbon emission intensity. Based on the FEM estimation, this study suggests to strengthen environmental regulations and their enforcement. ASEAN countries should focus on developing robust and stringent regulations that incentivize businesses to adopt sustainable practices and reduce carbon emissions. Additionally, governments can establish monitoring mechanisms and penalties for non-compliance. To support this, programs can be implemented to provide technical assistance and capacity building to regulatory agencies, ensuring effective implementation and enforcement of environmental regulations.

Secondly, promoting green technology transfer and innovation is essential. ASEAN countries can establish programs to facilitate the transfer of environmentally friendly technologies, particularly in sectors with high carbon emissions. This can be achieved through partnerships with developed countries, technology hubs, and research institutions. Governments should also invest in research and development, providing grants and incentives to businesses and start-ups focusing on clean technologies. By creating an ecosystem that supports innovation and technology adoption, ASEAN countries can accelerate the transition to low-carbon practices.

Aligning investment priorities with sustainability goals is another important step. Governments should actively attract foreign direct investment (FDI) in sectors that prioritize sustainability and low-carbon technologies. This can be done by offering financial incentives, tax breaks, and streamlined regulations for businesses engaged in renewable energy, energy efficiency, and sustainable infrastructure projects. Moreover, establishing green investment funds or venture capital programs dedicated to funding sustainable initiatives can further encourage private sector participation in low-carbon projects.

Enhancing public awareness and stakeholder engagement is vital for driving sustainable practices. ASEAN governments should invest in educational campaigns and public outreach programs to raise awareness about climate change and its impacts. They can collaborate with civil society organizations, businesses, and community groups to foster dialogue and partnerships. Additionally, governments can introduce initiatives such as eco-labeling schemes, consumer education programs, and sustainable lifestyle campaigns to promote green consumption patterns and behavioral changes among individuals and households.

Lastly, fostering regional cooperation is crucial for addressing climate change collectively. ASEAN countries should strengthen cooperation and knowledge sharing on environmental issues. This can be achieved through regional forums, workshops, and collaborative research projects. Governments can also explore joint initiatives such as regional carbon pricing mechanisms, renewable energy trading schemes, and cross-border infrastructure projects. By working together, ASEAN countries can leverage collective resources and expertise to achieve greater impact in reducing carbon emissions.

5.3 Limitations of the Study

It is important to acknowledge the potential limitations of this study. Firstly, the study focuses on a specific region, ASEAN, which may limit the generalizability of the findings to other contexts. Secondly, the study relies on aggregate data and may not capture the nuances and variations at the country level. Thirdly, the study does not delve into the mechanisms through which the identified determinants influence carbon emission intensity, which could be an avenue for future research.

Future research can build upon this study by addressing these limitations. It can expand the analysis to include a more specific set of ASEAN countries or regions, classifying based on particular characteristics, to enhance the generalizability of the findings. Additionally, incorporating more disaggregated data at the country or industry level particularly can provide deeper insights into the dynamics of carbon emission intensity to provide a more comprehensive understanding of the issue and inform effective policy interventions.

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