Palacký University Olomouc
Université Clermont Auvergne
Università degli Studi di Pavia

MASTER THESIS

In fulfillment of the Erasmus Mundus Joint Master's Degree in
Global Development Policy

Jannico G. Cabañero

Supervisor: Pascale Motel- Combes, Ph.D.

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Do financing sources affect CO2 emissions? The case of growing ASEAN

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Submitted by Jannico G. Cabañero

Supervised by Pascale Motel-Combes, Ph.D.[1]

May 2022

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Declaration

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another neither person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of any university or institute of higher learning.

Jannico G. Cabañero

May 2022

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Zásady pro vypracování

Southeast Asia is one of the fastest growing regions across the world and this comes with an increasing demand for energy consumption. Energy demand from all sectors, from industry transport and households, has doubled from 1995 to 2015 as the region experiences economic growth and improvementof living standards (Nagpal & Hawila, 2018). However, the region is still highly dependent on fossil fuel, mainly oil and natural gas, as its main energy source which can dampen its decarbonization target (Susanto et al., 2021). Thus, there is a growing need to diversify the energy source of the region through renewables not only to achieve the region's CO2 emission targets but also to ensure energy security in the long term. This thesis study will analyzethe impact of debt financing in renewable energy sector particularly green bond financing and other traditional debt and development financing on the greenhouse gas emissions in the region. Green bond financing has gained popularity over the last decade as it offers a new way of integrating the financial market in achieving climate-change and sustainable development goals (Azhgaliyeva et al., 2020). This study shall utilize econometric modeling in analyzing the impact of deby financing to the GHG emissions.

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Azhgaliyeva, D., Kapoor, A., & Liu, Y. (2020). Green bonds for financing renewable energy and energy efficiency in South-East Asia: a review of policies. *Journal of Sustainable Finance & Investment*, *10*(2), 113-140.

Nagpal, D., & Hawila, D. (2018). Renewable Energy Market Analysis Southeast Asia. *International Renewable Energy Agency (IRENA).*Susantono, B., Zhai, Y., Shrestha, R. M., & Mo, L. (2021). Financing Clean Energy in Developing Asia.

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> to my late father Ely, the most hardworking man I know, to whom I dedicate this work and everything I do.

And, finally, to the Ultimate Power in this universe that conspired to make all of this possible, thank you.

Foreword

During the writing of this thesis paper, I was doing an internship with PKF Malta, an auditing and consultancy firm in Birkirkara, Malta, for their advisory team. One of our projects is to research policies and interventions to promote green jobs in Malta. To accomplish this project, we have looked at the policies and incentives that encourage green job growth across the world, including the ASEAN. This project gave me a clear understanding and perspective on how the region recognizes and approaches the importance of green jobs in building sustainable societies. Ensuring the growth in renewable energy is one of the common themes that is being pushed forward to generate more labor opportunities. Some of the few policies being implemented to promote the inflow of funds to the sector are fiscal incentives such as subsidies, feed-in tariffs, and financial grants for green energy projects. This research project has greatly aided me in having a clearer grasp of my thesis work and, in particular, in developing policy implications based on my empirical findings.

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Abstract

ASEAN is becoming one of the fastest-growing economies in the world backed by rapid urbanization, higher mobility, and structural transformation. These developments came with concerns of rising carbon emissions due to high reliance on fossil fuel resources in both consumption and energy production. Thus, a need for more investment in renewable energy has emerged. This paper investigates the impact of financing sources on carbon emissions in the ASEAN region using panel data from six ASEAN states i.e., Indonesia, Laos, Malaysia, Philippines, Thailand, and Vietnam from 1986 to 2018. Four financing source variables were used in this analysis: domestic credit, government expenditure, FDI, and ODA. This study employed Pooled Mean Group estimation to assess the impact of each variable alongside Dynamic Fixed Effects to enrich the results. The results confirmed a long-run relationship among the variables and validated the EKC relationship between income and CO2 emissions. Among the interest variables, government expenditure and FDI are shown to induce carbon emissions in the long run while ODA is found to have an inverse effect on CO2 emissions in both the short and long run. Relevant policy implications were also discussed and presented in this study.

JEL classification: Q40, Q50, Q56

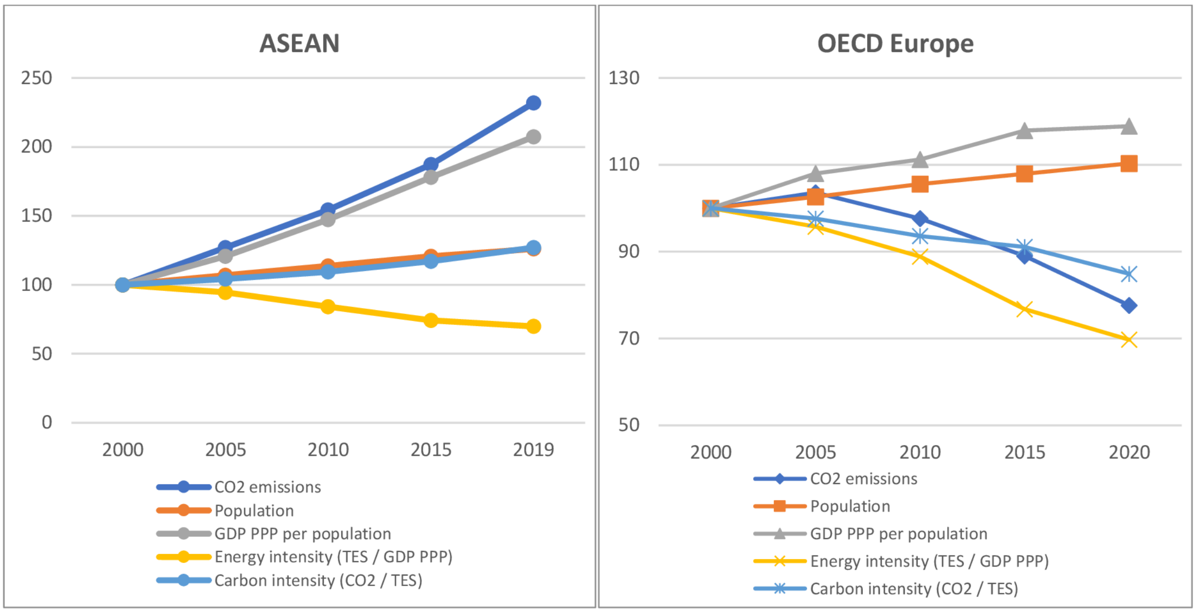
Keywords: carbon emissions, ASEAN, renewable energy, financing sources, PMG

1. Introduction

Southeast Asia is one of the fastest-growing regions across the world. The region progressed with income per capita increasing at a fast pace combined with rapid urbanization, higher mobility, and structural transformation. Before the pandemic, the region has grown by almost 5.1% in 2018 and 4.1% in 2019 due to the increased consumer demand (ADB, 2019). While the region flunked to a low level in 2020 at -3.2% and slightly recovered in 2021 at 2.9%, it is poised to return to its pre-pandemic levels at 4.9% and 5.2% for 2022 and 2023 (ADB, 2022). Along with this expansion, is the enormous rise in the energy demand in the region. The increasing energy demand has profound repercussions particularly on the greenhouse gas emissions of the region as it is continuously supported by fossil fuel sources.

Figure 1 Comparison of Kaya Equation for ASEAN & OECD Europe (index at 2000=100)

Source: International Energy Agency (IEA) database

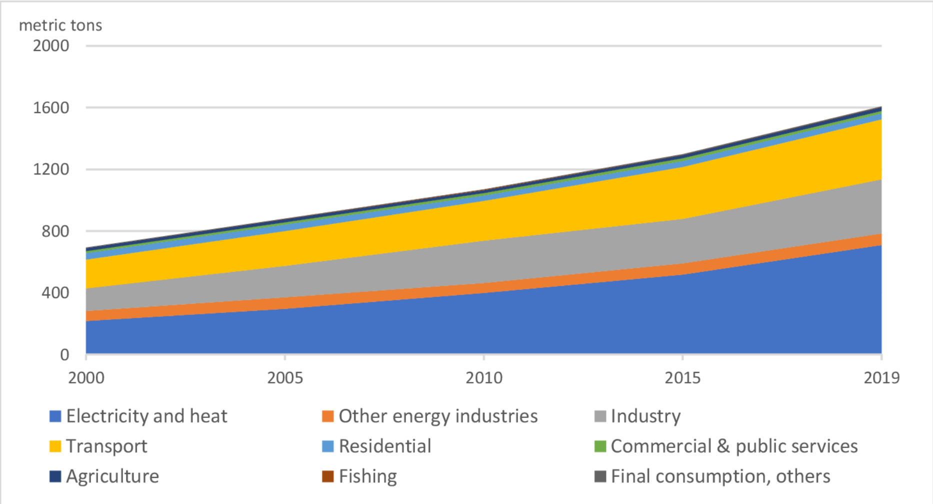


We start by looking at how CO2 emissions move with income in ASEAN (Association for Southeast Asian Nations) and compare it to another region such as OECD Europe. Figure 1 shows the Kaya Equation which expressed CO2 emission rate as a function of income, population, primary energy intensity, and carbon intensity for ASEAN and OECD Europe. The CO2 emission rate in ASEAN is skyrocketing and primarily driven by changes in income. While energy intensity went down, the persistent increase in income level combined with a slight rise in carbon intensity has pushed the CO2 emissions to go up. OECD Europe, on the other hand, has seen a decline in CO2 emissions which is owing primarily to falling energy and carbon intensity. This massive disparity, particularly in the scale of carbon intensity reduction, is caused by several factors such as sources of demand, technology, and level of investment in renewable energy sources. This rising trend of CO2 emission has serious implications for ASEAN as the region is one of the most vulnerable to weather extremes and rising sea levels due to climate change.

Figure 2 depicts the sources of CO2 emissions according to sector. Because of heightened consumer demand and greater dependence on coal and oil for energy production, the electricity and heat sector has emitted the most CO2. Industries and transportation followed as production increased and people's mobility went higher. These three major drivers are all linked to increased economic growth, trade, and urbanization throughout Southeast Asia.

Figure 2 CO2 emissions by sector for ASEAN, 2000-2019

Source: IEA database

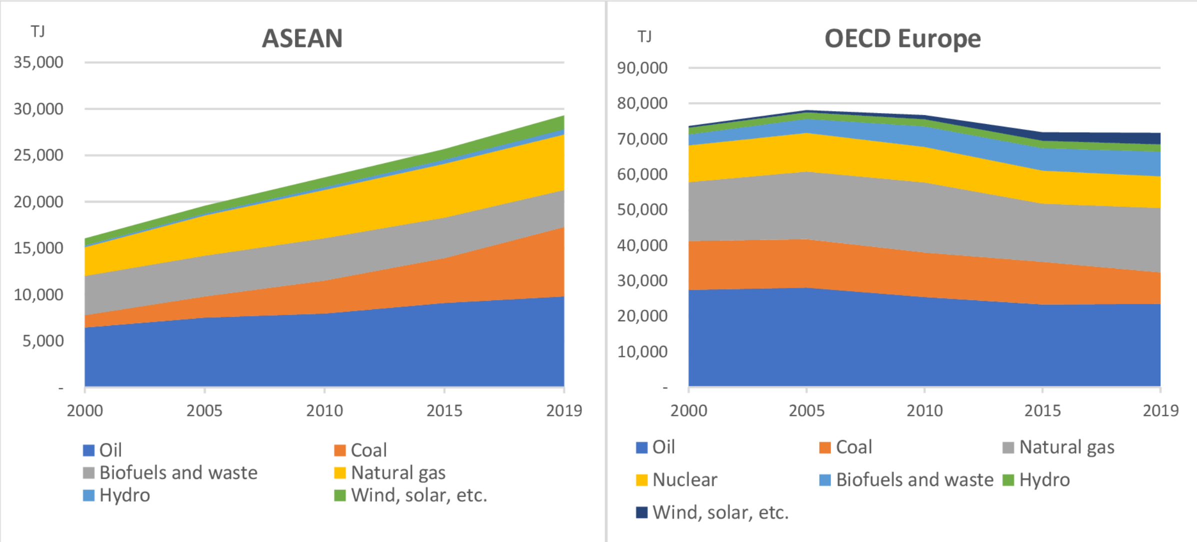


ASEAN is still heavily reliant on coal, oil, and natural gas as its primary energy sources, which may jeopardize its decarbonization goal. Figure 3 presents the total energy supply for both ASEAN and OECD Europe broken down by source. Oil has been a persistent source of energy for ASEAN, along with coal which has grown at 10% annually since 2000. Natural gas consumption has also accelerated in the last five years. In comparison to ASEAN, the European group recorded a 1% annual decrease in nonrenewable energy production. The OECD Europe also has nuclear resources, which contribute to their total energy stock, though they have been gradually decreasing over time.

There is an intensifying need to diversify the region's energy sources through renewables, not only to ensure long-term energy security but also to fulfill the region's other climate targets. As of 2017, all ASEAN states have ratified the Paris Agreement acknowledging its long-term goals with the majority of the countries formally adopting their intended nationally determined contributions into nationally determined contributions (NDC) in line with the accord (Yurnaidi et al., 2021). The region has set an energy target of 23% primary energy from primary sources by 2025, which is only at 17% as of 2017 (IRENA, 2018). Financing will be critical to achieving the energy target and the other NDCs as well as for ASEAN states to implement long-term strategies consistent with the Paris concord.

Figure 3 Total Energy Supply by source for ASEAN & OECD Europe, 2000-2020

Source: IEA database



Attaining the CO2 emission and other climate action targets of the region will warrant large-scale financing from different sectors of the local and global economy. One way to improve the level of energy financing within the region is to analyze how financing sources can influence CO2 emissions. This shall be the primary motivation of this study. While there has been a lot of research that delved into the drivers of the CO2 emissions in the region, there have been fewer studies that looked at the effect of financing. For example, financing flows may have a contradictory impact on carbon emissions. It can promote economic development, which intensifies energy consumption, but it could also help to alleviate carbon intensity. Also, different financing sources tend to have a varying presence in different energy sectors, and thus it can be argued that each type of financing source affects CO2 emissions distinctively.

Based on the existing studies on determinants of carbon emissions, this research paper will be analyzing four financing sources: domestic credit, public financing, foreign direct investment (FDI), and foreign aid. These four variables shall encompass the available financing in the region which will cover the funding for renewable energy capital layouts and other energy efficiency improving technology.

This research will fill a gap in the literature by investigating the effects of funding on CO_2 emissions. The goal of this study is to look into the impact of these various financing sources on carbon emissions in Southeast Asia in light of the region's rising income. The study shall contribute to the existing empirical works on CO_2 emissions in the ASEAN and provide potential policy insights toward increasing renewable energy financing.

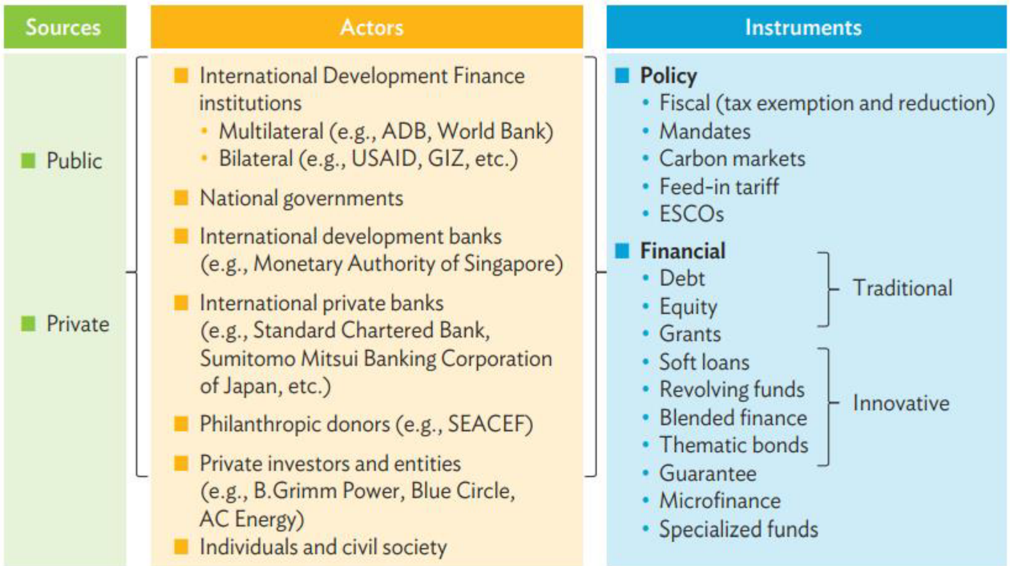
This paper shall be constructed as follows: Section 2 will discuss the current context of the ASEAN region, with a focus on the current trends and status of the energy financing sector. This section shall provide an in-depth understanding of the sources of financing and the variation of investments across sectors and countries. Section 3 shall present the review of related literature containing existing studies relating to the different financing sources and CO_2 emissions. A review of empirical works employing environmental Kuznets's curve on ASEAN shall also be presented to have a better understanding of how economic growth can affect CO_2 emissions. Section 4 will explain the empirical framework and the data to be used for the study. Section 5 shall present the unit root and cointegration tests, results of the empirical estimation, and policy implications. And lastly, section 6 shall contain the conclusion and recommendations for future research.

2. Energy Financing: the ASEAN context

Financing the renewable energy sector is one of the critical elements to achieve the decarbonization targets in the region. Climate mitigation needs various forms of financing, as investments in clean energy will necessitate massive capital outlays, extensive research, and rigorous training of the talent pool. Financing addresses climate mitigation through funding investments in renewable energy production, usage of technologies to improve energy efficiency, and support for clean energy and sustainability research. It was estimated that around USD 290 Billion is needed to reach the renewable energy target (IRENA, 2018). ADB (2021) provides an overview of the existing sources and flows of clean energy financing for Southeast Asia which they adapted from the New Climate Economy:

Figure 4 Prevailing Sources and Flows of Clean Energy Financing

Source: ADB (2021)



We begin by examining the overall contribution of the private and public sectors to energy financing. Figure 5 shows the sources of finance for power generation investment in the region from 2014 to 2018 classified between the public and private sectors. The financing of the energy sector is led by fossil fuels which USD 94.3 Billion or 72% of the total financial investment in the energy sector is given to coal and gas power. Public entities such as state-owned enterprises and public financial institutions have dominated the investment in the region accounting for USD 52.9 Billion or 53% of the total funds invested. On the other hand, the private sector is heavily involved in solar and wind energy investment, making up 95% of total investment in both the two energy sectors through foreign direct investment and private capital (IEA, 2019).

Figure 5 Sources of finance for power generation investment in ASEAN by year of final investment decision in USD Billions, 2014-2018

Source: IEA (2019)

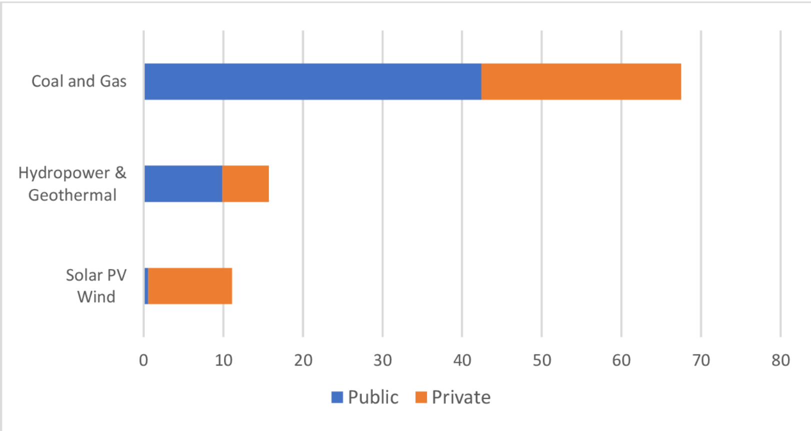


Figure 6 depicts the shares of different energy sources in renewable energy financing for private and public investment for the period 2000-2020. For private investments, the most heavily funded projects are under hydropower, which received about USD 21.5 Bn. Similarly, the public sector focused on hydropower investment with a total investment of USD 13 Bn. Meanwhile, Figure 7 provides the financing mix for each energy source at a relative level. As shown, coal and gas power have the same financing mix between private and public while solar and wind power are heavily funded by the private sector. Large-scale hydropower, coal, and gas projects require significant upfront capital, so public financing is common in these sectors.

Figure 6 Public & Private Investment in Energy Sector by Source, 2000-2020

Source: World Bank's Private Participation in Infrastructure (PPI) & International Renewable Energy Agency (IRENA) database

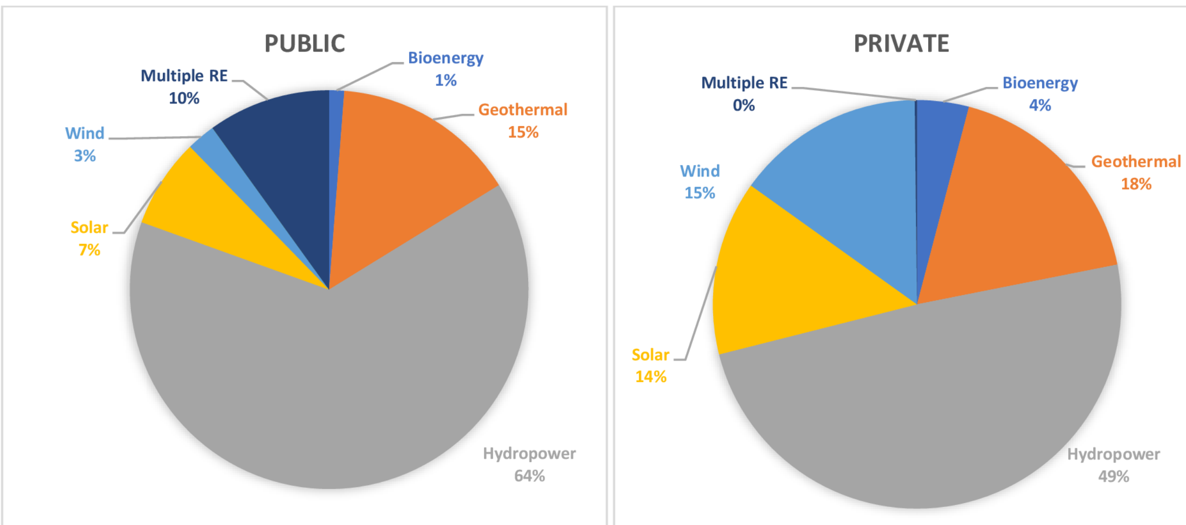
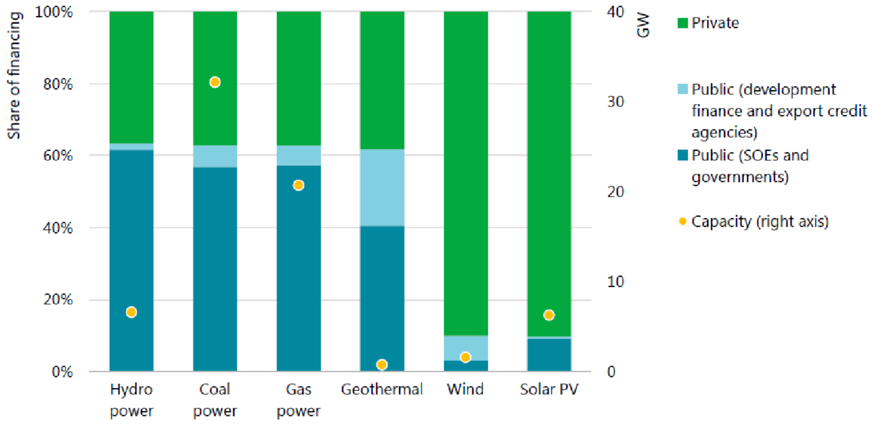


Figure 7 Sources of finance for power generation investment in SEA by type of capital provider (final investment decision in years 2014-2018)

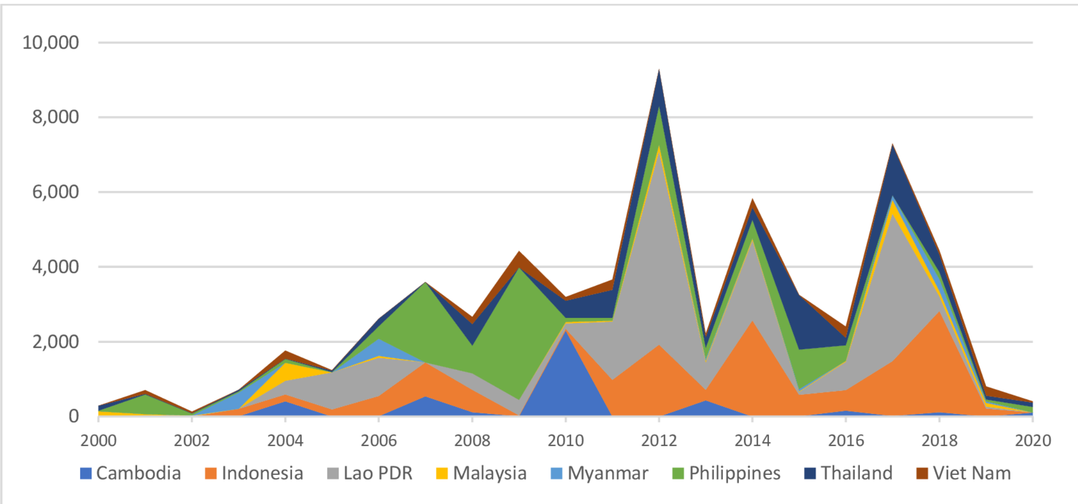
Source: IEA (2019)



Meanwhile, the private sector is becoming more involved in solar photovoltaic systems and wind energy due to the cost-competitiveness of these technologies. Domestic and international banks are both participating in the financing energy sector through debt and with a strong presence in Malaysia, the Philippines, Singapore, and Thailand. In newer markets such as Indonesia and Vietnam, banks are more predisposed to funding fossil fuel power plants due to a lack of technical knowledge to finance clean energy projects. Equity financing is ushered through investments from holding companies such as B. Grimm Power, Blue Circle, Sindicatum Renewable Energy Company, and others. (ADB, 2021).

Figure 8 Renewable Energy Investment per country (in USD Millions), 2000-2020

Source: World Bank PPI & IRENA database



Now, we look at the financing flows per country. Figure 8 illustrates the investment flows in the clean energy sector per country for the period 2000-2020. The two huge hydropower and dam projects for 2012 and 2017 have significantly raised Lao PDR's cumulative investment flow to USD 18.21 billion. Development finance institutions were the primary investors during the early stages of renewable energy development in ASEAN and from 2011 to 2020, they have financed over $9 Billion in renewable energy. World Bank, Asian Development Bank, and Japan Bank for International Cooperation were the top investors with each bank investing over USD 1 Billion from 2009 to 2016 (ADB, 2021).

For 2018, the energy investment for the region is around USD 65 Billion but has been trending downward since 2013 due to a decline in financing for oil and gas supply. Investment in renewables has remained relatively stable, despite the fact that oil and gas supply continues to account for the majority of investments. Improvement in energy efficiency, which can lead to lower investment spending in energy accounts only for 5% of Southeast Asia's energy investment (IEA, 2019).

Given the financial profile and sources of growth of energy investment in the region, Baral & Lee (2017) looked at the green finance opportunities and provided an estimate of current green flows for a USD 200 Bn green investment demand. They found a financing gap of USD 160 Bn as shown below:

Figure 9 Green Finance Flows in 2016, in USD Billions

Source: Baral & Lee (2017)

Yearly Green Investment Opportunities	**200**
Green Finance Flows (2016)	
Public Finance*	25
Other Investment (public)**	2
Multilateral Development Banks	3
Private	
Commercial Loans	7
Corporate Bonds	1
Microfinance	
Green bonds	1
Other investment (private)	1
Total	**40**
Yearly increase in finance required to meet demand	160

**Public finance refers to government/ state expenditures*

***Includes bilateral aid and other missing development finance institute financing*

Baral & Lee (2017) calculated the figures above using available information and a set of assumptions. For public finance, the researchers utilized annual expenditures of different countries and set a green share for each investment expenditure e.g., transport (10%), and telecommunications (10%). After computing for all the sectors, they added around 10% buffer from the initial estimate of USD 22.7 Billion. For commercial loans, they assumed that at least 2% of the total outstanding loans are green. Using an estimate of an average loan tenor of 6.23 years and an assumed growth rate of 5%, the calculated green loan is USD 7 Billion. A similar methodology was used for corporate bond and green bond estimates. Meanwhile, estimates from multilateral banks were taken from a joint multilateral report on climate financing in which they assumed that 60% share of the funds that flow into East Asia and the Pacific is allocated to ASEAN.

3. Literature Review

This paper shall examine the effects of the financing sources, namely domestic credit, public financing, FDI, and foreign aid, on CO_2 emissions in the context of economic growth in the Southeast Asian region. Analyzing financial flows is one of the key mechanisms in understanding CO_2 emissions. Financing sources are not only used to invest in renewable and/or non-renewable energy but also to consume polluting and/or environmentally -friendly goods and services. If funds flow into investing in non-renewable energy sources and/or consuming polluting goods and services, CO_2 emissions will rise. Consequently, the reduction in GHG emissions will be amplified if financing sources flow to investment in clean energy and/or consumption of environmentally-friendly goods and services.

We can classify the financing sources according to their origin: either domestic or foreign financing. Domestic financing refers to funds that originate within the country and can be either private or public. Private financing typically flows from the financial markets through the usual credit facilities such as commercial loans and other debt securities. Public financing originates from the government usually through fiscal mechanisms like asset purchases, subsidies, etc.

Foreign aid and foreign direct investment can be classified under foreign financing, which are inflows from outside of the country. Foreign direct investments are inflows typically from multinational enterprises and can take many forms, including the establishment of a subsidiary, private placement, share acquisition, mergers, and so on. Foreign aid, on the other hand, is provided by multilateral organizations or other states, typically in the form of financial grants or development assistance.

Thus, in this literature review, studies relating to the impact of these financing sources shall be discussed to provide an overview of the existing theories along with empirical evidence that explains the impact of such variables. A review of studies on EKC shall be presented initially to provide a deeper understanding of how increasing income can influence carbon emissions, which is extremely useful in the context of growing ASEAN. This will be followed by a review of each financing source variable to be delved into in sequence.

3.1. Economic growth and CO_2 emissions

A large number of studies have been conducted to investigate the relationship between income and CO_2 emissions. Energy consumption is the most direct path that economic growth can lead to environmental degradation. The greater the society's income, the greater the energy demand, resulting in increased carbon emissions. A non-linear trend is one way to look at this relationship. The Environmental Kuznets Curve (EKC) is a theorized relationship between income and environmental quality. As per the EKC, pollution emissions tend to increase in the initial stages of economic growth until it reaches a peak which afterward would lead to a reversal leading to improvement in environmental quality as income continues to grow. The EKC has been a major approach for many economists and researchers in looking at pollution emissions.

In the case of ASEAN, the existence of EKC, as explored by numerous studies, has not been unanimous. Chandran & Tang (2013), using the annual data from 1978 to 2008, found that the U-shaped conventional EKC curve is inapplicable to the ASEAN-5 (Indonesia, Malaysia, Philippines, Singapore, and Thailand) but found bi-directional long-run causality between economic growth and CO2 emissions in Indonesia and Thailand. Zhu et al. (2016), through quintile regression, did not find evidence for EKC as well. Similarly, Kisswani et al. (2019) tested EKC for the ASEAN-5 countries from 1971 to 2013 and also concluded that EKC is not evident. In contrast, Heidari et al. (2015) were able to validate the presence of the EKC curve from the ASEAN-5 through panel smooth transition regression (PSTR) model. A significant non-linear long-run relationship between carbon emissions and economic growth in Singapore and Thailand emerged from Saboori & Sulaiman's (2013) research which is a manifestation of EKC. Meanwhile, Adeel-Farooq et al. (2020) utilized methane emissions as a proxy for environmental degradation among six ASEAN countries for 1985- 2012: the study revealed that the EKC hypothesis for CH4 emission is valid. Salman et al. (2019), using quantile regression, also confirmed EKC with ASEAN-7 (i.e., ASEAN-5 plus Brunei and Vietnam). Several studies, albeit not employing the EKC model, found economic development to have a positive impact on the CO2 emissions in the region (Magazzino, 2014; Khan et al., 2019; Nasir et al., 2019). Conversely, Lee & Brahmasrene (2014) found an inverse bi-directional relationship between economic growth and CO2 emissions.

There are also plenty of studies that are outside of the ASEAN scope and delved into a group of countries through EKC lens. Le et al., (2020) found a u-shaped relationship between per capita RE consumption and income from 55 countries validating the presence of EKC. Data from 43 countries as studied by Narayan & Narayan (2010) showed EKC based on the short-run and long-run elasticities of their panel data results. Two studies, one that used developing Asian countries (Ullah & Awan, 2020) and the other that used 11 most populous Asian countries (Rahman, 2017) demonstrated the validity of EKC. Le & Ozturk (2020) have affirmed EKC in their study of 47 emerging economies. In contrast, Olubusoye & Musa (2020) found that among the 43 African countries in their sample from 1980 and 2016, EKC is accepted only in 21% of the sample. Mehmood & Tariq (2020) also have a resemblance in their study on South Asia: only Pakistan has demonstrated the presence of EKC while it is the inverse for the other South Asian countries. Destek & Manga (2021), on the other hand, detected more than one turning point for economic growth and CO2 emissions: M-shaped for Canada and the United Kingdom, N-shaped for France, inverted N-shape for Germany, and inverted M-shaped for Italy, Japanese and United States.

3.2. Domestic credit and CO2 emissions

Domestic credit has an essential role in countries' decarbonization processes; however, the link between credit and environmental quality may be inconclusive. Higher credit as a result of efficient financial intermediation can encourage the use of energy-intensive goods and services as well as more investment, which can lead to an increase in energy consumption and environmental degradation. (Zhang, 2011). However, domestic credit also provides support in developing the renewable energy sector with innovative firms and several empirical works have shown that domestic credit has a beneficial effect on renewable energy consumption. (Samour et al., 2022; Shahbaz et al., 2021; Anton et al., 2019).

Many studies that utilized domestic financing have framed it under financial development. In the case of Southeast Asia, private sector credit was found to induce carbon emissions as evidenced by Phong (2019) using data from ASEAN-5 countries. Nawaz et al. (2020) found similar results with carbon emissions and domestic credit having a positive relationship using nine ASEAN countries. Conversely, Rasiah et al. (2018) assessed that domestic credit is not a significant factor in determining carbon emission in the same region. Zhu et al. (2016) did not find domestic credit to reduce CO2 emissions in the ASEAN-5. Shahbaz et al. (2018) found that domestic credit reduces CO2 emissions in BRICS (Brazil, Russia, India, China, and South Africa) and Next-11 countries. Meanwhile, Anwar et al. (2021) and Anser et al. (2020) validated that financial development increases CO2 emissions for 15 Asian countries and Saudi Arabia, respectively. Tsaurai (2019) found that domestic credit provided by the financial sector resulted in a significant increase in carbon emissions in Western Africa.

3.3. Public financing and CO2 emissions

Public financing is a major source of energy investment in the region. Whereas public financing is less present in the renewables such as solar and wind, it plays a much more active role in hydropower and fossil fuel sector. As pointed out by Le & Ozturk (2020), there are four mechanisms by which government expenditure can impact the environment: scale effect, composition effect, technique effect, and income effect. Scale effect refers to the accumulation of physical and human resources that encourages income growth at the expense of environmental quality. When physical resources have a greater negative impact on the environment than their human counterpart, this is referred to as the composition effect. Based on the work of López et al. (2011), the technique effect describes cleaner energy and reduced environmental damage through R&D investment. The income effect is the induced demand for better environmental quality as a result of increased government spending. (Yuelan et al., 2019).

For ASEAN, Mughal et al. (2021) found that expansionary fiscal policy, as proxied by government spending as a fraction of GDP, increases CO2 emissions both in the short and long run. Le & Ozturk (2020) validated the positive impact of government spending on CO2 emissions. López et al. (2011), using data from 38 countries, confirmed that reallocation of fiscal spending towards public goods reduces pollution but increasing government expenditure without changing its composition has no effect. Bernauer et al. (2013), on the other hand, examined 42 countries from 1971 to 1996 and concluded that government spending is inversely related to environmental quality after controlling for governance quality. Halkos & Paizanos (2013), through a sample of 77 countries from 1980 to 2000 did not find a significant impact of government spending on CO2 emissions but found evidence for its negative impact on SO2.

3.4. Foreign direct investment and CO2 emissions

FDI is also one of the most studied variables when it comes to analyzing drivers of CO2 emissions. FDIs serve a vital role in financing both the renewable energy sector and the fossil fuel industry, particularly in developing countries and it is also an important element in integrated economies where the movement of capital is high. Positive externalities from improvements in clean energy technology can also be brought through FDIs. As discussed by Zhu et al. (2016), FDI's effect on the environment can be explained through (1) the pollution haven hypothesis which proposes that polluting industries would move to less stringent markets to conduct business, or (2) through the halo effect hypothesis which states that host countries will benefit from foreign firms' better operational techniques and more advanced technology. Using the dataset from ASEAN 5 countries, Zhu et al. (2016) validated that FDI has a negative effect on carbon emission in higher quantiles confirming the presence of the halo effect, complementary to Phung et al. (2022) which found that FDI can induce green growth. On the other hand, Baek (2016) found the reverse using pooled mean group on the same ASEAN-5 countries proving the pollution haven hypothesis. This is similar to the findings of Nasir et al. (2019), Ullah & Awan (2020), and Eriandani et al. (2020). Chandran & Tang (2013) did not find evidence of FDI's significance as a determinant of CO2 emissions in the ASEAN-5. Hanif et al.

(2019) also found evidence of the pollution haven hypothesis in Asian countries as FDI is proven to induce CO2 emissions.

3.5. Foreign aid and CO2 emissions

Foreign aid from multilateral institutions dominated the beginning of renewable energy investment in ASEAN. Foreign aid channels its way to CO2 emissions through scale, composition, and technique effect, similar to the other variables (Kretschmer et al., 2013). One interesting aspect of foreign aid is how it incentivizes recipients to invest in more energy-efficient and environmentally friendly technologies, especially if the grant is explicitly designated for sustainability measures. This type of grant usually requires regular reporting of financing proceeds to donor institutions as part of the grant agreements which can make the recipients more compliant with the sustainability targets. In addition, satisfying these targets can aid the recipients to secure more grants in the future. Lim et al. (2015) theorized that at low levels of globalization, higher foreign aid reduces pollution in aid-recipient countries; the inverse then leads to higher pollution. They were able to find evidence of this theory for 88 aid recipients for the period 1980 to 2005. Farooq (2022) has proven that foreign aid, alongside improved governance, can mitigate CO2 based on Asian economies. Similarly, Ikegami & Wang (2021) found that the early impact of energy aid is effective in reducing the recipient's CO2 emissions. Kibria's (2022) findings are also in line with them with Bangladesh, a heavy recipient of foreign aid, as his area of study. Bhattacharyya et al. (2018) validated the reverse using panel data from 128 countries: energy-related aid has no significant impact on emissions. Kretschmer et al. (2013) found no evidence for foreign aid's effect on carbon intensity although it has an impact on reducing energy intensity for recipient states.

4. Empirical Analysis of the Effect of Financing Sources on CO2 Emissions

In this section, we will begin by discussing the econometric model that will be used to describe the relationship between financing sources and CO2 emissions. Theories explaining the impact of each variable will be discussed in conjunction with the hypotheses that will be tested using the econometric model. Following that, we will describe the dynamic estimation method that will be used to estimate the econometric model—the panel Autoregressive Distributed Lagged (ARDL) model. The dataset for this study will then be presented with key information about the variables such as summary statistics, definitions, and data sources.

4.1 Econometric model

The primary objective of this research study is to investigate the impact of financing sources, particularly domestic credit, foreign direct investment, foreign aid, and public finance on the CO2 emissions in the ASEAN region. We can model CO2 emissions as a function determined by financing sources using the variables based on the existing literature. Domestic credit shall be the proxy for inflows from private domestic sources, similar to other studies that used the variable for domestic financial development. Public funding shall be captured by government expenditure. FDI shall represent funding from private multinational enterprises (MNEs) and companies. Foreign aid or inflows from multilateral organizations and other state entities, on the other hand, shall be represented by net official development assistance ODA. These shall be the interest variables for this study.

GDP per capita will be included in the model to account for the phenomenon of rising income in the region. EKC hypothesis testing shall also be incorporated similar to other studies with ASEAN as the reference region (Chandran & Tang, 2013; Saboori & Sulaiman, 2013; Heidari et al., 2015; Saboori & Sulaiman, 2013; Adeel-Farooq et al., 2020; Magazzino, 2014; Khan et al., 2019; Nasir et al., 2019). Urbanization shall be added as another control variable to account for social and demographic changes which can affect the carbon emission in the region as evidenced by other works (Wang et al., 2016; Brahmasrene & Lee, 2017; Batool et al., 2021; Jermsittiparsert, 2021; Tarasawatpipat & Mekhum, 2021; Huang et al., 2021). Urban cities also consume a vast portion of the world's energy supply and man-made heat emissions from a building, air conditioning, transportation, and industries are usually higher in urban areas.

Finally, the empirical framework shall be modeled as follows:

$$CO2_{it} = f(GDP_{it}, urban_{it}, credit_{it}, FDI_{it}, ODA_{it}, GOV_{it})$$

where *CO2* corresponds to the CO2 emissions in metric tons per capita, *GDP* is the GDP per capita (constant 2015 US$), *urban* is the urban population as a percentage of the population, *credit* is the domestic credit to the private sector by banks as a percentage of GDP, *GOV* is the government expenditure as a proportion of GDP, *FDI* is the net inflow of FDI as a fraction of GDP, and *ODA* is the net ODA received as a percentage of GNI. Here, i refers to the country and t refers to the year. Through this empirical model, we shall test the impact of the following financing sources:

Hypothesis 1: Domestic credit has ambiguous impact on CO2 emissions

> Private credit, as proxied by the level of domestic credit to the private sector, can lead to higher consumption of energy and ultimately to environmental degradation. However, financial development can also open up more opportunities for green technology and renewable energy investment.

Hypothesis 2: Public financing has a positive impact on CO2 emissions

> Public financing, in particular government expenditure, can move the CO2 emissions both ways. Both scale and composition effects lead to further environmental degradation whereas technique effect and income effect induce higher investment in clean energy resulting in lower emissions. However, if we scrutinize the status of the energy financing in the region, it is more plausible that the government spending is more predisposed towards higher carbon emissions since the public sector has high participation in fossil fuel financing. The scale and composition effect are more likely to be dominant than the income and technique effect.

Hypothesis 3: FDI has ambiguous impact on CO2 emissions

> The impact of FDI shall depend if ASEAN is a pollution haven for these MNEs which can further deteriorate the region's environmental quality or if FDI growth leads to positive externalities or halo effect on the ASEAN's technology, management, and production processes.

Hypothesis 4: Foreign aid has ambiguous impact on CO2 emissions

> Foreign aid's impact on CO2 emission can be primarily determined by how strong the incentives for aid recipients to utilize more energy-efficient and environmental-friendly

technology and to invest in clean energy. This is also affected by both scale and composition effects which can lead to more consumption of fossil fuels.

To estimate the empirical framework, we will be utilizing a panel data model with dynamic specification; in particular, the Autoregressive Distributed Lagged Model (ARDL). Panel ARDL offers several perks as an estimation model. It allows simultaneous estimation of short-run and long-run dynamics and can be used even if the order of integration among the variables is different (Ramos-Herrera & Prats, 2020).

An ARDL model, ARDL (p, q,q....,q), assumes that a dependent variable can be described by a linear function of its p lagged values and q lags of its independent variables. Using the model by Pesaran et al. (1999), a panel dataset that has time periods, t= 1, 2, ... T, and countries, i= 1,2,....,N, can be modeled into a general ARDL function:

$$y_{it} = \sum_{j=1}^{p} \lambda_{ij}\, y_{i,t-j} + \sum_{j=0}^{q} \delta'_{ij}\, X_{i,t-j} + \mu_i + \varepsilon_{it}$$

where, $X_{it}(k \times 1)$ refers to the vector of the explanatory variables for country i with δ'_{ij} as the corresponding $(k \times 1)$ coefficient vector; μ_i indicates the fixed effect; and λ_{ij} is the scalar for the coefficients of the lagged dependent variables.

The above model can be transformed into the below as shown by Teng et al. (2021):

$$\Delta y_{it} = \Phi_i(y_{i,t-1} - \theta'_i X_{i,t-1}) + \sum_{j=0}^{p-1} \lambda^*_{ij} y_{i,t-1} + \sum_{j=1}^{q-1} \delta'^*_{ij} \Delta X_{i,t-j} + \mu_i + \varepsilon_{it}$$

where

$$\Phi_i = -(1 - \textstyle\sum_{j=1}^{p} \lambda_{ij}); \; \theta = \textstyle\sum_{j=0}^{q} \frac{\delta_{ij}}{1-\sum_k \lambda_{ik}};$$

$$\lambda^*_{ij} = -\textstyle\sum_{m=j+1}^{q} \lambda_{im}, j = 1,2, \ldots, p-1; \text{ and } \delta^*_{ij} = -\textstyle\sum_{m=j+1}^{q} \delta_{im}, \; j = 1,2, \ldots, q-1$$

The vector Φ_i represents the speed of adjustment to the long-run equilibrium and is also known as the error correction term. Its coefficient is expected to be significant and negative in sign if a long-run relationship among the variables exists. The θ then corresponds to the long-run coefficients of the variables. The coefficients of the level variables shall be the long-run effects while the coefficients of the differenced variables are the short-run effects.

4.2. Data

This study shall cover a period of 32 years, from 1986 to 2018, and will include six ASEAN member countries namely Indonesia, Lao PDR, Malaysia, Philippines, Thailand, and Vietnam. The selection of the countries and the time period are based primarily on data availability. The data for this study were collected from World Bank Development Indicators, International Monetary Fund Data Mapper, and Asian Development Bank Key Indicators for Asia and the Pacific. Summary statistics, detailed description, and respective sources of the variables used in this paper are contained in Table 1.

The variables CO2 and GDP were transformed into their natural logarithm forms as the interpretation of the coefficients from the regression format will be easier as the resulting coefficients from the regression estimates will correspond to the elasticities of the variables. The natural logarithm of GDP is then squared to create a variable named lnGPCsq which will be used to test the presence of the EKC curve. The other variables were left at their level as these are already in percentage form.

Table 1 Summary Statistics & Description of the Variables

Variable Name	Short Description	Mean	Std. Dev.	Minimum	Maximum	Long Description	Source
CO2	CO2 emissions in metric tons per capita	2.004	1.934	.053	7.757	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.	World Bank Development Indicators
GDP	GDP per capita (constant 2015 US$)	3,072.260	2387.784	481.290	11,414.579	GDP per capita is gross domestic product divided by midyear population. GDP 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. Data are in constant 2015 U.S. dollars	World Bank Development Indicators
urban	Urban population (% of total population)	40.257	14.920	14.118	77.160	Urban population refers to people living in urban areas as defined by national statistical offices. The data are collected and smoothed by United Nations Population Division.	World Bank Development Indicators
credit	Domestic credit to private sector by banks (% of GDP)	58.634	45.903	.069	166.504	Domestic credit to private sector refers to financial resources provided to the private sector by financial corporations, such as through loans, purchases of nonequity securities, and trade credits and other accounts receivable, that establish a claim for repayment. For some countries these claims include credit to public enterprises. The financial corporations include monetary authorities and deposit money banks, as well as other financial corporations where data are available (including corporations that do not accept transferable deposits but do incur such liabilities as time and savings deposits). Examples of other financial corporations are finance and leasing companies, money lenders, insurance corporations, pension funds, and foreign exchange companies.	World Bank Development Indicators; Asian Development Bank Key Indicators
GOV	Government expenditure (as % of GDP)	20.621	3.902	13.570	37.746	Expense is cash payments for operating activities of the government in providing assets, goods, and services. It includes compensation of employees (such as wages and salaries), interest and subsidies, grants, social benefits, and other expenses such as rent and dividends.	World Bank Development Indicators; International Monetary Fund Data Mapper
FDI	Foreign direct investment, net inflows (% of GDP)	3.000	2.432	-2.757	11.939	Foreign direct investment are 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.	World Bank Development Indicators
ODA	Net official development assistance received (% of GNI)	2.352	3.813	-.643	17.520	Net official development assistance (ODA) consists of disbursements of loans made on concessional terms (net of repayments of principal) and grants by official agencies of the members of the Development Assistance Committee (DAC), by multilateral institutions, and by non-DAC countries to promote economic development and welfare in countries and territories in the DAC list of ODA recipients. It includes loans with a grant element of at least 25 percent (calculated at a rate of discount of 10 percent)	World Bank Development Indicators

5. Results & Discussions

The empirical model shall be estimated using Pooled Mean Group Estimation. Before executing the PMG estimation, a series of tests shall be performed to check the stationarity of each variable and to validate the presence of a long-run relationship among them. Afterward, the results from the PMG estimation shall be presented together with the analysis and policy implication of the findings.

5.1. Panel Unit Root & Cointegration Test

The objective of this paper is to test not only if the financing sources have a significant impact on the emission level but also to check if there exists a long-run relationship among the variables. Before conducting the cointegration test, which validates if the variables have a long-run relationship, we first employ unit-root tests to check for stationarity. Two-unit root tests are utilized for this analysis: Im, Pesaran, and Shin (2003) test and the non-parametric Fisher type Augmented-Dickey Fuller (ADF) test. Both of these tests work under the null hypotheses of non-stationarity (i.e., presence of unit root) and with an alternate of stationarity (i.e., no unit root). IPS is based on the average of the test statistics for the unit root test in individual series by allowing nonstationary series for some cross-section units (Das, 2019). Fisher type, on the other hand, is based on p values and is simple, robust, and reports four test statistics. These tests shall reveal the level of integration of the variables. If the variable is stationary at its level, it is an I(0) variable; if the first difference of a nonstationary variable is stationary, the variable is said to be I(1).

Table 2 presents the panel unit root tests for the variables to be used in the study. The reported test statistics are based on the coefficient of the AR process. Most of the variables appear to be I(1) except for FDI which is stationary at level in all the tests whereas GOV appears to be stationary in the IPS test but not in the Fisher test. We also test the log form of GDP and CO2 and lnGPCsq as this is the form that we will be using in the study. As shown, lnCO2, lnGDP, and also lnGDPsq are stationary at first difference. Given that most variables to be used in the estimation are integrated at the same level i.e., I(1), we can proceed to do the cointegration test to test whether or not the variables have a long-run relationship.

Table 2 Panel Unit Root Test Results

Variables	Im, Pesaran & Shin Test	Fisher Test[a]			
		P	Z	L	Pm
Level					
lnCO2	0.2665	19.8067	0.1193	0.0432	1.5935*
lnGDP	0.8568	9.9935	0.8815	0.9220	-0.4096
lnGDPsq	1.5561	7.8257	1.5841	1.6510	-0.8521
urban	0.2035	16.8325	-0.0382	0.132	0.9864
credit	-0.6604	18.5459	-0.8609	-0.7095	1.3362*
GOV	-2.4669***	26.5281	-2.6964	-2.7277	2.9655
FDI	-2.9495***	29.2038***	-3.2569***	-3.1862***	3.5117***
ODA	-0.6035	18.3009	-0.5722	-0.8562	1.2862*
First Differenced					
lnCO2	-4.9827***	55.2022***	-5.4863***	-6.253***	8.8186***
lnGDP	-5.9583***	80.739***	-6.2725***	-9.1459***	14.0313***
lnGDPsq	-2.1318***	67.8262***	-5.8934***	-7.6698***	11.3955***
urban	-1.5525*	24.4142**	24.4142**	24.4142**	24.4142***
credit	-5.2216***	58.113***	-5.7293***	-6.6045***	9.4128***
GOV	-10.1048***	147.6957***	-10.5943***	-16.8782***	27.6988***
FDI	-8.8586***	119.949***	-9.4171***	-13.7067***	22.035***
ODA	-11.1025***	172.2774***	-11.3883***	-19.6882***	32.7165***

H_o : All panels contain unit roots
H_A : At least one panel is stationary

[a] P is the inverse chi-squared test statistic
Z is the inverse normal test statistic
L is the inverse logit test statistic
Pm is the modified inverse chi-squared test statistic
, **, * corresponds to significance at 10%, 5% and 1% level, respectively*

Cointegration tests are performed on non-stationary variables with the same level of integration. If a series that is a linear combination of I(1) variables is stationary, they are said to be cointegrated. To put it simply, while the variables may wander arbitrarily, the relationship between the variables may move together in the long run. Pedroni's (1999, 2004) test is used in this study based on the null hypothesis of no cointegration and alternative of variables being cointegrated in all panels. This test allows slope coefficients to be different across cross-sectional units and allows heterogeneity (Ullah & Awan, 2020). We will also employ the cointegration test by Kao (1999) as a robustness check.

Table 3 Cointegration Test Results

Dependent variable	lnCO2		
Independent variables	lnGDP lnGDPsq urban credit GOV FDI ODA		
Pedroni test statistics		Kao test statistics [b]	
Modified Phillips-Peron	2.346***	Modified Dickey–Fuller	-2.0777**
Phillips-Perron	-1.8698***	Dickey–Fuller	-1.2687
Augmented Dickey-Fuller	-2.3546***	Augmented Dickey–Fuller	-2.8098***
		Unadjusted modified Dickey-Fuller	-1.9192***
		Unadjusted Dickey-Fuller	-1.2046

H_o : No cointegration
H_A : All panels are cointegrated

[b] *without cross-sectional means*
, and *** corresponds to significance at 10%, 5% and 1% level, respectively*

The cointegration test results are shown in Table 3. Pedroni test provides three test statistics and as shown in the table, there is sufficient evidence of cointegration among the variables. As a robustness check, we also used the Kao test in complement to the Pedroni test. Three of the test statistics from the Kao cointegration test show that the variables exhibit a long-run relationship. We can assess that the variables have a significant long-run relationship.

5.2. Pooled Mean Group Estimation Results

Pesaran et al.'s (1999) Pooled Mean Group (PMG) dynamic panel data estimation shall be employed to estimate the empirical framework. There are two commonly used dynamic panel estimation techniques: mean group estimator which estimates separate equations for each group and does not account for across groups similarities in parameters and traditional pooled estimators, such as fixed and random effects where the intercepts can differ across groups while all the other coefficients and variances must be the same. PMG provides a middle ground between these two as it allows the intercepts, short-run coefficients, and error variances to vary among the groups but limits the long-run coefficients to be the same (Pesaran et al., 1999). Aside from its flexibility, PMG can be utilized even if the variables have different levels of integration, and long and short-run inferences can still be conducted even if cointegration is not detected through the formal cointegration tests (Asafu-Adjaye et al., 2016). This model is also utilized by other studies that examine CO2 emissions with income and other economic variables (Baek, 2016; Ullah & Awan, 2020; Asafu-Adjaye et al., 2016; Mert & Bölük, 2016; Arshad Ansari et al., 2020; Nasir et al., 2019).

In PMG estimation, the coefficient of the error-correction term determines the speed of adjustment and validity of the long-run relationship. This coefficient must be negative and statistically significant, as discussed earlier. The coefficient of the level variables would represent the long-run effects of the variables while the coefficients of the differenced variables are the short-run impacts. In addition, lnGDPsq i.e., the squared value of the lnGDP is added to the PMG estimation to factor in the EKC hypothesis testing.

Table 4 PMG and DFE Estimation Results

Dependent Variable	PMG Estimation lnCO2	DFE Estimation lnCO2
EC	-0.2884*	-0.0827***
	(0.1503)	(0.0130)
Long-run estimates		
lnGDP	5.1420***	6.4060**
	(0.8807)	(2.9862)
lnGDPsq	-0.3225***	-0.3336*
	(0.0586)	(0.1975)
urban	0.0312***	-0.0172
	(0.0063)	(0.0567)
credit	0.0003	-0.0045
	(0.0011)	(0.0091)
GOV	0.0072*	0.0438
	(0.0041)	(0.0763)
FDI	0.0088	0.0349*
	(0.0062)	(0.0207)
ODA	-0.0153	-0.1284**
	(0.0229)	(0.0613)
Short-run estimates		
ΔlnGDP	-14.2187	-0.3977
	(8.7851)	(1.3503)
ΔlnGDPsq	1.0148*	0.0543
	(0.6024)	(0.0808)
Δurban	0.0610	-0.0170
	(0.1051)	(0.0331)
Δdom_credit	-0.0002	0.0010
	(0.0028)	(0.0013)
ΔFDI	0.0027	0.0012
	(0.0033)	(0.0015)
ΔODA	-0.0104	-0.0206***
	(0.0069)	(0.0076)
ΔGOV	0.0009	-0.0013
	(0.0027)	(0.0056)
constant	-6.2196*	-2.3506*
	(3.2697)	(1.3419)
N	189	189

Figures in parentheses are the standard errors
, and *** corresponds to significance at 10%, 5% and 1% level, respectively*

Table 4 provides the PMG estimation results for the long-run and short-run estimates alongside the dynamic fixed estimation (DFE) results to enrich the results of the study. As previously stated, DFE requires that other coefficients and variances be the same across the groups. EC is the error-correction term and its corresponding coefficient represents the speed of adjustment. If the coefficient of this term is negative and significant, the validity of the long-run relationship between the variables is not rejected. The coefficients of the level variables represent the long-run impacts whereas the coefficients of the differenced variables capture the short-run influence. The variable lnGDPsq is the squared value of lnGDP and is used to test the EKC validity in the model. EKC is confirmed if the sign of lnGDPsq is negative and significant, particularly the level form indicating an inverse U-shaped relationship with the income variable and CO2 emissions in the long run.

We begin with the PMG results. The error correction term is negative and significant, indicating that the variables are exhibiting a long-run relationship. The coefficient for lnGDP and lnGDPsq are positive and negative, respectively, which means that the data shows an inverted u-shape relationship between income and CO2 emissions; hence, evidence of EKC is present, as in prior studies (Heidari et al., 2015; Saboori & Sulaiman, 2013; Adeel-Farooq et al., 2020). Urbanization has a positive impact consistent with other empirical works (Wang et al., 2016; Brahmasrene & Lee, 2017; Batool et al., 2021; Jermsittiparsert, 2021; Tarasawatpipat & Mekhum, 2021; Huang et al., 2021). In our estimate, a 1 percentage point increase in the ratio of urban population to total population increases CO2 emissions by 3.12%.

We now examine the significance of the interest variables. Government expenditure has a long-run influence at a 10% level and as shown, a 1 percentage point increase in government spending as a fraction of GDP can increase the CO2 emissions by 0.72% in the long run. The findings are similar to those of Mughal et al. (2021) implying that the public financing needs more emphasis on energy-efficient technology and renewable energy sources. This is consistent with the energy financing figures reported in Section 2 which show that massive public funds are devoted to non-renewable energy infrastructures. The scale effect of government expenditure is strongly visible. We can assess that ASEAN states do not alter the composition of their expenditure which induces CO2 emissions as the share of government expenditure intensifies, as based on the theory of López et al. (2011). This also signifies that across Southeast Asia, government initiatives in R&D for climate change mitigation may have been inadequate.

Table 5 PMG Estimation Results with Short-Run Coefficients per Country

		ASEAN Countries					
Variables	PMG Results	Indonesia	Lao PDR	Malaysia	Philippines	Thailand	Vietnam
EC		-0.6231***	-0.0554	-0.2599***	-0.0693	0.1140**	-0.8369***
		(0.1658)	(0.0760)	(0.0843)	(0.0765)	(0.0461)	(0.1679)
Short-run coefficients							
ΔlnGDP		-1.1142	-15.0409	-30.2260***	-5.7689	13.4533***	-46.6156**
		(16.4282)	(12.3556)	(10.1713)	(7.9403)	(4.0914)	(18.2325)
ΔlnGDPsq		0.0492	1.1455	1.7711***	0.4051	-0.7334***	3.4511***
		(1.0825)	(0.9076)	(0.5811)	(0.5175)	(0.2463)	(1.3224)
Δurban		0.0719	-0.2638**	0.0190	0.0291	-0.0167	0.5265
		(0.0768)	(0.1290)	(0.0316)	(0.0339)	(0.0108)	(0.3251)
Δcredit		-0.0016	-0.0116	0.0000	0.0094***	0.0009**	0.0018
		(0.0013)	(0.0106)	(0.0005)	(0.0023)	(0.0004)	(0.0011)
ΔGOV		0.0054	-0.0059	0.0098***	-0.0064	0.0039**	-0.0014
		(0.0046)	(0.0091)	(0.0030)	(0.0102)	(0.0018)	(0.0035)
ΔFDI		0.0091	-0.0061	0.0096***	0.0080	0.0038	-0.0083
		(0.0079)	(0.0156)	(0.0035)	(0.0092)	(0.0024)	(0.0051)
ΔODA		-0.0294	-0.0348**	0.0032	-0.0017	-0.0001	0.0002
		(0.0257)	(0.0168)	(0.0214)	(0.0216)	(0.0172)	(0.0112)
Long-run coefficients							
lnGDP	5.1420***						
	(0.8807)						
lnGDPsq	-0.3225***						
	(0.0586)						
urban	0.0312***						
	(0.0063)						
credit	0.0003						
	(0.0011)						
GOV	0.0072*						
	(0.0041)						
FDI	0.0088						
	(0.0062)						
ODA	-0.0153						
	(0.0229)						
constant		-13.5040***	-0.9971	-5.4195***	-1.5341	2.3625**	-18.2255***
		(4.1167)	(1.7458)	(1.7354)	(1.7251)	(1.1281)	(5.1837)
N	189	189	189	189	189	189	189

Figures in parentheses are the standard errors
, and *** corresponds to significance at 10%, 5% and 1% level, respectively*

As for the other variables, domestic credit and FDI are positive in sign although not statistically significant. ODA, on the other hand, has exhibited an inverse relationship with CO2 emissions, although insignificant. None of the short-run dynamics in our variables are significant except for lnGDPsq which is positive.

There are more significant long-run coefficients in the DFE estimation, where the estimators and variances are constrained to be the same across units. Similar to the PMG results, the coefficient of the error correction term is negative and significant indicating the existence of a long-run relationship, The EKC theory is also confirmed based on the signs and significance of both lnGDP and lnGDPsq which complements the PMG estimates.

In terms of interest variables, the estimates show that ODA and FDI have a significant long-run impact at 10% and 5% levels, respectively. FDI is shown to induce CO2 emissions similar to other works (Baek, 2016; Nasir et al., 2019; Ullah & Awan, 2020; Eriandani et al., 2020) with a 1 percentage point increase in the FDI leading to a 3.49% increase in CO2 emissions. This solidifies the pollution haven hypothesis implying that the region's FDI initiatives attract polluting and/or fossil fuel industries.

ODA is shown to have decreasing impact on the CO2 emissions based on the DFE estimates. The long-run impact of a 1 percentage point increase in ODA reduction in CO2 emissions by 12.8%. The short-run dynamics of ODA is also significant and negative and provides an impact of a 2.06% decrease in carbon emissions for every 1 percentage point increase in ODA. These findings are reflective of the high inflow of funds coming from multilateral organizations and international development banks into hydropower projects as discussed in Section 2. These institutions are also active in providing funding and other financial grants for projects related to sustainability and energy efficiency.

PMG also has an option to specify the cross-section regression results for short-run coefficients. Country-specific short-run coefficients are shown in Table 5. Starting with Laos, urbanization and ODA promote a reduction in carbon emissions. While the ODA is consistent with the other findings, urbanization tends to be the reverse as compared to other studies. For Malaysia, FDI and government expenditure have short-run positive impact on CO2 emissions. In addition, income is significant and exhibits an inverted EKC trend with a positive coefficient of the lnGDPsq.

In the case of the Philippines, domestic credit is found to have a positive influence on carbon emissions. Government spending and domestic credit are positively significant in Thailand alongside income which exhibits EKC in the short run. For Vietnam, income is significant however the trend exhibits an inverted EKC. Meanwhile, none of the variables are significant in the short run for Indonesia. In summary, income variables tend to have varying signs and directions, and financing variables exhibit different levels of significance across countries.

5.3. Policy Implications

This section shall illustrate the existing programs and policy recommendations that are relevant to the empirical findings of this study. Policies that are currently in place in ASEAN to encourage renewable energy investment will be examined to acquire a deeper understanding of the regulatory environment and to identify potential areas for improvement. The researcher also used the information and other lessons learned from his internship to formulate policy proposals for strengthening the renewable energy sector's financing. While the internship focused on developing policies that can generate green jobs, one of the key takeaways that emerged from this internship is that green employment growth requires expansion in the renewable energy sector which is the ultimate policy goal of this study.

As presented in Section 2, the public sector is the biggest player in the energy infrastructure in the region, funding both the fossil fuel and renewable energy sectors. The findings indicate a gap in public investment in assets and projects that can aid in climate change mitigation. Furthermore, mobilization of public funds to the fossil fuel industry is almost unavoidable considering that the largest players in the oil and gas market in the ASEAN are the state-owned entities such as Petronas of Malaysia, PTT Public Company of Thailand, PT Pertamina of Indonesia, and Petrovietnam in Vietnam. This warrants stronger infrastructure planning and greater fiscal allocation for the renewable energy sector and also for the water and waste management sector as these two are key contributors to greenhouse gas mitigation. Public investment in mass transportation systems should also be buoyed up to address the rising car ownership and usage which exacerbates the current level of GHG emission. The ASEAN states should also increase their spending on R&D, particularly in the field of clean energy to ensure the long-term progression and technological advancement of the sector.

Fiscal instruments such as tax incentives, grants, and loan subsidies are also part of the financing arm of the government to encourage investment in renewable energy and other clean energy technology. ASEAN states are already implementing some of these programs. For example, the Malaysian government offers a subsidy of 2% on the interest payments on green infrastructure projects alongside tax incentives and exemptions on clean energy assets, projects, and services. Feed-in-tariff (FIT), a purchase agreement that provides a specific price for every kilowatt-hour of electricity generated, is also being rolled out in Indonesia, Malaysia, Philippines, Thailand, and Vietnam for hydro, solar PV, wind, biomass, biogas, geothermal and waste energy projects. However, challenges remain for FIT such as FIT's unattractiveness to some technologies, the lengthy permit application, and regulatory changes (ACE, 2018). Despite these initiatives, one setback among the policies being implemented in the region is the fossil fuel consumption subsidy which is still considerably sizeable. ASEAN states provided around USD 35 billion, equivalent to around 0.5% of its GDP in 2018 despite the recent reforms and lower fuel import costs (IEA, 2019). Greater efforts shall be implemented to further reduce fossil fuel subsidies and in the long run eventually be eliminated.

FDIs are also proven to contribute to CO2 emissions in the region. This is not surprising given that most international project financings were directed to infrastructure-related projects in the fossil fuel industry. From 2018 to 2020, the oil and gas sector received the largest share of the total international project finance at 17.1% and the power sector at 11.1%; in contrast, the renewable power industry received 16.9% (ASEAN & UNCTAD, 2021). Nevertheless, foreign investors and multinational enterprises still play an important role in digitalization and Industry 4.0 transformation which can help in reducing energy inefficiencies and promote decarbonization.

As a result, it is critical to attract and redirect FDI inflows into the renewable energy sector. Measures such as FIT, tax incentives, and renewable portfolio standards (RPS) were shown to attract FDI in the clean energy sector globally (Wall et al., 2018). While FIT and tax incentives are being implemented across the ASEAN countries, RPS is relatively new with the Philippines as the pioneer in rolling out such policy.

Foreign aid, and in general funding from multilateral organizations and other states is empirically shown to help in CO2 emission mitigation in the region. And in the wake of the COVID-19 pandemic, development assistance has been on the rise again for many ASEAN states with the help to stimulate the economy and rollout pandemic responses. In the context of decarbonization in the region, the proceeds of these aids must be directed towards sustainability projects and climate-change mitigation initiatives. A good practice that could be adapted is standard reporting and monitoring of grants and other aid proceeds related to sustainability at the recipient level. The evaluation of the sustainability and climate change impacts of aid proceeds, regardless of the purpose of the aid, could be institutionalized to encourage donors and project managers to incorporate sustainability aspects into their initiatives.

While domestic credit has no significant effect based on the regression results, there still is room for growth within the policy space to encourage credit for green financing. Singapore, for example, has started offering grants on green and sustainability-linked loans for borrowers to access the credit market of Singapore. The grant shall cover costs related to external review and validation of the green and sustainability credentials of the loan. Expenses by financial institutions related to developing green and sustainability frameworks for small to medium enterprises shall also be covered. Malaysia, as stated earlier, is also providing grant schemes to lower borrowing costs for green projects. Green and sustainability-linked loans are also on the rise, particularly for the solar PV industry.

The green bond market is also one of the most promising avenues for increasing credit for green and sustainability projects. Green bonds have been growing in the region since their first issuance in 2016 and there are certainly more areas for improvement. For example, the energy sector in ASEAN received only 33% of the total bond proceeds in contrast to the global level which is at 38%. Most of the green bond proceeds were allocated to green building construction, which is at 44%, a far higher figure that the world level of 18% (Kapoor et al., 2020). This is not disappointing since the building sector is one of the major CO2 emitters (24%) and final energy consumers (23%) in the region (IEA, 2022). Nonetheless, demand for green bonds for renewable energy projects can be ramped up through information provision, regional cooperation on green bond standards, and financing cost subsidies similar to Singapore's Sustainable Bond Grant Scheme.

All of these green finance initiatives require expertise and institutional adoption of environmental, social, and governance metrics (ESG) in the region. In Asia-Pacific, corporates are already displaying a high level of ESG disclosure although gaps are still present in ESG reporting. ESG metrics are also not standard in ASEAN and ESG professionals are still lacking in number.

6. Conclusions

ASEAN is experiencing one of the highest economic growths across the world alongside increasing urbanization, higher mobility, and structural transformation. In connection to this, a concern for rising carbon emissions and long-term energy sustainability has emerged due to strong dependence on fossil fuel resources in both consumption and energy production. Thus, a need for more investment in renewable energy has emerged. An analysis of how financing sources can influence CO2 emissions is one way of improving the level of energy financing within the region.

In this study, we investigated the impact of financing sources on carbon emissions in the ASEAN region. Four financing source variables were used in this study namely domestic credit, government expenditure, FDI, and ODA based on existing literature. Using data from 1986 to 2018 from six Southeast Asian countries i.e., Indonesia, Laos, Malaysia, Philippines, Thailand, and Vietnam, a panel data analysis was conducted through PMG estimation alongside DFE to enrich the results. Stationarity and cointegration tests were conducted prior to the estimation to validate the presence of unit root and long-run relationship among the chosen variables.

The long-run relationship among the variables was confirmed based on the cointegration test. This finding was complemented by PMG and DFE estimates based on the respective error-correction coefficient results being negative and statistically valid. EKC relationship between income and CO2 emissions is also confirmed. Among the interest variables, government expenditure and FDI are validated to induce carbon emissions in the long run whereas ODA is found to reduce CO2 emissions in both the short-term and long-term. Meanwhile, there was insufficient evidence to support the impact of domestic credit on CO2.

Based on the empirical results, an analysis of the policy implications was carried out to provide recommendations that can help induce the presence of each financing source in investing in the renewable energy industry and other sustainable initiatives. Existing policy measures and incentives in ASEAN are presented and examined to highlight the potential areas for improvement in the policy-making space. Several policy challenges in increasing the financing for the clean energy sector were also identified.

Moving forward, one aspect which can be explored as well as provide a closer examination of the financing aspect of energy is by conducting research with project level as the unit of analysis. While this study provided sound results with policy implications that are strongly relevant to the current state of the region, this study was limited to the countries as the unit of analysis which may not be able to unravel some micro-level aspects of energy financing. A study with infrastructure projects as units of analysis can uncover several interesting parts such as cost of financing, rate of return per project, the value of CO_2 emissions saved per money invested, etc. It can also reveal a more detailed classification of the projects being financed by each financing source i.e., whether the projects being financed are “green” or “dirty”. Findings from a micro-level study shall be able to complement the mostly macro-level empirical results and recommendations in this paper.

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Addendum

The final thesis has slightly deviated from the initial thesis assignment due to a lack of available data and resources. During the early stages of the research, the researcher realized that the available data for green bonds in Southeast Asia is insufficient, given that such debt facilities were only introduced in 2016. Furthermore, some information is only available through subscriptions or paid databases. The researcher recognized the constraints in data, time, and resources, and that he may not be able to deliver the required quantitative analysis to address the specific research questions that the initial thesis assignment requires. Thus, he opted to take a broader perspective and conduct research on financing sources rather than focusing solely on energy debt financing or green bonds. Nevertheless, the final thesis remains consistent with the general goal of the thesis assignment, which is to examine the impact of financing on CO2 emissions. The researcher's supervisor was notified of these matters and has approved these changes.