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

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Abstract

This paper investigates the impact of financing sources on carbon emissions in Southeast Asia 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, foreign direct investment FDI, and foreign aid. 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 environmental Kuznets curve 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 foreign aid is found to have an inverse effect on CO2 emissions in both the short and long run.

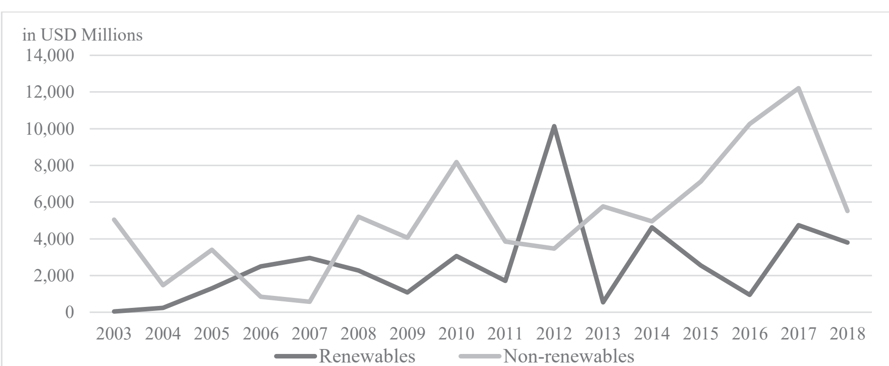
Keywords: Carbon emissions, ASEAN, Pooled Mean Group estimation, environmental Kuznets curve

1. Introduction

Southeast Asia is one of the fastest-growing regions in the world. The region progressed with income per capita increasing at a fast pace combined with rapid urbanization, higher mobility, and structural transformation. Along with this expansion is the enormous rise in the energy demand in the region. The increasing energy demand has profound repercussions on the carbon emissions of the ASEAN as the region is highly dependent on non-renewable sources such as coal and natural gas. In 2019 for example, 77% of the total energy generated in the region was from the coal (43%) and natural gas (34%) sectors.

Financing the renewable energy sector is one of the critical elements to decarbonizing the region. Rolling out decarbonization strategies and adopting low-carbon technologies will necessitate massive capital outlays, extensive research, and rigorous training of the talent pool. Financing addresses climate change mitigation through funding investments in renewable energy production, usage of technologies to improve energy efficiency, and support for clean energy and sustainability research. In order to meet ASEAN's renewable energy target, it is predicted that over USD 290 Billion will be required (IRENA, 2018).

Figure 1. Investment flows in renewable and non-renewable energy sector in Southeast Asia, 2003-2018

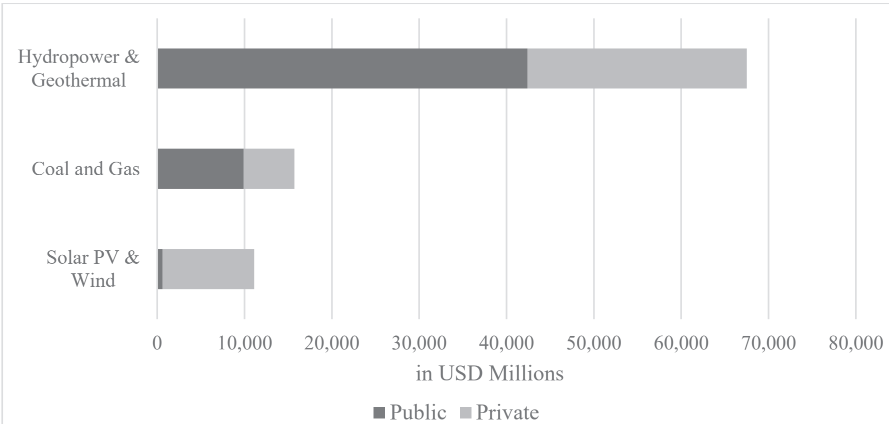


Source: World Bank Private Participation in Infrastructure (PPI)

We begin by looking at the financing trends between renewable and non-renewable sectors as presented in Figure 1. A notable observation is a rising trend in the non-renewable energy sector starting from 2008 due to higher investment in the coal sector, reflecting the region's dependence on coal particularly for power generation. Furthermore, a large gap between the clean and fossil fuel sectors can be observed between 2016 and 2017 when the inflow of funds to coal projects exceeded USD 10 Billion annually. Renewable energy production, on the other hand, has been growing more slowly and is mostly driven by hydropower projects, with a notable increase in 2012 attributed to a USD 6 Billion investment in Laos.

Both the public and private sectors have significant roles in financing the energy sector of the region. Figure 2 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 in 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. The public sector is active in both the non-renewable and clean energy sectors. Large-scale projects such as those in the hydropower, coal, and gas sectors require massive upfront capital spending, hence public finance is common in these industries.

Figure 2. Sources of finance for power generation investment in ASEAN by year of final investment decision in USD Billions, 2014-2018



Source: International Energy Agency (2019)

On the other hand, the private sector is more heavily involved in solar and wind energy investment, making up 95% of total investment in these energy sectors through foreign direct investment (FDI) and private capital (IEA, 2019). The private sector is more active in these industries due to the cost-competitiveness of these technologies. Both domestic and international banks are participating in the financing energy sector through debt fundraising with a strong presence in Malaysia, the Philippines, Singapore, and Thailand. Equity financing, meanwhile, is ushered through investments from holding companies such as B. Grimm Power, Blue Circle, Sindicatum Renewable Energy Company, and others (ADB, 2021).

There is an intensifying need to diversify the region's energy sources through renewables. One way to improve the level of renewable energy financing within the region is to analyze how financing sources can influence CO2 emissions. This shall be the primary motivation of this study. Based on the existing studies on determinants of carbon emissions, this research paper will analyze four financing sources: domestic credit, public financing, foreign direct investment, and foreign aid. These variables will encompass the available financing in the region that 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 financing sources on carbon emissions in Southeast Asia in light of the region's rising income.

A contribution of this research to the existing empirical works on carbon emissions in ASEAN is that it addresses the conflicting theories regarding each finance source's influence on CO2 emissions. For example, public investment can reduce carbon emissions via research and development on green and sustainability projects; however, greater government spending can also lead to the higher overall consumption of fossil fuels. Increased private funding through domestic credit, on the other hand, can encourage the use of carbon-intensive goods but can also support the utilization of renewable energy and other energy-saving technologies. Similarly, inflows from both FDI and foreign aid operate through different mechanisms, which may result in an ambiguous effect on carbon emissions.

Another contribution of this study is the addition of foreign aid as an interest variable, which is a novelty in comparison to other works that explored the environmental Kuznets curve (EKC) phenomenon in Southeast Asia. In addition, most empirical studies on EKC in ASEAN have focused on ASEAN-5 (Indonesia, Malaysia, Philippines, Thailand, and Singapore). The inclusion of Laos and Vietnam will enrich the results of this study given the rise of energy financing in these countries in recent years (ADB, 2021). Lastly, the findings of this work will provide potential policy insights toward increasing renewable energy financing in the region.

2. Literature Review

Analyzing financial flows is one of the key mechanisms in understanding CO2 emissions. If funds flow into investing in non-renewable energy sources and/or consuming polluting goods and services, CO2 emissions will rise. Consequently, the reduction in greenhouse gas (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 originating 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, e.g., asset purchases and subsidies.

Foreign aid and foreign direct investment can be classified under foreign financing, which inflows from outside 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, merger, 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.

In this literature review, studies relating to the impact of these financing sources will 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 will initially be presented to provide a deeper understanding of how increasing income can influence carbon emissions, which is extremely relevant in the context of growing ASEAN.

2.1 Economic growth and CO2 emissions

Numerous studies have used the environmental Kuznets curve model in analyzing the relationship between economic growth and carbon emissions. The EKC is a theorized relationship between income and environmental quality that states pollution emissions tend to increase in the initial stages of economic growth until they reach a peak which then leads to a reversal leading to improvement in environmental quality as income continues to grow.

The empirical existence of EKC in ASEAN has not been unanimous. Chandran and Tang (2013) found that the U-shaped conventional EKC curve does not apply to the ASEAN-5 (Indonesia, Malaysia, Philippines, Singapore, and Thailand), while there is bi-directional long-run causality between economic growth and CO2 emissions in Indonesia and Thailand. Zhu, Duan, Guo, and Yu (2016) found no evidence for EKC as well. Similarly, Kisswani, Harraf, and Kisswani (2019) tested EKC for the ASEAN-5 countries and also concluded that EKC is not present. In contrast, Heidari, Katircioğlu, and Saeidpour (2015) were able to validate the presence of the EKC curve from the ASEAN-5, and Saboori and Sulaiman (2013) found evidence of EKC between carbon emissions and economic growth in Singapore and Thailand. Adeel-Farooq, Raki, and Adeleye (2020) utilized methane emissions as a proxy for environmental degradation among six ASEAN countries; the study revealed that the EKC hypothesis is valid. Salman, Long, Dauda, Mensah, and Muhammad (2019) also confirmed EKC with ASEAN-5 plus Brunei and Vietnam. Several works, albeit not employing the EKC model, found economic development to have a positive impact on CO2 emissions in the region (Magazzino, 2014; Khan, Panigrahi, Almuniri, Soomro, Mirjat, & Alqaydi, 2019; Nasir, Duc Huynh, & Xuan Tram, 2019). Conversely, Lee and Brahmasrene (2014) found an inverse bi-directional relationship between economic growth and CO2 emissions.

2.2 Domestic credit and CO2 emissions

Domestic credit has an essential role in countries' decarbonization processes, but the link between credit and environmental quality may be inconclusive. Higher credit can encourage the use of energy-intensive goods and services leading to an increase in energy consumption and environmental degradation (Zhang, 2011). However, it can also support the development of the renewable energy sector with several empirical works showing that domestic credit has a beneficial effect on renewable energy consumption. (Samour, Baskaya, & Tursoy, 2022; Shahbaz, Topcu, Sarıgül, & Vo, 2021; Anton & Nucu, 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, evidenced by Phong (2019) using data from ASEAN-5 countries. Nawaz, Ahmad, and Hussain (2020) found similar results with carbon emissions and domestic credit having a positive relationship using nine ASEAN countries. Conversely, Rasiah, Guptan, and Habibullah (2018) assessed that domestic credit is not a significant factor in determining carbon emissions in the same region. Zhu et al. (2016) did not find domestic credit to reduce CO2 emissions in the ASEAN-5.

2.3 Public financing and CO2 emissions

Public financing is a major source of energy investment in the region. There are four mechanisms by which public expenditure can impact the environment: scale effect, composition effect, technique effect, and income effect (Le & Ozturk, 2020). The 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, Galinato, and Islam (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 and Ozturk (2020) also 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 toward public goods reduces pollution, but increasing government expenditure without changing its composition has no effect. Bernauer and Koubi (2013), on the other hand, examined 42 countries and concluded that government spending is inversely related to environmental quality after controlling for governance quality. In a sample of 77 countries, Halkos and Paizanos (2013), did not find a significant impact of government spending on CO2 emissions but found evidence of its negative impact on SO2.

2.4 Foreign direct investment and CO2 emissions

FDIs serve a vital role in financing both the renewable energy sector and the fossil fuel industry, particularly in developing countries; it is also an important element in integrated economies where the movement of capital is high. 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, Rasoulinezhad, and Luong Thi Thu (2022), who found that FDI can induce green growth. On the other hand, Baek (2016) found the reverse using datasets from ASEAN-5 countries, proving the pollution haven hypothesis. This is similar to the findings of Nasir et al. (2019), Ullah and Awan (2020), and Eriandani, Anam, Prastiwi, Nyoman, and Triani (2020). Meanwhile, Chandran and Tang (2013) found no evidence of FDI's significance as a determinant of CO2 emissions in the ASEAN-5.

2.5 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, Hübler, & Nunnenkamp, 2013). Foreign aid can also incentivize recipients in investing in environmentally friendly technologies through regular reporting of financing proceeds to donor institutions as part of the grant agreements. In addition, satisfying these targets can help the recipients secure more grants in the future which typically have lower borrowing costs than the usual credit facilities in the market. 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), Ikegami and Wang (2021), and Kibri (2022) found complementary results showing that foreign aid can reduce recipients' CO2 emissions. Meanwhile, Bhattacharyya, Intartaglia, and McKay (2018) found no evidence of energy-related impact with emissions. Similarly, 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.

3. Empirical Strategy

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. Then, we will present the dynamic estimation method that will be used to estimate the econometric model—the panel Autoregressive Distributed Lagged (ARDL) model—and the corresponding dataset.

3.1 Econometric model

We model CO2 emissions as a function determined by financing sources using the variables based on the existing literature. Domestic credit will be the proxy for inflows from private domestic sources, similar to other studies that used the variable for domestic financial development. Public funding will be captured by government expenditure, while FDI will represent funding from private multinational enterprises (MNEs) and companies. Foreign aid or inflows from multilateral organizations and other state entities, on the other hand, will be represented by net official development assistance. These will 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, and EKC hypothesis testing will also be incorporated similarly to other studies with ASEAN as the reference region. Urbanization will 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, Chen, & Kubota, 2016; Brahmasrene & Lee, 2017; Batool et al., 2021; Jermsittiparsert, 2021; Tarasawatpipat & Mekhum, 2021; Huang, Sadiq, & Chien, 2021). Urban cities also consume a vast portion of the world's energy supply, and man-made heat emissions from buildings, air conditioning, transportation, and industries are usually higher in urban areas.

Finally, the empirical framework shall be modelled as follows:

$$CO2_{it} = f(GDP_{it}, urban_{it}, credit_{it}, GOV_{it}, FDI_{it}, ODA_{it},) \quad (1)$$

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 official development assistance received as a percentage of GNI. Here, *i* refers to the country, and *t* refers to the year.

To estimate the empirical framework, we will be utilizing a panel data model with dynamic specification, in particular, the ARDL model. 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, Shin, Smith, and Hashem (1999), a panel dataset that has time periods, t= 1, 2, …. T, and countries, i=

1,2,….,N, can be modelled into a general ARDL function:

$$y_{it} = \sum_{j=1}^{p} \lambda_{ij}\, y_{i,t-j} + \sum_{j=0}^{q} \delta'_{ij}\, X_{i,t-j} + \mu_i + \varepsilon_{it} \qquad (2)$$

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. J. Z., Khan, M. K., Khan, M. I., Chishti, M. Z., & Khan,

The above model can be transformed into the below as shown by Teng, Khan, Khan, Chishti, and Khan (2021):

$$\Delta y_{it} = \Phi_i(y_{i,t-1} - \theta'_i X_{i,t-1}) + \sum_{j=0}^{p-1} \lambda^*_{ij} y_{i,t-1} + \sum_{j=1}^{q-1} \delta'^*_{ij} \Delta X_{i,t-j} + \mu_i + \varepsilon_{it} \qquad (3)$$

where

$$\Phi_i = -(1 - \sum_{j=1}^{p} \lambda_{ij}) \qquad (4)$$

$$\theta = \sum_{j=0}^{q} \frac{\delta_{ij}}{1 - \sum_k \lambda_{ik}} \qquad (5)$$

$$\lambda^*_{ij} = -\sum_{m=j+1}^{q} \lambda_{im}, j = 1,2, \dots, p-1 \qquad (6)$$

$$\delta^*_{ij} = -\sum_{m=j+1}^{q} \delta_{im},\ j = 1,2, \dots, q-1 \qquad (7)$$

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 are the long-run effects, while the coefficients of the differenced variables are the short-run effects.

3.2. Data

This study will cover a period of 32 years, from 1986 to 2018, and include six ASEAN member countries, i.e., Indonesia, Lao PDR, Malaysia, Philippines, Thailand, and Vietnam. The selection of the countries and the time period are based primarily on data availability, and data were collected from World Bank Development Indicators, International Monetary Fund Data Mapper, and Asian Development Bank Key Indicators for Asia and the Pacific.

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 since 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, 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.

4. Results & Discussions

The empirical model will be estimated using Pooled Mean Group (PMG) estimation. Before executing the PMG estimation, a series of tests will 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 will be presented together with the analysis and policy implications of the findings.

4.1. 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 a long-run relationship exists 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: the Im, Pesaran, and Shin (IPS) (2003) test and the non-parametric Fisher-type Augmented-Dickey Fuller (ADF) test. Both tests work under the null hypotheses of non-stationarity (i.e., presence of unit root) and with an alternative of stationarity (i.e., no unit root). The 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). The Fisher test, on the other hand, is based on p values and is simple, robust, and reports four test statistics. These tests 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 1. 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***

Notes: 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; and Pm is the modified inverse chi-squared test statistic. *, **, *** correspond to significance at 10%, 5%, and 1% level, respectively.

Table 1 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 use in the study. As shown, lnCO2, lnGDP, and 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.

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. Simply put, 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 the alternative of variables being cointegrated in all panels. This test allows heterogeneity and for coefficients to be different across cross-sectional units (Ullah & Awan, 2020). We will also employ the cointegration test by Kao (1999) as a robustness check.

Table 2. 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

Notes: H_o: No cointegration; H_A: All panels are cointegrated; and [b] without cross-sectional means. *,**, and *** correspond to significance at 10%, 5%, and 1% level, respectively.

The cointegration test results are shown in Table 2. The 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.

4.2. Pooled Mean Group Estimation Results

Pesaran et al.'s (1999) PMG dynamic panel data estimation was used 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, Byrne, & Alvarez, 2016).

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 coefficients of the level variables 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 3. PMG and DFE estimation results

Dependent Variable	PMG Estimation	DFE Estimation
	lnCO2	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)
Δcredit	-0.0002	0.0010
	(0.0028)	(0.0013)
ΔGOV	0.0009	-0.0013
	(0.0027)	(0.0056)
ΔFDI	0.0027	0.0012
	(0.0033)	(0.0015)
ΔODA	-0.0104	-0.0206***
	(0.0069)	(0.0076)
constant	-6.2196*	-2.3506*
	(3.2697)	(1.3419)
N	189	189

Notes: Figures in parentheses are the standard errors; *,**, and *** correspond to significance at 10%, 5%, and 1% level, respectively.

Table 3 provides the PMG estimation results for the long-run and short-run estimates alongside the dynamic fixed estimation (DFE) results to enrich the findings 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, indicating an inverse U-shaped relationship between 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 coefficients for lnGDP and lnGDPsq are positive and negative, respectively, which means the data show an inverted U-shaped 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; in our estimate, a 1 percentage point increase in the ratio of urban population to total population increases CO2 emissions by 3.12%.

Moving on to 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 CO2 emissions by 0.72%. The findings are similar to those of Mughal et al. (2021) implying that public financing needs more emphasis on energy-efficient technology and renewable energy sources. The results also show the scale and composition effect of public spending on environmental degradation. This is consistent with the energy financing figures reported which show that massive public funds are devoted to non-renewable energy infrastructures. For example, in 2018, fossil fuel subsidies in ASEAN went as high as USD 35 Billion, equivalent to around 0.5% of the GDP of the region (IEA, 2019).

As for the other variables, domestic credit and FDI are positive in sign although not statistically significant. ODA, on the other hand, exhibits an inverse relationship with CO2 emissions, although insignificant. None of the short-run dynamics in our variables is 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. Like 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 the 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 in the long run. This solidifies the pollution haven hypothesis implying that the region's FDI initiatives and regulatory environment attract polluting and/or fossil fuel industries. 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 only 16.9% (ASEAN & UNCTAD, 2021).

ODA is shown to have decreasing impact on CO2 emissions based on the DFE estimates, confirming that the incentive mechanisms surrounding foreign aid can reduce environmental damage. The long-run impact of a 1 percentage point increase in ODA is a reduction in CO_2 emissions by 12.8%. The short-run dynamic 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. The findings are in line with the high presence of multilateral organizations and international development banks in geothermal and hydropower projects (ADB, 2021). These institutions are also active in providing funding and other financial grants for projects related to sustainability and energy efficiency.

5. Conclusions

This paper 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. An EKC relationship between income and CO_2 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 CO_2 emissions in both the short term and long term. Meanwhile, there was insufficient evidence to support the impact of domestic credit on CO_2.

The results of this research indicate that redirecting these financing flows toward the clean energy sector is needed. Fiscal instruments such as tax incentives, grants, and subsidies can be used to empower public spending on renewable energy technologies. Greater efforts in reducing fuel subsidies should also be carried out and, in the long run, be eventually eliminated. Meanwhile, measures such as feed-in-tariff, renewable portfolio standards (RPS), and other tax incentives were shown to attract FDI in the clean energy sector globally (Wall, Grafakos, Gianoli, & Stavropoulos, 2018).

As for the findings on foreign aid, ASEAN states could design financing schemes or incorporate incentive mechanisms that are similar to what is being implemented by the international development agencies to guarantee the greening of the economy. In addition, 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. Regarding domestic credit, the results indicate that it has no significant impact; however, there is still room for expansion within the policy framework by promoting the markets for green/sustainable loans and bonds through information dissemination, regional collaboration on green bond standards, and financing cost subsidies.

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