Probing the Nexus of Trade, FDI, HDI, Non-renewable Energy, Subsidy and Globalization on Carbon Emission in ASEAN Countries: Evidence from Panel Estimations

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Abstract. Devastating and excessive carbon emission leading to climate change has been the utmost concern globally, with not being limited to estimate its most fitting countermeasures to mitigate but also gauging the exact parameters that become the antecedent. Rapid progress of globalization, high demand of trade, robust flow of FDI and subsidy, firm dependence on non-renewable energy sources and the quality of human capital were being evaluated and analysed, becoming the purpose of this paper, to determine which of those have a significant linkage with the increase of carbon emission. Six of developing countries of ASEAN (Cambodia, Indonesia, Malaysia, Philippines, Singapore, and Thailand) from year 2010 to year 2019 were processed as the panel data which was tested with the Lagrange multiplier and Chow test before being calculated with pooled least square (PLS) and fix effect model (FEM) after figuring out the irrelevancy of employing random effect model (REM and ARDL model as the research approach. This study, in agreement with The Environmental Kuznets Curve (EKC) hypothesis, found that all exogenous variables have a significant effect on carbon emission, except non-renewable energy, which means the switch from traditional or oil-based energy sources to renewable ones have been adequately applied. Based on the findings, corresponding recommendation and suggestions were presented at the end to diminish the intensity of carbon in selected ASEAN countries.

Keywords: Carbon emissions · FDI · HDI · Globalization · Panel estimations

1 Introduction

It is paramount for each country as a part of global to have some countermeasures and strategies to climate mitigation in accordance with Paris agreement, eliminating the worst possibility of climate change impact in which comprehensive structural transformation on the global system of production is required. Energy transition, use of land, infrastructure, systems of industry, and urban must be rapidly developed to be more energy-efficient to set a 1.5 °C warming temperature and downscale carbon emissions with number of broad prevention schemes, being associated with fundamental investment increase.

Y. A. Yusran et al. (Eds.): BIC 2022, AEBMR 235, pp. 69–80, 2023.
https://doi.org/10.2991/978-94-6463-140-1_8

To effectively mitigate climate change, grasping how greenhouse gas (GHG) emissions might be associated with other macroeconomics variables is necessary inasmuch as governments which all policies are rooted would be the utmost principle stakeholders. By accurately measuring the link amongst all variables with GHG emissions, all related stakeholders, especially government could set more effective ecological policies that will not only considerably incentivize the economic growth while sustaining environmental preservation, but also ensure the well-being of its citizens.

Green technologies absorption should not only be implemented with environmental taxation, but also be promoted with subsidies. However, Li et al. [1] argued that what confused governments was what to employ to have more efficient production results between the subsidy of green product and green innovation, underlining that both would be greater in impacting social welfare when the cost of both were low.

Being initially aimed to also gauge the short-term significant variables impacting GHG, the model was not valid when being tested with ECM (Error Correction Model) approach and random effect model due to the significant coefficient of the residuals. As a result, PLS-FEM model was chosen to be employed in figuring out the findings. This paper sheds light on how in long-term, carbon emissions is influenced by subsidy, FDI, human capital, globalization level, trade and rate of non-renewable energy use, with the objective to help estimating carbon mission extent and its proper preventive measures in which it, thus, could be well-controlled by specifically designing more desirable and appropriate policies fitting the variables' significance influencing its fluctuation. Apart from the introduction, the remainder of this paper proceeds along these lines. Literature review is concisely presented in Sect. 2, whilst Sect. 3 depicts the study area, variables in use and the specification of the model. Elaborating the results and discussion in Sect. 4, the last section which is Sect. 5 sets forth the policies recommendation and conclusion.

2 Literature Review

Studies previously investigating that the increase of foreign direct investment were not always in line with the increase of greenhouse gas emissions. This, furthermore, settled a legitimacy confirming a long run sustainability for the stakeholders as an evidence of halo hypothesis. Shao [2] added that halo effect might only be achieved through foreign direct investment in high-income to low-income countries only when they chose the investments with stronger protection policies toward environment, while specializing in eco-friendly products at once. In contrast, Teng et al. [3] found a contradicting result, that foreign direct investment negatively affected the environment owing to the less initiative from the investors, especially in developing countries which relied strongly on more intensive polluting industries [4].

Despite being perceived to not be able to suppress the environmental pollution in the short-run, Alvarado et al. [5], Opoku et al. [6], Pata & Caglar [7], and Pervaiz et al. [8], revealed that carbon emission and fossil fuels consumption could be reduced, improving generally the environment, if the rate of education along with real income were both empowered, elevating citizens life expectancy in the long run. Accordingly, environmental degradation might diminish with higher HDI which led to relatively a higher level of income with the awareness to fulfil environment-based sustainability

goals. Liu et al. [9] confirmed a negative causality between HDI and carbon emission that was unidirectional, implying the harms of the later toward wellness and health of human. China witnessed an increase of carbon emission as the result of expanded economic scale as the biggest globally exporting country, affirming the considerable negative effect of globalization toward environment [7].

In attempt to enhancing the living standards and meeting expected economic growth and demanding energy requirements, Asian countries [10] and most of South America countries' dependency on fossil fuels are high [11], which rationally connected the reasons on why non-renewable energies inflict excessive environmental pollution. Anwar et al. [12] thought that that overwhelming energy consumption would lead to substantial emission which provide different trade-offs, in which in photovoltaic (PV) trade for instance, countries that exported it encountered excessive energy consumption cost and carbon emissions in production process, while the imported one took the benefits, creating imbalanced circumstances to calculate the emission reduction amongst related trade countries. Shao [2] deemed that being capable of transferring a more energy efficient and cleaner technologies, trade openness was a significant determinant of carbon emission reduction. By contrast, with the decrease of consumption of production activities as a result of global crisis, the production slowed down and fossil fuels in use was less intensified, altering the reliance more on trade [7].

Fang et al. [13] underlined the significance of supporting allocation scheme to ensure regional pressure and commitments toward emission reduction, laying a basis for strategic mitigation scheme for both climate change and emission reduction. Subsidies, according to Machado et al. [14], were classified into bad, good and ambiguous, highlighting that the good one, being associated with well-controlled and monitored practices, while bad subsidies might lead to resources exploitation and thus promote the carbon emission expansion. In China, the application of NEVs (New Environmental Vehicles) subsidy policy had successfully fixed the air quality, whilst considerably met inhabitants' commuting needs and emission reduction [15]. In German, farmers approved that the adoption of more ecological-friendly farming methods was feasible if subsidies were granted as a token of acknowledgement of their efforts.

3 Data and Method

Balanced panel data was used from the World Bank and KOF Index to start the investigation on the role of other variables to carbon emissions in the selected developing ASEAN countries. The countries were filtered based on the availability of annual data and time periods, discovering that data on human development index was limited, and if any, the data was particularly incomplete. For the sake of data continuity and statistical standards, other emerging nations were not included in the analysis where there was inadequate information on related variables. The following ultimate selected ASEAN developing countries were Cambodia, Indonesia, Malaysia, Philippines, Singapore, and Thailand. The variables used to measure environmental degradation in those countries were foreign direct investment, non-renewable energy, globalization index, economic subsidies, trade openness, human development index with the range of period from 2010 to 2019.

3.1 Description of Variables

Greenhouse gas emission (GHG): carbon emissions (CO_2) metric tons per capita was employed as a dependent variable. Most of the greenhouse gas emissions from the industry are carbon dioxide (CO_2), although there are also minor emissions of nitrous oxide (N_2O) and methane (CH_4). In this study, it served as a measure of the country's environmental degradation.

3.1.1 Foreign Direct Investment (FDI)

Foreign direct investment net inflows are applied to assess how much capital injections into ASEAN nations on the effect over their carbon intensity. Our assumption that FDI had a negative and significant relationship toward environmental degradation, if foreign investors were conscious of the significance of a clean environment, considering today's investors prefer to host countries that applied environmental standards. Comparatively, the majority of developing nations were willing to entice investors with polluting sectors through ineffective competition, hence FDI could potentially have a positive impact on carbon emissions [16].

3.1.2 Non-Renewable Energy (NRE)

Fossil fuels consumption (% of total) was deployed to examine the impact of non-renewable energy over carbon emissions. It was hypothesized that the use of non-renewable energy over time significantly soared the intensity of carbon [7], given that the most crucial components of manufacturing and human endeavors were fossil fuels.

3.1.3 Trade Openness (TRA)

Trade openness is the ratio of the number of exports and imports of goods and services with other countries measured as a share of Gross Domestic Product (GDP). Our hypothesis that trades generally had positive coefficient [6] denoting that a growth in trade openness harmed the environment.

3.1.4 Globalization Index (GI)

Globalization represents the interdependence of countries, through industrial capacity and international trade, scrutinizing their impact on carbon emissions. This globalization case was the same as that applies to foreign direct investment, positive or negative relationship to the environment [17], not only depending on the state in its efforts to achieve globalization, but also energy-efficient technologies advancement in the production stage.

3.1.5 Economic Subsidies (SBD)

Economic subsidies (% of expense) were employed to assess the role of the economic aid supplied by the government, the massive amount of which was in the form of subsidies for fuel and gas prices or called energy subsidies, on carbon emissions. Given that lower

fuel prices might well encourage individuals to consume more [18], we presumed that this might have a positive effect on carbon intensity.

3.1.6 Human Development Index (HDI)

Human Development Index was used to measure the knowledge and awareness of the population in protecting the environment, given that it was an essential indicator for evaluating the success of efforts to raise the standard of living in communities. In general, with adequate literacy, it should be able to reduce carbon emissions, but it could not be denied if positive coefficient was embedded on it since people's literacy as well might support them to use more efficiency system that it would be directly proportional to the fuel released [19].

3.2 Model Specification

To design a model that analysed the effects of foreign direct investment, non-renewable energy, globalization, economic subsidies, and human development on carbon emissions, due to data limitation on human development index the present study used panel regression among pooled least square and fixed effect after considering random effect and ARDL model could not be applied, which most of previous study utilized them, that required the minimum amount of observations. Hence, the discussion suggested the following model:

$$GHG_{it} = \alpha + \beta_1 FDI_{it} + \beta_2 NRE_{it} + \beta_3 TRA_{it} + \beta_4 GI_{it} + \beta_5 SBD_{it} + \beta_6 HDI_{it} + \varepsilon_{it} \quad (1)$$

After defining model with selected variables (see Table 1), all data is left in its original form without transforming it into logarithm. Table 2 displayed the descriptive statistics for the variable utilized. The result of correlation matrix showed that all the correlation

Table 1. Summary of variables

Variable	Description	Units	Sources
GHG	Environmental degradation (carbon emission)	Metric tons per capita	WDI
FDI	Foreign direct investment	Net inflows (BoP, current US$)	WDI
NRE	Fossil fuel energy consumption	% of total	WDI
TRA	Trade openness	% of GDP	WDI
GI	Economic globalization	Index	WDI
SBD	Economic subsidies	% of expense	WDI
HDI	Human development	Index	KOF Index

*WDI-World development indicators World Bank (2022), **KOF Index- KOF Swiss Economic Institute Globalization Index (2022)

Table 2. Descriptive statistic

	GHG	FDI	NRE	TRA	GI	SBD	HDI
Mean	3.863	1.990	200.141	139.973	63.083	31.283	0.732
Median	2.875	9.900	183.605	124.813	63.000	28.154	0.719
Maximum	8.755	1.110	645.416	379.098	84.000	67.107	0.938
Minimum	0.359	1.070	5.010	37.421	32.000	0.233	0.533
Standard Dev.	3.078	2.560	172.548	99.316	13.419	16.481	0.112

Source: author's own calculation

coefficients between the variables were less than 0.8, where the relationship of non-renewable energy with economic subsidies was at the tolerance limit. The probability value of normality and heteroscedasticity test indicated over 0.05, meaning that the model did not generally have data issues.

We also took the initiative to test the effect of the variable on carbon intensity in the short term, which therefore the stationary test and cointegration test were carried out to meet the standard error correction model assumption. A key feature of the model in the short term was that the residual must be negatively significant, or otherwise the estimation was not reliable.

4 Results and Discussion

The balanced panel data model estimated in this study used least squares to specify either a fixed effect model or a Pooled Least Square (PLS) model; the results were shown in Table 3. Shown from the value of the R-squared fixed effect model is excessively high, indicating that external variable of percentage of the rest value (0.002) affected the model. Based on Morck et al. [18] an over R-squared value was not that decent, after a consideration, we utilized Pooled Least Squares for long-term estimation. In addition, this decision was taken based on the results of the Lagrange multiplier and chow test, all of which showed the probability less than 0.05, exhibiting that it could be selected between the two models by looking at the preferable model due to no corroboration outcomes on the two tests.

Table 3 denoted that the amount of foreign direct investment (FDI) dramatically reduced carbon emissions. In more specific terms, each unit inflows increased in foreign direct investment causes an overall 1.61 percent rise in carbon emissions, ceteris paribus. FDI inflows were the important feature behind lowering the consumption of fossil fuel and stimulate the use of renewable energy [2]. It encouraged overseas investors to open up new enterprises or develop their current businesses in the host nations, as an outcome, high consumption and demand of energy in the region might exist. Furthermore, FDI inflows brought efficient technology, knowledge sharing of the advanced production processes, and human skill enhancement, resulting from less reliance on fossil energy, then it could help the host countries to reduce their carbon intensity. Comparatively, Teng et al. [3] found positively and significant coefficient on foreign direct investment over

Table 3. The regression result with all the samples (long-run and short-run)

	Long Run		Short run	
	PLS	FE	PLS	FE
FDI	−1.610 (5.630)***	5.030 (3.050)	4.220 (2.850)	2.000 (2.610)
NRE	0.000 (0.000)	0.002 (0.000)**	0.004 (0.001)**	0.008 (0.002)***
TRA	0.018 (0.001)***	0.001 (2.160)	0.001 (0.003)	0.000 (0.002)
GI	−0.086 (0.007)***	0.047 (0.012)***	0.022 (0.024)	0.019 (0.024)
SBD	0.023 (0.009)**	0.008 (0.004)*	0.004 (0.005)	0.003 (0.005)
HDI	20.732 (1.060)***	2.490 (2.160)	2.601 (6.338)	1.862 (5.599)
C	−9.086 (0.995)***	−2.025 (1.234)*	−0.011 (0.043)	−0.300 (0.039)
ECT(−1)			−0.064 (0.062)	−0.587 (0.152)***
R-squared	0.982	0.998	0.259	0.523
Durbin-Watson	0.518	1.503	1.969	1.830

The standard error in parentheses and the sign ***, **, * represent 1%, 5% and 10% significance level, respectively.

carbon emissions. Many developing nations were likely to drawn foreign investment through polluting industries by attempting to engage in inefficient competition, such as lowering environmental standards that applied. In the current context as well, if low-priced fossil fuels were used to cut the cost of production. Subsequently, host nations must deal with a high Carbon emissions ratio.

The results of non-renewable energy indicated that it had no significant on carbon intensity in ASEAN countries. This was beyond our expectations, because in previous studies, the majority of non-renewable energy had a positive effect on carbon emissions [7]. Fossil fuels were employed in developing nations to both spur economic expansion and meet rising energy demands, moreover, increased energy use would accelerate environmental degradation by releasing carbon dioxide into the atmosphere. On the other hand, natural resource exports, such as those of fuel, mineral, and metal resources, to other nations throughout the world, reduced carbon emissions. Natural resource richness could reduce the import of fossil fuels, which in turn reduced carbon emissions.

Trade result represented that it contributed on carbon emissions with positive and significant coefficient, indicating that a rise one percent in trade openness boosts 0.01 percent on carbon emissions, if other factors were constant. The result supported Mahmood et al. [4] findings that trade openness led environmental damage. This was in

line with the pollution haven hypothesis, which basically argued that developing nations trade openness would cause more pollution in those nations. Comparatively, trade substantially was able to lower carbon intensity. Increased trade openness might enable countries to acquire technology which is cleaner and more energy-efficient.

The results depicted a negative statistically significant association between globalization and carbon emissions in the ASEAN countries. A one percent globalization increased in ASEAN raises carbon emission by about 0.08 percent, if other variables remained the same. This supported Farouq et al. [20] findings that globalization was a gradual process that ultimately lowered carbon emissions. The adoption of sophisticated energy-efficient technologies in the production processes could be the cause of the negative relationship. These innovative technologies lessened firm reliance on fossil fuels without compromising business output rates. Accordingly, production using clean and green technologies improved environmental quality by reducing carbon emissions. On the other hand, globalization immediately supported international trade and manufacturing, and increased the demand for energy. Developing nations that did not have environmental concerns employ more polluting sources to assist economic expansion in the process of globalization.

The result of economic subsidies showed that it was positively associated with carbon emission. Each one percent rise in economic subsidies caused carbon emission to increase for about 0.02 percent. Indicating that lower fuel prices, more individuals would be able to purchase fuel, resulting more pollution was generated, or subsidies might boost carbon emissions through a rise in the cost of goods. People would be incentivized to purchase more fuel if the price of subsidized energy increased, since their real income would grow as well. This finding confirmed previous study of Machado et al. [14]. However, subsidies were able to have negative correlation as well, if economic subsidies were more context specific and offered to groups that could actually process it and were dedicated to lowering carbon emissions. Hence, it can be argued that economic subsidies came in a variety of forms that attempted to lower carbon intensity rather than only energy subsidies.

Although we understood that human development made a significant contribution to the knowledge and decent living in general, the price for that benefit could be expressed in terms of assuming its negative significant on their environment and less carbon emission. The estimation outcomes, however, were inversely related to the fundamental premise. The result showed that human development index had positive correlation on carbon emission, meaning that a one percent rise on human development increased carbon emission around 20.7 percent, the largest number in the estimation model. This could be possible because education related to environmental issues was lacking or indeed with high standards of life expectancy and a decent living, the focus of the community was not on a healthy environment (less carbon emissions), but focused on enriching themselves to get a targeted position with fossils fuels played significant role in the process due to its affordability, which caused carbon emissions to increase.

4.1 Stationary and Cointegration Test

We have examined the unit root on all variables, where the average variable had been significant at the level. So far, only human development had a probability of at the 0.05

Table 4. Unit root test

	Levin, Lin and Chu t		ADF-Fisher Chi-square		PP-Fisher Chi-square	
Variable	Intercept	Intercept and trend	Intercept	Intercept and trend	Intercept	Intercept and trend
At level						
GHG	−1.131	−3.713***	13.654	11.246	8.043	13.631
FDI	−0.026	−1.154	10.810	10.089	25.063***	35.160***
NRE	−1.182	−3.792***	13.809	9.155	6.371	23.758**
TRA	−3.970***	−4.079***	17.105	13.971	5.788	31.057***
GI	−4.172***	−2.398***	20.612**	9.107	32.929***	7.879
SBD	−2.362***	−3.003***	16.355	14.669	22.688***	18.358*
HDI	4.060	−0.378	0.421	13.244	0.908	23.574**
At first difference						
GHG	−2.741***	−2.846***	15.763	9.320	24.888***	24.197***
FDI	−2.682***	−3.791***	22.361**	13.367	74.655***	53.974***
NRE	−2.554***	−3.343***	15.781	12.057	36.114***	35.872***
TRA	−3.231***	−3.457***	18.406*	10.932	28.524***	19.100*
GI	−2.608***	−3.510***	15.509	10.923	24.763***	31.417***
SBD	−4.908***	−1.724**	22.028**	6.258	30.182***	16.259
HDI	−2.804***	−4.268***	26.627***	18.669*	44.597***	53.861***

***, **, *represent 1%, 5% and 10% significance level, respectively.

level, the rest of the variables were significant at the 0.01 level. Table 4 depicted that from the three stationarity tests used, the variable passed more on Levin, Lin and Chu t and PP-fisher chi-square, rather than on Augmented Dickey fuller [17]. For cointegration, the result depicted that are from two methods which were Pedroni residual test and error correction term. Both were significant at the 0.01 level; thus confirm the cointegration of the estimated model.

Finally, the results of the error correction framework deputized that the error correction term (EC_{t-1}) had a negative and statistically insignificant (see Table 3), which confirmed the insignificance of the estimated model in the short run. Nevertheless, we attempted to estimate the fixed effect model in the long-run using an error correction framework, and the findings revealed that the model could be estimated inasmuch as the residual probability was less than 0.05 and the results passed the standard short-run assumption. Non-renewable energy was the only significant variable, with a positive coefficient which was quite surprising because in the long-run pooled least square, it was the only variable that had no contribution to carbon emissions. The result of short run depicted that every non-renewable energy rose in line to the rise of carbon emission by 0.008 percent. It also confirmed the study of Hanif et al. [10] that found only fossil

fuel consumption that was positively significant in the short term. Carbon emissions might be more responsive to positive shocks to the usage of non-renewable energy.

5 Conclusion

This study attempted to provide evidence to support the hypotheses that foreign direct investment, non-renewable energy, trade openness, globalization, economic subsidies, and human development augmented to the intensity of carbon emission in ASEAN. Though the impact of non-renewable energy on carbon emissions was found to be positive as well, this had not proved significant in the long-run by pooled least square. In contrast, it was significant in the short-run of fixed effect results. The strong empirical findings enabled us to draw the conclusion that the rapid of reducing carbon emission of these region's had been due to massive foreign direct investment for the sake of benefiting the advanced technology and cleaner energy. The findings of this study strongly emphasized the issue of human development index on increasing carbon emissions in the region in which the development of the quality of human capital could be ideally in line with the high awareness to help protecting the environment and create fresher air, meaning the less carbon emissions in the surroundings. Given that situation, it was indeed conceivable that the government's policy or role related to environmental education had not yet been put into practice or widely disseminated. However, more empirical research was required since the incompleteness of the data for the ASEAN countries covered in this study.

In regard with the policies recommendation, this study, based on the significant influence of both human development and foreign direct investment on carbon emissions, suggested for the government to keep maintaining and gradually improving the quality of both. As for the human development that tended to also increase the carbon emission can be anticipated by opening more entrepreneurship opportunities for public, to not only fill the gap of the knowledge on how to increase eco-friendly productivity through renewable energy sources, but also build up their awareness toward negative externalities. While the increase of trade openness was assessed to merely reach economic benefits, ASEAN countries uniquely were less dependent on the use of non-renewable energy. To decipher first notion, government might regulate the limitation of investment schemes, encouraging the investors to prefer clean energy projects, while being given subsidies for their taxes. Subsidies and incentives could be alternatives to stimulate the shift of people and industries respectively to rely more on renewable energy, while limiting the distribution and increasing tax for dirty products/non-renewable energy sources.

Acknowledgments. With regard to this paper publication, the authors declare no conflict of interest. The authors would like to thank to the anonymous reviewers for their insightful comments and ideas. Funding research support has been partly funded by UIII.

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