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Evaluating the Impact of Financial and Economic Factors on Environmental Degradation: A Panel Estimation Study of Selected Asean Countries

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ABSTRACT

Global warming is one of the most significant challenges facing the world today, as it poses an alarming threat to the entire ecosystem, human health, the economy, and national security. With the ever-increasing emission of carbon dioxide and other greenhouse gases, there has been a progressive rise in mean temperatures recorded, causing global sea levels to increase as a result of the acceleration of warming oceans, shrinking ice sheets and glacial retreat. Global warming has heightened the ferocity and frequency of extreme calamities such as heat waves, drought, wildfires, hurricanes, floods and storm surges. Extreme mitigation measures must be taken to stop this trend, failing which global warming could cause a devastating impact on the entire planet and its communities. It is imperative that more research be carried out to evaluate the impact of various factors affecting carbon emissions, as it is one of the main greenhouse gases. This study is therefore in the right direction, as it examines the long-run relationships and short-run dynamic interactions between carbon emissions and its determinants comprising of income per capita, energy use, trade openness and financial development, over the period 1970–2016. The study applies the dynamic heterogenous panel estimation techniques of mean group (MG), Pooled MG (PMG) and dynamic fixed effects to analyse a set of macro panel data of the ASEAN-5 countries, to establish the possible causal relations between these variables. An analysis of the results reveal the existence of a long-run causality between carbon emissions and its explanatory variables, indicated by the significant error correction terms for all the models tested in this study. There is evidence that energy use, trade openness and per capita income significantly contribute to carbon emissions, with energy use being the most dominant contributor. Interestingly, the study also reveals that financial development is not significant in determining carbon emissions in these selected countries. The study concludes with an examination of policy implications of the findings.

Keywords: Carbon Emission, Financial Development, Pooled Mean Group, ASEAN-5

JEL Classifications: L70, G29

1. INTRODUCTION

Carbon dioxide (CO2) emissions from the burning of fossil fuels is one of the main causes of global warming (Davis and Caldeira, 2010; Danbaba, et al., 2016; Gill et al., 2017). Global warming is a phenomenon that refers to the warming of earth, and it is characterised by rising temperatures and drastic climatic change. It is one of the greatest threats to human kind and the entire eco-system., which has not spared any country. NASA (2016) reported that global temperatures have risen by as much as 1.7° Fahrenheit since 1880, with 2015 being the hottest year. If left unattended, this situation could further worsen in coming years, trapping heat and endangering life.

Climate change, as a consequence of global warming, increases the frequencies of natural calamities (NASA, 2016). As earth warms, it hastens the melting of icebergs and the occurrence of calamities such as floods, drought, wild fires, hurricanes, tornadoes, heat wave, haze and glacial retreat, resulting in significant increases in global sea levels. The frequent occurrences of these calamities have seen over a million animal species being driven to extinction due to the massive destruction of habitats and ecosystems (National Wildlife Federation, 2016) It is estimated that by 2050, a total of 15–37% of plant and animal species would be completely destroyed, if the problem of climate change persist, and if no further mitigation measures are taken to preserve and sustain Mother Earth.

Globalisation and its subsequent economic liberalisation, has significantly increased trade and foreign direct investment between countries, with the less developed and developing countries fervently opening up their nations to trade and investment opportunities offered by the more wealthy developed countries. This is often carried out in a manner that seems to advantage the developed countries, at the expense of the developing and less developed countries. Multinational corporations in the affluent countries seek to set up their subsidiaries in developing and less developed countries, commonly known to have lax environmental policies, creating pollution havens in the poorer countries as explained by the pollution haven hypothesis (Copeland and Taylor, 1994). Developing countries that have become pollution havens will eventually bear the brunt of the effects of global warming and climate change, despite the fact that these countries make great efforts to overcome poverty and enjoy economic growth.

This study contributes to the body of knowledge in a number of ways. Firstly, while the literature examining the link between macroeconomic factors and carbon emissions have been fairly vast (Lee and Chang, 2008; Narayan and Narayan, 2010; Sharma, 2011; Iwata et al., 2012; Ozturk and Acaravci, 2013; Adebambo et al., 2014; Henry, 2014; Rasiah et al., 2015; Zomorrodi and Zhou, 2016; Alkali and Imam, 2016; Zambrano-Monserrate et al., 2016; Zomorrodi and Zhou, 2017; Zhang, 2017; Kahouli, 2017; Khan et al., 2017; Zhang, 2017; Bakari, 2017), the impact of financial development on carbon emissions has, however, been rather neglected (neglect spotting gap). The second contribution comes from the fact that although many studies have been carried out on the various macroeconomic antecedents of carbon emissions, there exists ambiguity in the findings (confusion spotting). Last but not least, this study further contributes by employing a technique that is not commonly used in many studies. Most studies in this field have used various econometric techniques such the Generalised Method of Moments, autoregressive distributed lag (ARDL), granger causality, cointegration, and vector error correction model, but not many studies have employed the Pooled Mean Group (PMG) estimation technique for long panel data (application spotting), which this study is employing.

Aside from economic liberalisation, it is also important to study the role of financial development in explaining carbon emission or environmental degradation. Do countries with developed financial markets have better corporate social responsibility agendas that will reduce carbon emission? Do countries with highly developed financial markets exercise corporate governance that will deter firms from polluting? These are interesting areas that needs to be explored, which this study aims to handle.

This study makes it mark to the existing literature by empirically examining long-run co-movement and the causal relationship between energy consumption, real GDP, trade openness, financial development, and carbon emissions. The study seeks to contribute further to the limited body of knowledge that exist on the impact of financial development on carbon emissions, with new evidence from the ASEAN-5 nations. This approach is of interest because global warming is increasingly becoming a major threat to Mother Earth and its inhabitants.

2. REVIEW OF LITERATURE

Carbon emissions and its determinants have been the subject of intense debate. Most scholars have extensively studied the relationship between economic growth, energy consumption, trade openness and carbon emissions. However, there is a lack of studies on to the impact of financial development on carbon emissions. A review of the past literature also reveals findings that are somewhat mixed. Realizing the gaps in the extant literature, more research is needed to explore the effects of financial development and macroeconomic factors on carbon emissions.

Income appears to be one of the most important and well-researched determinants of carbon emissions (Hussain et al., 2012; Bae et al., 2016). When an economy first embarks on industrialization, environmental quality deteriorates due to the extensive use of natural resources and inefficient technologies. Most studies carried out on the income-carbon emissions nexus have found that, as income increases, pollution also rises, but after a certain threshold level of income is achieved, carbon emissions starts decreasing with any further increases in income, revealing what appears to be an inverted U-shaped relationship between carbon emissions and per capita income.

Hussain et al. (2012) employed Johansen cointegration, vector error correction model and Granger causality tests, and found income to have a significantly positive relationship with carbon emissions in Pakistan from 1971 to 2006. Halicioglu (2009) found income to be the most significant variable affecting carbon emissions in Turkey. Ahmed and Long (2013), who adopted ARDL cointegration tests, found a long run inverted U-shaped curve between economic growth and carbon emissions in Pakistan from 1971 to 2008, hence confirming the validity of EKC in the long run. Ozturk and Acaravci (2013), on the other hand, employed the bounds F-test for cointegration test, error-correction, and granger causality and found evidence of a long-run relationship between per capita carbon emissions and per capita real income, using data from 1960 to 2007 in Turkey. However, Soytas and Sari (2009) revealed evidence of the lack of a long run causal link between income and emissions, contrary to what most studies revealed.

As far as energy consumption was concerned, several studies found energy consumption to have a positive relationship with carbon emissions (Sharma, 2011; Iwata et al., 2012; Jamel and Derbali, 2016). Iwata et al. (2012) incorporated nuclear energy in their study of 11 OECD countries and their findings suggest a positive and significant relationship between energy consumption and carbon emissions in most OECD countries, implying that increasing energy consumption had a damaging impact on the environment. Using bootstrap panel unit root and cointegration tests, Sharma (2011) found similar results for the case of 69 countries which were subdivided into 3 sub-panels of high, middle and low-income countries within the period 1985–2005. Each sub-panel data revealed a positive relationship between energy consumption and CO2 emissions. Chebbi (2009) also found a positive, long run relationship between energy consumption and carbon emissions in Tunisia. This positive relationship is further supported by Jamel and Derbali (2016), who found energy consumption to have a long run positive and statistically significant impact on environmental degradation. Rasiah et al. (2015) however, found a negative relationship between energy and carbon emissions in Malaysia from 1971 to 2008, which contradicted the results of most studies.

The vast literature on the impact of trade openness on carbon emissions have been somewhat controversial. Naranpanawa (2011), employed the ARDL technique on data from Sri Lanka in the 1960–2006 period, and found the existence of a short run uni-directional causality running from trade openness to carbon emissions. Halicioglu (2009), on the other hand, found trade to have a long run relationship with carbon emissions in the case of Turkey, while several other studies concurred with the positive trade-CO_2 emissions relationship. These include Gu et al. (2013) for China, Fotros and Maaboudi (2011) for Iran, and Chebbi et al. (2011), for Tunisia. The above findings however did not concur with the results of Sharma (2011), who revealed that, for the global panel of 69 countries, trade openness had a negative effect on carbon emissions. Jalil and Mahmud (2009), on the other hand, found trade to be statistically not significant in determining carbon emissions in China from 1975 to 2005. Iwata et al. (2012) also found the relationship between trade openness and carbon emissions in most OECD countries to be not significant, similar to what Zaman (2012) found in Bangladesh. Therefore, based on the review of literature thus far, the relationship between trade openness and carbon emissions remain inconclusive.

In recent years, the impact of financial development on carbon emissions has gained much attention from researchers worldwide. In a number of studies, financial liberalisation and development have been found to play an important role in reducing carbon emissions through various channels: Such as through improved governance (Claessens and Feijen, 2007); through technological improvements in the supply of energy (Kumbaroglu et al., 2008); through research and development-related foreign direct investment that would help reduce environmental degradation (Tamazian et al., 2009); or through the setting up of a robust foundation for the sustainable development of the economy (Ali et al., 2014). Jalil and Feridun (2011) concurred that financial development had a beneficial role in reducing carbon emissions, by employing the ARDL bounds testing procedure for data from 1953 to 2006 in China.

There have also been many studies (Sadorsky, 2010; Zhang, 2011; Bassem, 2017) that reveal the existence of a positive relationship between financial development and carbon emissions. Zhang (2011) employed a combination of econometric techniques including cointegration, Granger causality test, and variance decomposition and found financial development to have a harmful effect on carbon emissions in China. Tamazian and Bhaskara Rao (2010), in their study on 24 transition economies using panel data for the 1993–2004 period using the standard reduced-form modelling approach and generalised methods of moment (GMM) estimation, concurred with Zhang's (2011) findings of the possible harmful effects of financial liberalization on environmental quality in a weak institutional framework.

There have also been studies that establish an insignificant relationship between financial development and carbon emissions. One such study is that of Ozturk and Acaravci (2013) who found financial development to have no significant effect on CO_2 emissions in the long run in Turkey. Having read the literature on the impact of financial development on carbon emissions, the findings reflect a confusion spotting gap where there exist *"some kind of confusion in existing literature"* (Sandberg and Alvesson, 2011. p. 29). Our study therefore contributes to the body of literature on the role of financial development in explaining carbon emissions.

3. RESEARCH METHODOLOGY

3.1. Data

The objective of this study focuses on the relationship between carbon emissions and its chosen explanatory variables comprising of income per capita, energy use, trade openness and financial development, in the ASEAN-5 countries involving Malaysia, Indonesia, Thailand, Singapore and Phillipines over the period 1970–2016 (macro or time-series panel data). The data was obtained from the World Development Indicator of World Bank.

The summary details of all variables involved in this study are shown in Table 1.

3.2. Methodology

The study employed three different estimation techniques for dynamic heterogenous panels involving macro panel data as suggested by Pesaran and Smith (1995) namely, the MG, PMG and the dynamic fixed effect (DFE) techniques. For the case of large time series panel data (where T > N)), the traditional panel estimation techniques such as fixed effect, instrumental variables and GMM could lead to inconsistent and potentially misleading estimates of the average values of the parameters in a heterogeneous panel which violates the pooling assumption. The PMG estimation technique as suggested by Pesaran et al. (1999) is able to establish the short-run and long-run causality among the variables used in this study, by allowing the short-run coefficients and error variances to differ across groups in the cross-section, while maintaining the long-run homogeneity across all slope coefficients. For comparative purposes and to validate the robustness of results, this study also employs the MG (Pesaran and Smith, 1995) and the DFE estimation techniques in a multi-model framework.

The logarithmic version for our baseline estimation model, with a given data on time periods of $t = 1, 2.....,T$ and number of countries of $i = 1, 2....., N$, the PMG is generated from a generally-specified ARDL ($p, q, q....., q$) model which can be written as follows:

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

Where $X_{i,t-j}$ is the $(k \times 1)$ vector of explanatory variables for group i which comprises of GDP per capita, energy use, trade openness and financial development; while u_i represents the fixed effects; λ_{ij} are scalars representing the coefficients of the lagged dependent variables; and γ_{ij} are k × 1 coefficient vectors. This study also estimated the model for each individual group separately, as t is large (47 years).

We re-parameterized equation (1) to estimate the general error-correction equation as follows:

$$\Delta LCO_{2it} = \begin{array}{l} \varnothing_i LCO_{2i,t-1} + \beta_i' X_{it} + \sum_{j=1}^{p-1} \lambda_{ij}^{*} \Delta LCO_{2i,t-j} + \\ \sum_{j=0}^{q-1} \gamma_{ij}^{*'} \Delta X_{i,t-j} + \mu_i + \varepsilon_{it} \end{array} \quad (2)$$

Where $\phi_i = -(1 - \sum_{j=1}^{p} \lambda_{ij})$ and

$$\beta_i = \begin{array}{l} -(1 - \sum_{j=0}^{p} \lambda_{ij}^{*}) = -\sum_{m=j+1}^{p} \lambda_{im},\ j = 1, 2, \ldots p-1 \\ \text{and } \gamma_{ij}^{*} = -\sum_{m=j+1}^{q} \gamma_{im} \end{array},$$

j = 1, 2,…, q-1.

This study also estimated the error correction and cointegration model for carbon emission by specifying the following ARDL *(p, q1, q2, q3, q4)* model so that the long-run and short-run adjustments can be obtained.

$$\begin{array}{l} LCO_{2it} = \mu_i \sum_{j=1}^{p} \lambda_{ij} LCO_{2i,t-j} + \\ \quad \sum_{j=0}^{q_1} \gamma_{1ij} LGDPpc_{i,t-j} + \sum_{j=0}^{q_2} \gamma_{2ij} LEU_{i,t-j} + \\ \quad \sum_{j=0}^{q_3} \gamma_{3ij} LTO_{i,t-j} + \sum_{j=0}^{q_4} \gamma_{4ij} LFD_{i,t-j} \end{array} \quad (3)$$

Equation 4 shows the ARDL unrestricted error-correction equation:

$$LCO_{2it} = \begin{array}{l} \phi_i (LCO_{2i,t-1} + \beta_{1i} LGDPpc_{i,t-1} + \beta_{2i} LEU_{i,t-1} + \\ \beta_{3i} LEU_{i,t-1} + \beta_{4i} LFD_{i,t-1}) + \sum_{j=1}^{p-1} \lambda_{ij}^{*} \Delta LCO_{2i,t-j} + \\ \sum_{j=0}^{q_1-1} \gamma_{1ij}^{*} \Delta LGDPpc_{i,t-j} + \sum_{j=0}^{q_2-1} \gamma_{2ij}^{*} \Delta LEU_{i,t-j} + \\ \sum_{j=0}^{q_3-1} \gamma_{3ij} \Delta LTO_{i,t-j} + \sum_{j=0}^{q_4} \gamma_{4ij}^{*} \Delta LFD_{i,t-j} + \cdot + \varepsilon_{it} \end{array} \quad (4)$$

For $i = 1, 2., N$ and $t = 1, 2., T$; while

$$\phi_i = \begin{array}{l} -(1 - \sum_{j=1}^{p} \lambda_{ij}); \beta_{1i} = \sum_{j=0}^{q1} \gamma_{1ij}; \\ \beta_{2i} = \sum_{j=0}^{q2} \gamma_{2ij}; \beta_{3i} = \sum_{j=0}^{q3} \gamma_{3ij}; \beta_{4i} = \sum_{j=0}^{q4} \gamma_{4ij} \end{array}$$

And $\lambda_{ij}^{*} = -\sum_{m=j+1}^{p} \lambda_{im}$, j = 1, 2, ..., p - 1;

While $\gamma_{1ij}^{*} = -\sum_{m=j+1}^{q1} \gamma_{1im}$ for $j = 1, 2., q1\text{-}1$;

$\gamma_{2ij}^{*} = -\sum_{m=j+1}^{q2} \gamma_{2im}$ for $j = 1, 2., q2\text{-}1$;

$\gamma_{3ij}^{*} = -\sum_{m=j+1}^{q3} \gamma_{3im}$ for $j = 1, 2., q3\text{-}1$;

$\gamma_{4ij}^{*} = -\sum_{m=j+1}^{q4} \gamma_{4im}$ for $j = 1, 2., q4\text{-}1$;

The Akaike Information Criterion and Schwarz Bayesian Criterion was employed to conduct lag selection. Following from equation (2), assume we take the maximum lag as being 1; thus the ARDL (1, 1, 1, 1) equation is

$$LCO_{2it} = \begin{array}{l} \mu_i + \gamma_{10i} LGDPpc_{i,t} + \gamma_{11i} LGDPpc_{i,t-1} + \\ \gamma_{20i} LEU_{i,t} + \gamma_{21i} LEU_{i,t-1} + \gamma_{30i} LTO_{i,t} + \\ \gamma_{31i} LTO_{i,t-1} + \gamma_{40i} LFD_{i,t} + \gamma_{41i} LFD_{i,t-1} + \\ \lambda_i LCO_{2i,t-1} + \varepsilon_{it} \end{array} \quad (5)$$

Following Pesaran et al. (1999), the estimation equation (5) can be re-written as an error correction representation of the ARDL model as follows:

$$\Delta LCO_{2it} = \begin{array}{l} \phi_i (LCO_{2i,t-1} - \beta_{0i} - \beta_{1i} LGDPpc_{it} - \beta_{2i} LEU_{it} - \\ \beta_{3i} LTO_t - \beta_{4i} LFD_{it}) - \gamma_{11i} \Delta LGDPpc_{it} - \\ \gamma_{21i} \Delta LEU_{it} - \gamma_{31i} \Delta LTO_{it} - \gamma_{41i} \Delta LFD_{it} + \varepsilon_{it} \end{array} \quad (6)$$

Where

$$\beta_{0i} = \begin{array}{l} \dfrac{\mu_i}{1-\lambda_i}; \beta_{1i} = \dfrac{\gamma_{10i} + \gamma_{11i}}{1-\lambda_i}; \beta_{2i} = \dfrac{\gamma_{20i} + \gamma_{21i}}{1-\lambda_i}; \\ \beta_{3i} = \dfrac{\gamma_{30i} + \gamma_{31i}}{1-\lambda_i}; \beta_{4i} = \dfrac{\gamma_{40i} + \gamma_{41i}}{1-\lambda_i} \\ \text{and } \phi_i = (1 - \lambda_i) \end{array}$$

The coefficient of the error correction term ϕi represents the speed of adjustment of $\ln CO_2$ towards its long-run equilibrium following any shocks in the short-run.

4. RESULTS AND DISCUSSION

4.1. Descriptive Statistics

Prior to conducting the empirical estimation of the determinants of CO_2 emissions, it is worth displaying the descriptive or summary statistics of all variables used in the study as shown in Table 2. The results reveal that a higher level of variability in the data is explained by the between variance component. For CO_2 emissions, the overall variance is 1.106^2 (= 1.223), of which the within variance is 0.514^2 (= 0.264), indicating that only 26.4% of the overall variability in the data occurs within-country.

Similarly, for energy use, the within variance is 0.446^2 (= 0.199), indicating that only 19.9% of the overall variability in CO_2 emissions occurs within-country, suggesting that the between variance component dominates in explaining the variability of the data.

Table 1: Summary details of variables

Variable	Descriptor	Data source	Expected sign
Carbon emissions	CO_2 emissions (metric tons per capita)	WDI, World Bank	N/A
Economic growth	GDP per capita (constant 2010 US$)	WDI, World Bank	+
Energy consumption	Energy use (kg of oil equivalent per capita)	WDI, World Bank	+
Trade openness	$\frac{\textit{sum of exports and imports of goods and services (constant 2010US\$)}}{\textit{GDP at market prices (constant 2010US\$)}}$	WDI, World Bank	+
Financial development	Domestic credit to private sector (% of GDP)	WDI, World Bank	+

Table 2: Descriptive statistics for key variables of the CO_2 model

Variable	Mean	SD	Minimum	Maximum	Obs
LCO_2					
Overall	0.768	1.106	−1.165	2.951	220
Between		1.092	−0.248	2.407	
Within		0.514	−0.601	1.778	
LGDPC					
Overall	8.267	1.088	6.649	10.87	235
Between		1.082	7.421	10.033	
Within		0.495	7.015	9.109	
LEU					
Overall	6.904	0.859	5.694	8.905	220
Between		0.819	6.121	8.148	
Within		0.446	5.920	7.791	
LTO					
Overall	−0.207	0.732	−1.317	1.392	235
Between		0.704	−0.936	0.849	
Within		0.370	−0.862	0.447	
LFD					
Overall	3.987	0.673	2.270	5.115	235
Between		0.549	3.352	4.422	
Within		0.465	2.660	4.814	

Source: Authors' Calculation, World Development Indicators, World Bank (2017)

4.2. Panel Unit Root Test

It is important to firstly ascertain whether the estimated equations are actually cointegrated through determining the stationarity of the variables in the study, prior to estimating the CO_2 emissions equation. The Im, Pesaran and Shin or IPS (1997, 2003) test and the Maddala and Wu (1999) test were employed to verify for the presence of unit roots in the panel data series of the study. Table 3 confirms that all variables are non-stationary at level (do not reject the null hypothesis of the presence of a unit root) and stationary at first-difference at a 1% level of significance, for both the IPS and the MW tests. The results therefore confirms that all variables in this study are I(1); that is, integrated of order 1.

4.3. MG, PMG and DFE Estimation Estimated Long Run Coefficients, Speed of Adjustment and Short Run Coefficients

Since all variables are stationary at first difference, we proceed with the chosen dynamic estimation techniques, namely the MG, PMG and DFE. Table 4 reports the short-run and long-run coefficients as well as the error-correction terms for two alternative models using the above-mentioned estimation techniques.

Model 1 is the baseline model that utilises the control variables which impact CO_2 emissions, while Model 2 is the full model. The control variables include income level *(LGDPC)*, energy use *(LEU)* and trade openess *(LTO)*. In Model 2, financial development is added to the control variables to analyse their relationship to the dependent variable (CO_2) for the three alternative pooled estimates: MG, PMG and DFE. The two specifications (models) with varying sets of explanatory variables were analysed to obtain generally valid results, ensuring that we proceeded in accordance with the literature on carbon emissions.

The results in Table 4 clearly reveals that the signs and magnitude of the coefficients are almost similar across the different estimators. Income and energy use have significant long-run coefficients in both the baseline and full models that explicitly explain carbon emissions, while trade openness and financial development display significance only in the full model, using the PMG and MG estimators respectively. Table 4 also reveal that despite utilizing two different models, the results are quite consistent and robust across all three estimation techniques. There is evidence to point that the chosen explanatory variables are cointegrated with CO_2 emissions. The MG estimation technique is the least restrictive procedure, allowing for heterogeneity of all parameters. As a result, the estimates are potentially not efficient. On the other hand, the PMG estimation technique, being the intermediate estimator between the MG and the DFE estimators, allows the intercepts, short-run coefficients and error variances to differ, while imposing long-run homogeneity to all slope coefficients. The DFE estimator on the other hand, only allows intercepts to vary across countries.

In order to test the long-run homogeneity, the Hausman test was employed, and the results reveal the consistency and efficiency of the PMG estimator with standard errors that are much lower than those of the MG estimator. When the PMG estimation technique is used, the error-correction term (or convergence coefficient) is also lowered significantly, as compared to the use of the MG estimation technique. However, the speed of adjustment and standard errors become lower if the DFE estimation technique is employed, as a result of the downward bias in dynamic heterogeneous panels. The direction and significance of the long-run coefficients are also affected when the DFE estimation technique is used, as it restricts the short-term dynamics.

The Hausman test results shown in Table 4 indicate that the PMG estimator is the most superior estimator, being the most consistent and efficient. An analysis of the results indicate that long-run causality exists between the explanatory variables and CO_2 emissions, as seen in the significant error correction

Table 3: Im et al. (2003) and Maddala and Wu (1999) panel unit root test

Variable	IPS		MW (Fisher-ADF)	
	Level	First difference	Level	First difference
LCO_2	0.079 [0.531]	−8.558 [0.000]***	4.279 [0.934]	94.433 [0.000]***
LGDPC	1.243 [0.893]	−6.562 [0.000]***	10.623 [0.388]	83.455 [0.000]***
LEU	0.516 [0.697]	−8.865 [0.000]***	7.999 [0.629]	90.359 [0.000]***
LTO	0.569 [0.715]	−8.883 [0.000]***	7.818 [0.647]	107.27 [0.000]***
LFD	−1.379 [0.084]	−6.804 [0.000]***	13.342 [0.205]	60.943 [0.000]***

The numbers in parentheses represents the P values. The asterisks *** and ** indicate the rejection of unit root null hypothesis at 1% and 5% of significance levels, respectively. Probabilities for MW (Fisher-ADF) test are computed using an asymptotic Chi-square distribution. IPS test assumes asymptotic normality. Source: Authors' Calculation, World Development Indicators, World Bank (2017)

Table 4: Estimated long-run coefficients and speed of adjustment

Dependent variable: lCO_2	Model 1 (baseline)			Model 2 (full model)		
	(1)	(2)	(3)	(4)	(5)	(6)
	MG	PMG	DFE	MG	PMG	DFE
Long-run coefficients						
LGDPC	0.560**	0.754***	−0.232	0.434*	0.528***	−0.481
	(0.251)	(0.192)	(0.951)	(0.260)	(0.200)	(0.920)
LEU	1.438	0.370*	0.481	0.347***	0.686***	0.594\
	(0.907)	(0.207)	(0.997)	(0.102)	(0.194)	(0.903)
LTO	−0.149	0.162	0.576	−0.108	0.168*	0.491
	(0.552)	(0.106)	(0.690)	(0.633)	(0.100)	(0.668)
LFD				−0.019***	−0.049	0.308
				(0.117)	(0.035)	(0.393)
Error correction coefficient	−0.378***	−0.225***	−0.059**	−0.472***	−0.236*	−0.066**
		(0.083)	(0.024)	(0.129)	(0.139)	(0.028)
Short-run coefficients						
Δ*LGDPC*	0.482	0.545**	0.580**	0.410	0.608***	0.636***
	(0.347)	(0.232)	(0.227)	(0.317)	(0.229)	(0.236)
Δ*LEU*	0.284	0.353**	0.440***	0.141	0.225	0.409***
	(0.152)	(0.152)	(0.116)	(0.222)	(0.230)	(0.119)
Δ*LTO*	−0.052	−0.097	−0.056	−0.065	−0.096	−0.103
	(0.082)	(0.118)	(0.099)	(0.081)	(0.116)	(0.106)
Δ*LFD*				0.086**	0.073***	0.018
				(0.04)	(0.010)	(0.062)
Constant	−3.948	−1.77***	−0.034	−3.103**	−1.891*	−0.034
	(0.915)	(0.654)	(0.288)	(1.389)	(1.111)	(0.318)
Number of countries	5	5	5	5	5	5
Observations	210	210	210	201	201	201
Hausman test		0.5064			0.2084	

1 - The numbers in parentheses are standard errors. 2 - The asterisks ***, **, and ' indicate the rejection of null hypothesis at 1%, 5%, and 10% of significance levels, respectively.
3 - Source: Authors' Calculation, World Development Indicators, World Bank (2017)

terms for both models. It can be seen that the magnitude of the disequilibrium correction is low for both models (0.225 and 0.236 respectively), reflecting that only approximately 23% adjustment or correction takes place in 1 year for Model 1 and approximately 24% adjustment takes place in Model 2 to restore long-run equilibrium.

Based on the results of the PMG estimation technique, which was found to be the most efficient; there is a significantly positive long-run coefficient for income reflecting the positive relationship that income has on carbon emissions. This result clearly aligns with the findings of Halicioglu (2009); Lean and Smyth (2010); Shahbaz et al. (2012); Hussain et al. (2012); Arouri et al. (2012); and Almohaimeed (2015). The positive long-run relationship between energy consumption and carbon emissions in our study concurs with the findings of Sharma (2011); Iwata et al. (2012); and Jamel and Derbali (2016). As for the role of trade openness, our study finds a significant positive coefficient (at 10%) that explains carbon emissions in the ASEAN-5 nations, similar to the findings of Gu et al. (2013) for China, Fotros and Maaboudi (2011) for Iran, and Chebbi et al. (2011) for Tunisia. Financial development however, did not have a significant long-run effect on carbon emissions, contradicting most studies which established either a positive relationship (Claessens and Feijen, 2007; Kumbaroglu et al., 2008; Tamazian et al., 2009; Ali et al., 2014; Jalil and Feridun, 2011), or a negative one (Sadorsky, 2010; Tamazian and Bhaskara Rao, 2010; Zhang, 2011; Bassem, 2017). Our findings on the insignificant financial development-carbon emissions relationship only concurred with that of Ozturk and Acaravci (2013).

5. CONCLUSION

This paper investigates the causal relationship between income, energy consumption, trade openness, financial development, and carbon emissions in the ASEAN-5 countries involving Malaysia, Indonesia, Thailand, Singapore and Philippines over the period 1970–2016. The study employed the MG, PMG and DFE estimation techniques, yielding evidence of a long-run relationship between per capita carbon emissions, per capita income, energy consumption, trade openness and financial development. The Hausman test established the efficiency of the PMG estimation technique, with results revealing the long run significant and positive coefficients of per capita income, energy consumption and trade openness in explaining carbon emissions. This shows that an increase in income, or energy consumption, or trade openness results in an increase in per capita carbon emissions. However, financial development did not display a significant effect on carbon emissions in our study, contrary to most studies. As far as the coefficients of estimated error-correction terms were concerned, our study found that, for both models using all three estimation techniques were found to be negative and statistically significant, reflecting the robustness of the results. These values indicate that any deviation from the long-run equilibrium between variables is corrected for each period to return to the long-run equilibrium level or steady state.

It is hoped that policy makers in the ASEAN region will take a more serious view of the role played by income, energy consumption and trade openness in increasing carbon emissions. This is to ensure that policies are designed to promote sustainable development.

One of the most important ways in maintaining environmental sustainability is through the improvement of energy efficiency. Policy makers should provide incentives to encourage investments in energy-saving and emission-reducing measures that will not only save cost and bolster growth in the long-run but are also environmentally friendly. A higher amount of budget should be allocated in these investments to reach a breakthrough in clean, renewable and sustainable energy sources such as biofuel, hydroelectricity, geothermal, solar, wind, tidal and wave energy that are less harmful to the environment. This is a more effective mitigating measure to control global warming as compared to the enforcement of carbon taxes that will not only hinder growth but also leave the problem unsolved.

In conclusion, it is imperative that countries join forces and work towards a common sustainable environmental goal for the benefit of the society as a whole.

Finally, the results of this paper may be further enriched in the future, with alternative econometric estimation techniques that will allow us to further explore how the ASEAN nations can reform financially and economically in an effort to intensively reduce carbon emissions. We hope that other researchers will gain some insights from our results.

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