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Article

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A Multivariate Cointegration Analysis of the Macroeconomic Determinants of Carbon Emissions in Malaysia

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ABSTRACT

Global warming is one of the greatest threats to mankind, as it adversely affects mother earth and its ecosystem, human health, the greater economy and is considered a threat to national security. There has been an exponential growth in the number of environmental studies carried out over the past few decades as scholars, climate researchers and governments search for the various factor causing global warming and the feasible solutions to address this potentially catastrophic problem. This paper will contribute further to the existing body of knowledge on the underlying causes of global warming, with the specific aim of investigating the long-run relationships between carbon emissions and its regressors comprising of per capita income, energy use, trade openness (TO), and financial development in Malaysia over the period from 1970 to 2016. The econometric time series analysis of multivariate cointegration is applied in this study to establish the possible causal relations between the variables concerned. The cointegration test and the vector error correction model display evidence of positive long-run relationships between per capita income and carbon emissions, and between TO and carbon emissions, while energy use is negatively related to carbon emissions. There is also evidence that the bulk of the variations in the CO_2 emissions is attributed to its own variations through further innovation analysis using variance decompositions. The study concludes with an examination of policy implications of the findings.

Keywords: Carbon Emissions, Trade Openness, Energy, Financial Development, Vector Error Correction Models
JEL Classifications: Q39, Q56

1. INTRODUCTION

One of the greatest challenges facing the world today is global warming. Global warming has posed an alarming threat not only to the planet Earth, but also to the entire ecosystem, human health, economy and national security. In essence, global warming refers to the progressive rise in Earth's mean temperature due to the emission of greenhouse gases. Global sea level has escalated for the past decade due to the acceleration of warming oceans, shrinking ice sheets and glacial retreat. Furthermore, global warming has also heightened the ferocity and frequency of extreme calamities such as heat waves, drought, wildfires, hurricanes, floods and storm surges1 (NASA, 2016). Collectively, global warming could cause a devastating impact on the entire planet and community if no further mitigation measures are taken.

Global warming is a real and serious issue which will remain a threat to Mother Earth, unless proper mitigation measures are taken. There is a pertinent need for further studies to address this problem. Hence, this paper attempts to study the underlying cause of carbon emissions which has been discovered as an important source of global warming, and the actions that could be taken to address it.

This study attempts to eliminate the gaps in the prevailing literature by offering a fresh perspective on carbon emissions. This is done by including additional exploratory variables, such as trade openness (TO) and financial development (FD), to investigate if they also contribute to carbon emissions besides the highly studied variables, economic growth and energy use. Most importantly, this research hopes to contribute to the formulation of better economic and environmental policies surrounding the keys drivers of carbon emissions to efficaciously address global warming.

Countries across the globe are facing the aftermath of global warming, resulting mainly from the emission of carbon dioxide (CO_2). Climate change has heavily impacted the economy in many ways, ranging from the reduction in agricultural productivity to the spread of diseases resulting in lesser labour productivity in various ways. Job losses, productivity losses, increased absenteeism and reduced turnover rates resulting from climate change–induced diseases could lead to decreased household income. The overall decrease in economic efficiency could hinder economic growth. These problems can escalate further as global warming is a real and serious issue which will not stop unless proper mitigation measures are taken. In view of the life-threatening effects that global warming has brought and continues to bring to the planet as a whole, it is imperative that countries, climate scientists, researchers and individuals work together to act promptly on this issue. There is a pertinent need for further studies to address this problem. Hence, this paper attempts to study the underlying causes of carbon emissions which is an important source of global warming and the actions that could be taken to address it.

2. LITERATURE REVIEW

Carbon emission is the liberation of (CO_2) gas from human activities such as fossil fuel combustion, cement production and deforestation (World Bank, 2016). Many scholars (Manabe and Stouffer, 1980; Plattner et al., 2008; Eby et al., 2009; Solomon et al., 2009; Başarir and Çakir, 2015; Zomorrodi and Zhou, 2016) have attempted to study carbon emissions in particular because CO_2 is regarded as the main contributor to global warming and climate change. The use of carbon emissions, CO_2, as a proxy for environmental degradation is supported by Ang (2008), Lean and Smyth (2009), Akpan and Chuku (2011), Ong and Sek (2013), Albiman et al. (2015) and Rasiah et al. (2015).

Gross domestic product per capita (GDPC) is the total income of people, divided by the country's population (World Bank, 2016). A number of studies have included income as a key determinant of environmental degradation by applying the Environmental Kuznets Curve analysis (Lacheheb et al., 2015; Grossman and Helpman, 1991; Harbaugh et al., 2002; Galeotti et al., 2006; Cole et al., 1997; Moomaw and Unruh, 1997). The environmental Kuznets curve proposes an inverted U-shaped relationship between income and CO_2, where the early stage of growth leads to higher environmental degradation, however after a peak, economic growth will lead to a decrease in CO_2 emission (Lacheheb et al., 2015; Grossman and Helpman, 1991). However the studies on the relationship between income and environmental degradation has remained largely inconclusive. A number of studies have confirmed the possibility of an inverted U-shaped relationship (Aldy, 2005; Cole et al., 1997; Galeotti et al., 2006), while others studies have disputed this (Lacheheb et al., 2015; Harbaugh et al., 2002; Moomaw and Unruh, 1997). Other studies have moved away from the Kuznet curve analysis and proposed a linear relationship between income and CO_2 emission (Shafik 1994; Azomahou et al., 2006; Ang, 2007).

Energy use is the utilization of primary energy from the source before it transforms into other end-use fuels (World Bank, 2016). Studies indicate a positive relationship between energy consumption and CO_2 emission in a wide number of countries such as Saudi Arabia (Alshehry and Belloumi, 2015), the BRIC countries (Pao and Tsai, 2010), Japan (Hossain, 2012), Turkey (Halicioglu, 2009), South Africa (Kohler, 2013) and France (Ang, 2007). Interestingly, the industrial, transportation and commercial sectors that have historically been considered as high polluters are replaced by the consumers sector. A study by Wei et al. (2007) highlights that energy use in homes, food, education, personal travel are the most energy-intensive and carbon-emission-intensive activities in China. A conclusion supported by Bin and Dowlatabadi (2005) highlighting that consumer demands are instrumental for the energy use and the resulting CO_2 emission in the US while Feng et al. (2011) dissects the consumer market further by highlighting increased CO_2 emissions among urban households.

TO is measured as the sum of exports and imports, as share of GDP (World Bank, 2016).[1] Literature investigating the role of TO on environmental degradation provides mixed findings. Sebri and Ben-Salha (2014) and Halicioglu (2009) highlighted the toxic impact of TO on the environment. Similar conclusion is reported by Chebbi et al. (2011) of a direct positive effect in both the short and long run, but reports of a negative indirect effect through income and economic activity in the long-run. However a number of other studies have also highlighted that TO does not impact CO_2 emission (Hossain, 2011; Jayanthakumaran et al., 2012).

Financial Development is proxied by domestic credit provided by financial sector (% of GDP) (World Bank, 2016).[2] Studies examining the impact of FD on environmental degradation are rather consistent in reporting a positive relationship between the two variables (Sadorsky, 2010; Zhang, 2011; Tamazian and Rao, 2010). The negative impact of FD is said to encourage investment in new projects, attract investment and encourage domestic consumption which eventually culminates in increased carbon emission (Zhang, 2011). While, Tamazian and Rao (2010) highlights a concern that FD without a strong institutional framework could be harmful for environmental quality (Figure 1).

3. MATERIALS AND METHODS

Following Ang (2008), Lean and Smyth (2009), and Rasiah et al. (2015), the empirical long-run relation between carbon emissions, real GDPC, energy use, TO, and FD is written in the following form:

1 Many studies like Sepehrivand and Azizi (2016); Uremadu et al. (2017); Islam and Fatema (2017); Majidi (2017); Alhakimi (2017) have used that trade openness proxy in their studies.

2 Many studies like Al-Khulaifi (2013); Mhadhbi (2014); Demirhan (2016); Fukuda (2017) have used that financial development proxy in their studies.

$$LCO2_t=\beta_0+\beta_1 LGDPC_t+\beta 2LEUt+\beta 3LTO_t+\beta 4FD_t+\varepsilon_t \quad (1)$$

where CO_2 is carbon emissions (metric tons per capita), GDPC is real GDPC (constant 2011 USD), EU is energy use (kg of oil equivalent per capita), TO is TO which is calculated as follows: TO = (Exports+Imports)/GDP, and FD is FD, proxied by domestic credit provided by financial sector (% of GDP). The subscripts indicate time (t) and ε is the usual error term.

As the purpose of this study is to determine the causal direction between the variables in question, the following vector-error correction model (VECM) are estimated as follows:

$$\Delta y_t = a_0 + \sum_{i=1}^{k} \alpha_i \Delta y_{t-i} + \sum_{j=1}^{k} \alpha_j \Delta x_{t-j} + \gamma_1 ecm_{t-1} + \varepsilon_{1t} \quad (2)$$

$$\Delta x_t = b_0 + \sum_{i=1}^{k} \beta_i \Delta y_{t-i} + \sum_{j=1}^{k} \beta_j \Delta x_{t-j} + \gamma_2 ecm_{t-1} + \varepsilon_{2t} \quad (3)$$

Where ecm_{t-1} is the lagged residual from the cointegration between y_t and x_t in level. Granger (1988) points out that based on equation (2), the null hypothesis that x_t does not Granger cause y_t is rejected not only if the coefficients on the x_{t-j}, are jointly significantly different from zero, but also if the coefficient on ecm_{t-1} is significant.

The study utilises annual time series data of carbon emissions (CO_2), GDPC, energy use (E), TO and FD from 1970 to 2016 for Malaysia. The data was sourced from World Bank Development Indicators.

4. ANALYSIS AND RESULTS

The study first tests the variables for stationarity by employing the Augmented Dickey–Fuller and Phillips-Perron unit root tests. Thereafter, the maximum likelihood approach to cointegration test developed by Johansen (1988) and Johansen and Juselius (1990) was employed to analyse whether the set of non-stationary variables under consideration are tied together by the long-run equilibrium path. Finally, an examination of the dynamic properties of the model is carried out through the generalized variance decomposition analysis based on the unrestricted vector autoregressive (VAR) model, to establish the explanatory power of the regressors in forecasting CO_2 variance.

4.1. Unit Root Test

The order of integration of the relevant variables was determined prior to performing a cointegration test as only integrated variables of the same order could be co-integrated. Table 1 shows evidence that confirms the stationarity of the variables when they are first-differenced, that is, all variables used in this time series are I (1).

4.2. Johansen's Cointegration Test

The Johansen-Juselius cointegration test was performed using non-correlated errors as the lag selection criterion. Since all variables in this time series are I (1), there is a likelihood of an equilibrium relationship between them. The cointegration test of Johansen (1988) and Johansen-Juselius (1990) was applied to investigate the presence of a long-run equilibrium relationship among the variables in study. Table 2 estimates the number of long run relationships that exist between carbon emissions and its explanatory variables. There is evidence of the presence of a long run cointegrating relationship between carbon emissions and its regressors made up of per capita income, energy use, TO and FD. As shown by both the trace statistics and maximum-eigenvalue statistics, indicating the presence of a unique cointegrating vector at 1% level.

4.3. Vector-Error Correction Model

The VECM was utilised in order to capture the long-run equilibrium dynamics of the time series. With the evidence of the existence of cointegration, the dynamic relationships

Figure 1: Theoretical framework

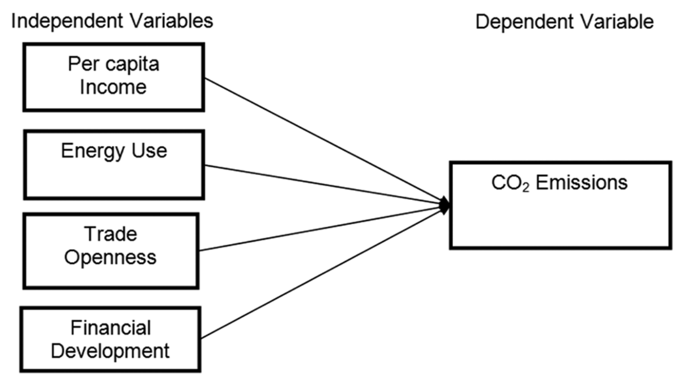

Table 1: ADF and PP Unit Root Tests

Level	ADF	PP
LCO_2	−0.9323 (0)	−0.9323 [0]
LGDP	−1.5663 (0)	−1.5663 [0]
LEU	−1.1008 (0)	−1.6425 [11]
LTO	−1.1571 (0)	−1.1571 [0]
FD	−2.0386 (0)	−2.0386 [0]
First difference		
LCO_2	−7.9412 (0) ***	−7.9340 [1]***
LGDP	−5.793 (0)***	−5.8036 [1]***
LEU	−6.9402 (0)***	−7.1511 [6]***
LTO	−5.7203 (0)***	−5.7203 [0]***
FD	−6.1332 (0)***	−6.1332 [0]***

***Denotes significant at 1% significance level. The figure in parenthesis (…) represents optimum lag length selected based on schwatz info criterion. The figure in bracket […] represents the Bandwidth used in the Phillips–Perron test selected based on Newey–West Bandwidth criterion. ADF: Augmented Dickey–Fuller, FD: Financial development

Table 2: Results from Johansen's cointegration test: Unrestricted cointegration rank test (trace and maximum eigenvalue)

NULL	Test statistics		Critical value (5%)	
	Trace	Max eigenvalue	Trace	Max eigenvalue
r=0	80.225***	40.514***	69.819	33.877
r≤1	39.712	20.566	47.856	27.584
≤2	19.145	13.676	29.797	21.132
r≤3	5.469	4.204	15.495	14.265
r≤4	1.266	1.266	3.842	3.842

This table shows the results from Johansen's cointegration test for both trace and maximum eigenvalue which shows the presence of cointegration for this system of variables. ***Denote significance at 1%

Table 3: Generalised variance decomposition

Period	S.E.	LCO_2	LGDPC	LE	LTO	DCFS
Variance decomposition of LCO_2						
1	0.087929	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.114573	93.73532	1.698710	2.295731	2.187582	0.082655
3	0.147111	91.95360	1.043842	2.582383	3.994431	0.425745
4	0.170603	90.47751	0.835896	2.118319	5.982321	0.585958
5	0.190200	91.15448	0.800365	1.714524	5.818660	0.511967
6	0.205132	91.69848	0.688155	1.492184	5.680991	0.440195
7	0.221319	92.14144	0.596751	1.419176	5.451126	0.391506
8	0.237046	92.19052	0.520380	1.394758	5.524838	0.369507
9	0.252110	92.28301	0.469430	1.284598	5.606047	0.356910
10	0.265359	92.36760	0.429047	1.185078	5.677417	0.340859
Variance decomposition of LGDPC						
1	0.033628	35.28495	64.71505	0.000000	0.000000	0.000000
2	0.051346	49.85636	47.66761	0.519687	0.171017	1.785328
3	0.068667	66.44551	29.37531	0.293941	2.327368	1.557874
4	0.082407	73.32066	21.71759	1.180907	2.428933	1.351907
5	0.092072	75.63145	9.24467	1.727084	2.206271	1.190528
6	0.102021	78.03208	17.37604	1.679431	1.877969	1.034483
7	0.111401	79.81517	16.02544	1.515145	1.725546	0.918700
8	0.120424	81.23829	14.77252	1.450664	1.675372	0.863154
9	0.128524	82.14691	13.86836	1.472277	1.678625	0.833826
10	0.136074	82.87625	13.18021	1.506273	1.635140	0.802123
Variance decomposition of LE						
1	0.059858	21.93314	15.72460	62.34225	0.000000	0.000000
2	0.084048	12.82237	26.58163	56.47451	1.940337	2.181150
3	0.101941	19.00218	25.40904	45.83515	5.155706	4.597923
4	0.115991	24.24622	22.24835	43.03086	5.802023	4.672543
5	0.129812	26.37395	19.28018	44.86787	5.420618	4.057391
6	0.142248	26.80940	18.38124	45.93944	5.169829	3.700088
7	0.153275	27.79993	18.35195	45.15756	5.053260	3.637303
8	0.163524	29.14438	17.95269	44.19797	5.104831	3.600129
9	0.173573	30.12713	17.26585	43.91112	5.171944	3.523956
10	0.183100	30.55121	16.78154	44.02025	5.191448	3.455556
Variance decomposition of LTO						
1	0.053459	38.53944	1.512827	0.898842	59.04889	0.000000
2	0.082248	44.98945	0.679165	3.289531	45.21810	5.823752
3	0.107649	48.13336	2.480420	6.605410	38.38164	4.399174
4	0.128763	52.09132	3.426076	10.79319	30.61462	3.074790
5	0.142634	54.51927	3.022805	11.84592	28.10592	2.506086
6	0.157893	57.96057	2.626634	11.12407	26.13857	2.150152
7	0.173250	59.76192	2.520803	10.59240	25.22788	1.896994
8	0.187879	60.59720	2.613370	10.81171	24.29799	1.679737
9	0.200275	61.01798	2.609778	11.18921	23.66604	1.516984
10	0.211679	61.71907	2.552777	11.30009	23.03641	1.391645
Variance decomposition of DCFS						
1	16.77346	1.411958	9.175359	4.144956	26.02086	59.24686
2	24.38794	0.835758	7.094871	4.450936	30.61923	56.99920
3	28.14849	1.395949	5.718201	4.345298	32.51750	56.02305
4	31.34650	2.745965	5.282315	4.236806	32.25827	55.47664
5	34.40433	3.503508	5.522836	4.431378	31.03578	55.50650
6	37.27206	3.845901	5.673243	4.835745	30.42657	55.21855
7	40.00930	4.023678	5.639311	5.093729	30.30794	54.93534
8	42.63535	4.239933	5.567843	5.173922	30.24185	54.77645
9	45.05048	4.456067	5.513106	5.196537	30.10471	54.72958
10	47.29283	4.658694	5.500233	5.243502	29.94455	54.65302

between the cointegrated variables can be studied using an error-correction model. The cointegrating vector (normalized on the CO_2 emissions) representing the long-run relationship (with lag 1) is shown as follows:

$$LCO_{2t}=7.574+1.697LGDPC_t{}^{***}-0.775LEU_t{}^{***}+0.642LTO_t{}^{***}-0.000289FD_t+\varepsilon_t \quad (4)$$

***Denotes significance at 1%.

The coefficients found in the normalized cointegrating vector in Equation (4) are long-term elasticity measures, as the variables have undergone logarithmic transformation. The coefficients reveal that energy use, per capita income and TO have significant relationships with CO_2 emissions, while FD does not.

It must also be noted that the estimated coefficients of the cointegrating vector shown above only represents the long-term relationship that exists and does not reflect the short-term dynamics that these variables could possibly share. In order to study the short-term dynamic relationships amongst the variables, the variance decompositions are generated based on the unrestricted VAR model.

4.4. Variance Decomposition

The variance decomposition was generated based on the unrestricted VAR model, in an effort to study the short-term dynamic relationships amongst the variables. The variance decomposition in Table 3 reveals the proportion of the movements that a variable undergoes, as a result of shocks to itself and to other variables. It is useful in assessing how shocks to economic variables reverberate through a system.

It can be seen that over the longer time horizon (10 years), TO forecasts an estimated 5.68% of CO_2 emissions' variance, whereas energy use forecasts only approximately 1.185% of the variance while GDPC innovations generates an even lesser fluctuation in CO_2 emissions, forecasting only 0.428% of CO_2 emissions' variance. It can be seen that the bulk of the variations in the CO_2 emissions is attributed to its own variations. Even after 10 years, almost 92.37% of the variation in CO_2 emissions is explained by its own shock, implying that it is relatively exogenous to other variables. The results also demonstrate the insignificant role played by GDPC and FD in forecasting the variance of CO_2 emissions.

The most explained variable is GDPC, as approximately 87% of its variance is explained by the shocks in all other variables, with CO_2 emissions playing the dominant role in forecasting 82.88% of GDP'Cs variance. CO_2 emissions is also the dominant variable in explaining the variance in TO, as 61.72%of the variance in TO is explained by shocks in CO_2 emissions, as opposed to 23.04% by its own shocks.

5. DISCUSSION

The results in section 3 clearly show evidence of the damaging effect per capita income and TO have on CO_2 emissions in Malaysia, while energy use mitigates this effect. As revealed by the coefficients in the VECM model in equation (4), energy use has a negative relationship with CO_2 emissions, with increases in energy use bringing about lower CO_2 emissions, which is a step closer to a cleaner environment. However, per capita income and TO have a positive and significant impact on CO_2 emissions, reflecting the damaging effects of economic development (proxied by per capita income) and international trade (proxied by TO) on the environment, as far as Malaysia is concerned.

The positive relationship between income per capita and carbon emission is consistent with the findings of a number of studies (Tucker, 1995; Adrangi et al., 2004; and Halicioglu, 2009). The negative relationship between energy use and carbon emissions was found to contradict the empirical evidence provided by Ang (2007; 2009), and Jalil and Mahmud (2009). The plausible explanation for the negative energy use-CO_2 link is the possibility that national and global environment policies and cooperation between governments have provided a stronger push for cleaner environment, and the use of alternative cleaner energy. Such policies include the imposition of green taxes on pollutants and subsidies for green companies, encouraging the use and further development of more sustainable energy technologies. It must also be noted that the estimated coefficients of the cointegrating vector shown above only represents the long-term relationship that exists and does not reflect the short-term dynamics that these variables could possibly share. In order to study the short-term dynamic relationships amongst the variables, the variance decompositions are generated based on the unrestricted VAR model.

6. CONCLUSIONS AND RECOMMENDATIONS

This paper investigates the causal relationship between gross domestic per capita, energy use, TO, FD and carbon emissions in Malaysia between 1970 and 2016. The Johansen-Juselius cointegration test yields evidence of a long-run relationship between carbon emissions and per capita income, energy use, TO and FD. The long-run equilibrium dynamics in the time series is captured by this study using the vector error-correction model which reveals that energy use, per capita income and TO are significant in explaining carbon emissions for Malaysia.

It is imperative that governments and policymakers acknowledge the devastating impact of economic development and international trade on the environment. Countries should invest 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. More stringent pollution controls should be put in place, and greater use of green technology and methods of production should be encouraged or incentivized, with the hope that it leads to a drop in carbon emissions. 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.

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