A Panel Study of the Environmental Kuznets Curve for Carbon Emissions in ASEAN-5 Countries

GOH HAN HWA[1]*, YOU HUI LI[2], NUR SYAIRAH KHAN BINTI BERAM KHAN[1], TAN SU HONG[2]

[1]Faculty of Management, Multimedia University, MALAYSIA
[2]Faculty of Accounting, Finance & Business, Tunku Abdul Rahman University College, MALAYSIA

*Corresponding author: hhgoh@mmu.edu.my

Abstract: - Environmental degradation has now been one of top concerns for scientists, environmentalists, policymakers and people all around the world alike. Carbon dioxide (CO_2) is believed to be one of the major components of greenhouse gases that contribute to air pollution and thus global warming and climate change. This research is conducted to investigate the relationship between economic growth and CO_2 emissions in ASEAN-5 countries in the presence of foreign direct investment inflow (FDI) and trade openness for the period between 1981 and 2010. In order to carry out the study, various tests are applied such as panel unit root tests, Pedroni panel cointegration test, the Dynamic Ordinary Least Squares (DOLS) and Fully Modified Ordinary Least Squares (FMOLS) regressions, as well as panel vector error correction model (PVECM). The results of the study indicate that the relationship between economic growth and CO_2 emissions exists in inverted-S shape in both short- and long-run for ASEAN-5 countries after controlling two additional explanatory variables, i.e. FDI inflow and trade openness. In addition, the outcome of this study also offers some fundamental policy recommendations to policymakers.

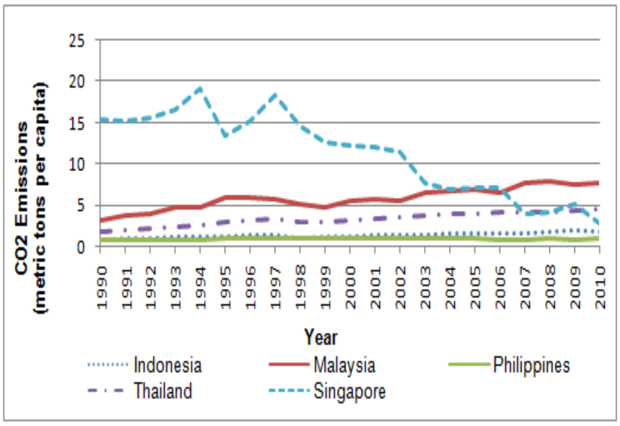
Key-Words: - Carbon dioxide emissions, economic growth, Environmental Kuznets curve, ASEAN-5 countries

1. Introduction

Globalization is both a motivator and motivation for economic growth. However, in addition to wealth growth, it has also catalysed many other weather events that bring about one of the most prominent concerns of the world at present: global warming. Scientists have discovered that Carbon dioxide (CO_2) is one of the main gases causing the global warming problem. This has led to the questioning of whether economic growth would worsen the issue of CO_2 emissions from economists and environmentalists alike, which piqued the interests of policymakers in countries across the world.

Over the last three decades, ASEAN-5 countries (Indonesia, Malaysia, the Philippines, Singapore, and Thailand), among others, have seen rapid industrialization with the highest economic growth (Lean & Smyth, 2009). Moreover, the ASEAN region is known to be one of the most trade-oriented within developing countries. They also have a highly dependent relationship with foreign direct investment (FDI) for growth (Intal, Narjoko, & Simorangkir, 2012). Thus, factors such as trade openness and FDI are chosen as controlled variables in this study.

Fig.1. CO_2 emissions (metric tons per capita) in ASEAN-5



[Source: Worldbank.org]

Fig.1 shows that over the years, the trend of CO_2 emissions in Singapore has declined rather sharply, while the other four countries continue to experience an increase, with the exception of the Philippines. Malaysia seemed to be in the lead among ASEAN-5 in the production of CO_2. It was reported that Malaysia is one of the top producers of CO_2 gas in the region of Asia (Lau, Choong, and Eng, 2014). The recent reoccurrences of open burning of forests for palm oil trees and the production of biodiesel and oil in Indonesia, which resulted in bad haze that tended to spread over to neighbouring ASEAN countries, have undoubtedly increased the CO_2 pollution over the years (Intal, Narjoko, and Simorangkir, 2012). Besides, Thailand is no exception and it has also experienced an increasing trend in its CO_2 emissions.

One of the objectives of ASEAN Vision 2020 is to "work towards a world class standard and conformance system that will provide a harmonised system to facilitate the free flow of ASEAN trade while meeting health, safety and environmental needs". In other words, the ASEAN Vision 2020 is claimed to safeguard the region's environment and sustain its natural resources (ASEAN, 1997). Many of the environmental problems faced by ASEAN countries are trans-border, which demands a joint response from ASEAN as a region. The governments of ASEAN-5 nations need to be aware of the economic factors that contribute to CO_2 emissions in the ASEAN-5 region. It is essential for the enactment and implementation of the proper strategy or policy to improve and therefore sustain the ASEAN-5's natural environment in the pursuit of economic growth.

2. Literature Review

The environmental Kuznets curve (EKC) is a hypothesized relationship between environmental variables and income per capita. In the early stages of economic growth degradation and pollution increase, but beyond some level of income per capita the trend reverses, so that at high-income levels economic growth leads to environmental improvement. This implies that the environmental impact indicator is an inverted U-shaped function of income per capita (Cohen, 2012; Lau, Choong, & Eng, 2014; Lean & Smyth, 2009). There was also a mention of an N-shaped curve. Curves that are N-shaped may lead to an increase in CO_2 emissions alongside high levels of income (Mazzanti, Montini, & Zoboli, 2007). The paper emphasized that the curves vary for many countries in various stages of development, and that the "one-size fits all" assumption of the EKC is not supported. This is presumed because developing and late-developing groups of nations are still at the beginning phases of the development process and have yet to reach an appropriate income level.

Pollution is encouraged by the actions of goods processing, which is caused by greater trade intensity or trade openness (Hossain, 2012). A study in Tunisia was carried out by Chebbi, Ollareaga, and Zitouna (2011) and showed that over the last two decades, Tunisia has progressively become a more open trade system. At the same time, it has attempted to control the level of environmental degradation by applying environmental reforms. Unfortunately, the positive effects expected of the reforms cannot be seen because of the continuous rising of emission levels of CO_2 from the country, with the reallocation of resources shifting more towards polluting industries. In addition, a study conducted in Indonesia also found that trade openness adversely affects the level of CO_2 emissions in the country (Saboori, Sulaiman, & Mohd, 2012). However, there are always two sides of the same coin. Trade openness may lead to higher competition and therefore more pressure on countries participating in trade to use their resources in a more efficient way so that they can reduce the amount of pollution contribution (Loi, 2010).

On the other hand, FDI also reduces welfare because it may cause a rise in pollutions level. A study carried out by Hassaballa (2014) signified that there is a positive relationship between FDI inflows and lax regulatory laws for the environment. Besides, Blanco, Gonzalez, and Ruiz (2013) carried out a study on the relationship between FDI and CO_2 pollution in Latin American countries and they found that FDI did cause more CO_2 emissions to be produced in these countries.

2. Data and Methodology

Instead of doing a single-country study, a group of countries (ASEAN-5) is chosen for our study. Using the panel-based tests enables us to focus on more than one country which would provide us with more data and more stability in estimations (Lean & Smyth, 2009). The techniques used in this study are panel unit root tests, panel cointegration and panel long-run estimates as well as panel VECM (vector error correction model).

The EKC suggests that in the early stages of economic growth environmental degradation increases, but after a certain level of income is attained, the degradation decreases and improvement starts (Markandya et al., 2002). Some studies (Suri and Chapman, 1998) have included a cubic term to determine whether an N-shaped curve is observed after income level increases significantly, resulting in reoccurrences of environmental degradation due to luxury spending. Besides, following Lau, Choong, and Eng (2014)(for trade openness) and Blanco, Gonzalez, and Ruiz (2013) (for FDI), our econometric model also includes trade openness and FDI to reduce specification bias in the econometric estimation. In short, this research utilizes the CO_2 emissions, economic growth in the form of GDP per capita along with its square and cubic terms, foreign direct investment inflow and trade openness. All the variables are transformed into natural log form. The log-linear specification can produce more consistent and efficient results than the linear model. In addition, according to Chang et al. (2001), converting the model into natural logs can help to induce stationarity in the variance–covariance matrix. Hence, the model is estimated as follows:

$$\ln CO_{2it} = \alpha_i + \beta_{1i} \ln GDP_{it} + \beta_{2i} \ln GDP_{it}^2 + \beta_{3i} \ln GDP_{it}^3 + \beta_{4i} \ln TRADE_{it} + \beta_{5i} \ln FDI_{it} + \varepsilon_{it} \quad (1)$$

where CO_2 is carbon dioxide emissions (metric tons per capita), GDP is GDP per capita while GDP^2 and GDP^3 are the square and cubic terms of GDP per capita respectively. TRADE represents the trade openness ratio (sum of total exports and imports by the GDP). FDI is foreign direct investment inflow. ε_{it} is the regression error term. This study utilizes panel data (annual) for ASEAN-5 over the period 1981–2010, obtained from the World Bank data base.

2.1 Panel unit root tests

We use the panel unit root tests proposed by Levin, Lin, and Chu (2002), Im, Pesaran, and Shin(2003), Maddala and Wu (1999). By using more information, panel unit root tests are able to amend some significant flaws of existing single time series tests, including low-power and large-size distortions (Perman & Stern, 2003). The unit root test by Levin, Lin, and Chu (2002) has a panel based proposition based on the Augmented Dickey-Fuller (ADF) test which examines the presence of homogeneity in the dynamics of the autoregressive coefficients. This is tested for all panel units with cross-sectional independence. The t-bar test, which was proposed by Im et al. (2003), takes the assumption that "all countries converge towards the equilibrium value at different speeds under the alternative hypothesis". The test proposed by Maddala and Wu (1999) takes the form of the Fisher Augmented Dickey-Fuller (F-ADF) test. This test, which is a non-parametric statistics suitable for small sample sizes, uses the p-values of the test statistics obtained to check for a unit root in each residual cross-sectional unit.

2.2 Panel cointegration

Given that each of the variables contains a panel unit root, we proceed to examine whether there is a long-run relationship among the variables using the panel cointegration test developed by Pedroni (1999, 2004). The panel cointegration technique is used to pool information on common long-run relationships and, simultaneously allow for short-run dynamics and fixed effects to be heterogeneous across the different members of the panel. The test statistics are computed using the residuals of the hypothesized cointegrating regression of Equation (1), with tests on the null of no cointegration based on the residuals $\hat{\varepsilon}_{it}$ as follows:

$$\hat{\varepsilon}_{it} = \rho_i \hat{\varepsilon}_{i,t-1} + \mu_{it} \quad (2)$$

Since the α_i and the various β_i of Equation (1) are permitted to differ across the *i* members of the panel, this approach allows for considerable short- and long-run heterogeneity. Based on the cointegrating residuals, ε_{it}, Pedroni (1999, 2004) develops seven panel cointegration statistics. Four of these statistics, named panel cointegration statistics, are within-dimension-based statistics constructed by totaling both the numerator and the denominator terms over the N dimension separately. Meanwhile, the other three statistics, called group mean panel cointegration statistics, are between-dimension-based statistics constructed by dividing the numerator by the denominator prior to totaling over the N dimension. In terms of power, Pedroni illustrates that the group-ADF (augmented Dickey–Fuller) statistic generally performs best followed by the panel-ADF statistic, while the panel variance and group statistics do poorly.

2.3 Panel long-run estimates

2.3.1 Dynamic Ordinary Least Squares (DOLS)

To acquire an unbiased estimator of the long-run parameters of Equation (1), this study uses the dynamic ordinary least squares (DOLS) estimator proposed by Kao and Chiang (2000). The DOLS estimator is an extension of Stock and Watson's (1993) estimator, which enhances the static regression with the leads, lags, and contemporaneous values of the regressors in the first differences. Consider a panel model with fixed effect:

$$y_{it} = \alpha_i + x'_{it}\beta + \mu_{it}, \; i = 1, ..., N; t = 1, ..., T \quad (3)$$

where y_{it} is a matrix (1, 1), β is a vector of slopes (*k*, 1) dimension, α_i is an individual effect, and μ_{it} is an error term. We presume that the x_{it} (*k*, 1) vector is an autoregressive process of the first order difference:

$$x_{it} = x_{it-1} + \varepsilon_{it} \quad (4)$$

The DOLS estimator is obtained from the following equation:

$$y_{it} = \alpha_i + x'_{it-1}\beta + \sum_{j=-q_1}^{j=q_2} c_{ij}\Delta x_{it+j} + v_{it} \quad (5)$$

where c_{it} is the coefficient of a lead or lag of first differenced explanatory variables.

2.3.2 Fully Modified Ordinary Least Squares (FMOLS)

In addition to DOLS, the FMOLS method proposed by Pedroni (2001) is also utilized in the present study to attain the panel data estimates for Equation (1). This method applies the semi-parametric correction into the ordinary least squares estimator to exclude bias caused by endogeneity of the regressors. The group mean panel FMOLS *t*-statistics for β is as follows:

$$\bar{t}_{\hat{\beta}_{NT}} = N^{-1}\sum_{i=1}^{N}\hat{L}_{11i}^{-1}\left[\sum_{t=1}^{T}(x_{it}-\bar{x}_i)^2\right]^{-1/2}\left[\sum_{t=1}^{T}(x_{it}-\bar{x}_i)y_{it}^{*} - T\hat{\tau}_i\right] \to N(0,1) \quad (6)$$

where $$y_{it}^{*} = (y_{it} - \bar{y}_i) - \frac{\Omega_{21i}}{\Omega_{22i}}\Delta x_{it}$$

$$\tau_i \equiv \Gamma_{21i} + \Omega_{21i}^{0} - \frac{\Omega_{21i}}{\Omega_{22i}}\left(\Gamma_{22i} + \hat{\Omega}_{22i}^{0}\right) \quad (7)$$

where the $\hat{\Omega}_i$ and $\hat{\Gamma}$ are covariances and sums of autocovariances procured from the long-run covariance matrix for Equation (1), and the associated *t*-statistic follows standard normal distribution.

2.4 Panel Vector Error Correction Model (PVECM)

Once cointegration is proved to exist in the model, the PVECM is used to find out the direction of causality among the variables employed in the study.

$$\begin{bmatrix} \Delta LCO2_{it} \\ \Delta LRGDPC_{it} \\ \Delta LRGDPC2_{it} \\ \Delta LRGDPC3_{it} \\ \Delta TRADE_{it} \\ \Delta FDI_{it} \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \end{bmatrix} + \sum_{p=1}^{r} \begin{bmatrix} \beta_{11p}\beta_{12p}\beta_{13p}\beta_{14p}\beta_{15p}\beta_{16p} \\ \beta_{21p}\beta_{22p}\beta_{23p}\beta_{24p}\beta_{25p}\beta_{26p} \\ \beta_{31p}\beta_{32p}\beta_{33p}\beta_{34p}\beta_{35p}\beta_{36p} \\ \beta_{41p}\beta_{42p}\beta_{43p}\beta_{44p}\beta_{45p}\beta_{46p} \\ \beta_{51p}\beta_{52p}\beta_{53p}\beta_{54p}\beta_{55p}\beta_{56p} \\ \beta_{61p}\beta_{62p}\beta_{63p}\beta_{64p}\beta_{65p}\beta_{66p} \end{bmatrix} \begin{bmatrix} \Delta LCO2_{it-p} \\ \Delta LRGDPC_{it-p} \\ \Delta LRGDPC2_{it-p} \\ \Delta LRGDPC3_{it-p} \\ \Delta TRADE_{it-p} \\ \Delta FDI_{it-p} \end{bmatrix}$$

$$+ \begin{bmatrix} \emptyset_1 \\ \emptyset_2 \\ \emptyset_3 \\ \emptyset_4 \\ \emptyset_5 \\ \emptyset_6 \end{bmatrix} ECT_{it-1} + \begin{bmatrix} \varepsilon_{1it} \\ \varepsilon_{2it} \\ \varepsilon_{3it} \\ \varepsilon_{4it} \\ \varepsilon_{5it} \\ \varepsilon_{6it} \end{bmatrix} \quad (8)$$

where Δ is the first differenced operator, ECT is the error correction term, *p* represents lag length, and ε is the serially uncorrelated error term. Using the least squares estimator, the panel VECM equations are estimated. The optimal lag length is chosen using the vector autoregressive (VAR) lag length criteria, which is the Schwarz and Akaike information criteria. While the short-run causality is determined by the statistical significance of the partial *F*-statistic of the right hand side variables, the long run causality is determined by the significance of the error-correction terms using a *t*-test.

3. Results

3.1 Panel unit root tests

According to Table 1, the panel unit root tests on average indicate that all variables are non-stationary at level. However, after taking the first difference, all the variables become stationary at 1%.

Table 1: Panel Unit Root Tests

Test/ variable	Levin, Lin & Chu		IPS		ADF-Fisher	
	Level	First difference	Level	First difference	Level	First difference
CO_2	-1.15	-6.74***	-0.92	-3.80***	3.34	58.46***
GDP	-0.12	-4.90***	-0.20	-3.31***	2.63	43.38***
GDP^2	0.30	-4.89***	-0.05	-3.35***	1.92	44.47***
GDP^3	0.70	-4.84***	0.09	-3.38***	1.41	45.44***
TRADE	-0.70	-8.81***	-1.60	-5.29***	9.40	85.38***
FDI	-1.55	-11.30***	-2.22	-6.41***	16.30	109.04***

Notes: *** denote rejection of the null hypothesis of non-stationarity at 1% level of significance. The maximum number of lags is set to be three. SBC is used to select the lag length.

3.2 Panel cointegration

Referring to Table 2, both models of 2a and 2b show that four out of seven statistics reject the null hypothesis of no cointegration among the variables. For panel v-stat, the result is significant with trend and intercept. While the panel v-stat statistics show significance at 5%, the others are significant at 1%. The outcome of the Pedroni cointegration test supports that there is a cointegrating relationship among the variables.

Table 2: Results of Pedroni Panel Cointegration Test (Dependent variable: CO_2 emissions in metric tons per capita)

	Model 2a: Without Trend	**Model 2b: With Trend**
Within Dimension		
Panel v-stat	*1.59*	*1.96***
Panel rho-stat	*0.97*	*1.07*
Panel pp-stat	*-3.00****	*-6.43****
Panel ADF-stat	*-3.06****	*-6.19****
Between Dimension		
Group rho-stat	*1.28*	*2.31*
Group pp-stat	*-2.52****	*-6.76****
Group ADF-stat	*-2.28****	*-4.87****

Note: ** and *** denote rejection of the null of non-stationarity at 5% and 1% levels of significance respectively

3.3 Panel long-run estimates (DOLS and FMOLS)

Models 1 and 2 in the Table 3 below present the results of long-run relations between economic growth and CO2 emissions in the presence of trade openness and FDI. In general, the results are quite similar and robust except that FDI is insignificant in Model 2. According to the findings, the CO_2 emissions exhibit an inverted-S shaped curve where the emission levels first decrease and then increase when incomes reach a high level, but decrease again at higher levels of income. This is indicated by the significant negative sign of GDP followed by the significant positive GDP^2 and then significant negative GDP^3. As for the trade openness variable, the outcome of both models is positive and statistically significant. Nevertheless, FDI suggests a positive and statistically significant relationship with CO_2 emissions in Model 1 but insignificant in Model 2.

Table 3: Results of DOLS and FMOLS Estimations (Dependent variable: CO2 emissions in metric tons per capita)

	Model 1: DOLS (Lag = 1, Lead = 2)	**Model 2: FMOLS**
Real GDP per capita (lnGDP)	-13.25689 (-2.231216)**	-34.38612 (-21.52462)***
Square of Real GDP per capita ($\ln GDP^2$)	2.017058 (2.895846)***	4.596323 (23.77559)***
Cube of Real GDP per capita ($\ln GDP^3$)	-0.095320 (-3.527904)***	-0.196108 (-25.68388)***
Trade Openness (lnTRADE)	0.456374 (4.158790)***	0.141742 (3.950122)***
FDI Inflow (lnFDI)	0.157149 (1.900628)*	0.011752 (0.667608)

Notes: *, ** and *** denote the levels of significance at 10%, 5% and 1% respectively. Figures in parentheses are t-statistics.

3.4 Panel Vector Error Correction Model (PVECM)

Table 4 shows the panel causality test results based on Model 2 - FMOLS. It can be seen that there is a unidirectional relationship from GDP, GDP^2, and GDP^3 to CO_2 emissions and trade openness, respectively. On the other hand, trade openness Granger causes FDI. These linkages are summarised in Fig.2. Besides, the results shown in the Table 4 indicate that there is a long run Granger causality running from economic growth, trade openness and FDI to CO_2 emissions due to its error correction term (ECT) being significant at 1%.

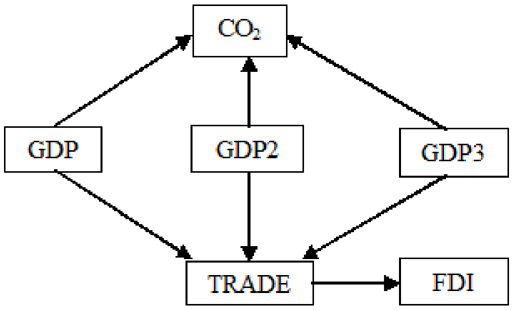


Fig.2 Causality Diagram

Table 4: Panel Vector Error Correction Model (FMOLS)

Dep. variable	F-statistics						ECT	
	Δ CO_2	Δ GDP	Δ GDP^2	Δ GDP^3	Δ TRADE	Δ *FDI*	Coef	t-stat
ΔCO_2	-	10.74**	11.53***	12.57***	5.85	2.52	-0.20	-2.80***
ΔGDP	0.85	-	0.98	0.89	4.68	0.36	-0.02	-0.77
ΔGDP^2	1.06	0.69	-	0.73	4.85	0.53	-0.33	-0.71
ΔGDP^3	1.44	0.63	0.74	-	4.75	0.77	-3.89	-0.64
ΔTRADE	2.96	9.76**	8.84**	8.26**	-	4.41	0.06	0.85
ΔFDI	3.19	4.97	4.15	3.45	15.65***	-	0.28	1.22

Note: ** and *** denote rejection of the null of non-stationarity at 5% and 1% levels of significance, respectively.

4. Conclusion

This study has used panel unit root tests, panel cointegration, Dynamic Ordinary Least Squares (DOLS), Fully Modified Ordinary Least Squares (FMOLS), and panel vector error correction model (PVECM) to examine the relationship between economic growth and CO_2 emissions in ASEAN-5 countries in the presence of foreign direct investment (FDI) and trade openness from 1981 to 2010.

After controlling the trade openness and foreign direct investment (FDI) variables, the results of our study show that an inverted-S shaped relationship does exist between economic growth and CO_2 emission in both short-run and long-run for ASEAN-5 countries. Referring to Fig.1 - CO_2 emissions (metric tons per capita) in the ASEAN-5 countries, all ASEAN-5 seem to be on the uptrend except Singapore. Accordingly, it is most likely that Singapore is on the downward sloping area of the inverted-S shaped curve at higher levels of income while the other 4 countries may be on the upward sloping area. Based on the PVECM results, economic growth does influence both CO_2 emissions and trade openness while trade openness influences FDI in ASEAN-5 countries.

In the process of achieving economic development, ASEAN-5 is generally bearing the consequence in the form of CO_2 pollution. The direction and strength of causality between growth-CO2, growth-trade, and trade-FDI can aid in fashioning policies to boost foreign investments and trade in a more eco-friendly approach. The existence of the inverted-S shaped curve indicates that there is a need for ASEAN-5 to step up their efforts to reduce CO_2 emissions in the future. ASEAN-5 economies may consider regional agreement as an in-house solution to this matter.

Policy makers of ASEAN-5 countries can encourage local firms to invest in environmentally friendly technologies via tax exemptions. The tax exclusions can also be made valid for foreign investors looking to set up subsidiaries or factories in ASEAN-5 countries, with the condition that they bring in green technology that would be less harmful to the environment. Additionally, government spending on research and development of greener technologies can be increased to boost the motivation of creating and innovating eco-friendly tools. Last but not least, ASEAN-5 countries can join forces through collaboration and come up with the suitable parameters to curb carbon emissions while generating economic growth for the countries.

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