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CO_2-GDP NEXUS: Case for ASEAN 5

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ABSTRACT

This paper examines the causal relationship between carbon dioxide emission (CO_2) and Gross Domestics Product (GDP). The nature of causality between CO_2 per kilo tan (CO_2) and GDP per capita were utilized using a cross country panel data from 1980 to 2010. The test was carried out using panel unit root tests, panel co-integration test, and panel vector error correction estimation and panel Granger causality tests to access the relationship between the respective variables. Our empirical results show the existence of long-run relationship and also suggested that GDP causes CO_2 emissions in ASEAN-5. Granger-Causality test result found a one way direction (unidirectional) and no reverse causality. The results also provided indications that a change in CO_2 would give favorable impact to the country economic growth. This research would be useful for policy-making by implementing the sustainable energy approach to control the emission and to reduce a green-house effect.

1. Introduction

The relationship between carbon emissions and economic growth is based on Environmental Kuznets Curve (EKC). According to EKC, hypothesis pollutions increase as a country develops but decrease rising incomes beyond a turning point. In other words, there is a threshold level of economic growth beyond which further increase is able to redress the environmental impacts of the early stages of economic development. These studies are essential for ASEAN-5 as this region is in developing stage, and any precautious strategy or corrective action to combat the environmental degradations still relevant. Most of the previous researcher examined the relevance of EKC in developing countries, while fewer studies focus on the full distance of the nexus between CO_2 and GDP. Even where the same studies have been done but the research focus more to Europe, Middle East and Latin America countries. Studies on environmental economics still few in ASEAN countries.

This research aims to discover the linkages of CO_2 and GDP as these variables are connected in contributing towards global warming and climate change. The research specifically focuses on ASEAN-5 namely Malaysia, Indonesia, Philippines, Singapore and Thailand as these countries share similarity in the level of economic development since 1980 that coincided with significant increase in fossil fuel usage. ASEAN-5 has a healthy and progressed economic growth compared to the other five ASEAN member countries (Chandran and Tang, 2013). Furthermore, these five countries were the original founding members of ASEAN in 1967 and remain the most influential members of ASEAN in the 21 century. One of the challenges for ASEAN-5 is to achieve an economic growth manages CO_2 into the environment by utilizing energy efficiency.

In ASEAN, from the period of 1980 to 1999, its economy grew by nearly 5% a year and energy consumption by 7.55. The economy is expected to continue to grow at this rate over the period from 2000 to 2020, and it is estimated that annual energy supply must increase by 4.2% a year to sustain this growth (Balce, 2001). CO_2 are expected to grow over the years to be in line with the aspiration in achieving an economic growth. ASEAN is linked with its diverse energy resources, high-level urbanization and rapid industrialization (Karki et al., 2005).

ASEAN-5 has progressed economically well compared to other members of ASEAN. Among the ASEAN countries (excluding Brunei), in terms of per capita income in 2008, Singapore (USD 39,991) ranked the highest followed by Malaysia (USD 8032), Thailand (USD 4103), Indonesia (USD 2245) and the

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Philippines (USD 1840). The average GDP growth of ASEAN-5, between 2004 and 2009, was 5.9% with Singapore and Indonesia recording over 5% growth rates. The rapid growth of the ASEAN-5, specifically for Singapore and Malaysia compared to the rest, poses an interesting question among policymakers. The level of economic growth is expected to grow further and in line with that, CO_2 are expected to increase due to extensive energy use. It is essential to heavily investigate the relationship between CO_2 and GDP in ASEAN in order to make preventive actions before it is too late; avoiding the dilemma like what is happening in China.

The rapid economic growth for ASEAN can be seen as in 2011, ASEAN GDP per capita per US dollar was US$3,601 billion, which is equivalent to 67% of China and 7% of United State GDP. The data was taken from ASEAN economic chart book, 2012. ASEAN makes up one of the largest regional markets in the world; contributing a combined gross domestic product (GDP) of US$578 billion in 2000. The region hosts approximately US$53 billion in direct US investments, and it is the third largest overseas market for US exports with two-way ASEAN-US trade totaling up to US$120 billion in 2001 (ACE, 2002).

1.1. Objectives of the study

The aim of the research are to investigates the long-run and short-run relationships between CO_2 emissions and GDP from 1980 to 2010 and examine the causality interplay between CO_2 emissions and GDP.

1.2. Research questions and hypotheses

The research questions and hypotheses that have been framed for the present research are to find a possible existence of causality relationship between CO_2 emissions and GDP whether it has bidirectional, unidirectional causality or no causality. Furthermore, the long-run and short-run relationships that can affect the country policy implementations are identified.

1.3. The rationale for the research

The rational of the research are exclusively investigating the linkages between CO_2 and GDP in ASEAN-5, and the results of the exploration is useful for developing environmental policies. If emission is found to Granger-cause economic growth, any policies that decrease CO_2 emissions will lead to a reduction in economic growth. It may be possible to reduce emission without having a negative impact on economic growth, Azlina et al. (2014). This research lead to further studies on environmental economics to curb the increase of global carbon emissions effectively, and solving global warming problem by not adding the expense of declining economic development and people's living standards. Environment and economics seem to be connected to each other; hence, in-depth studies or research on the relationships between economic growth and the environment can result in different conclusions. In addition, possible new theories on environmental economics can be explored.

2. Literature review

2.1. Economic theory on the relationship between CO_2 and GDP

2.1.1. Environmental Kuznet curve

EKV curve hypothesis theory tells that an inverted U-shaped relationship exists between various indicators of environmental pollution and economic activity. The theory behind this hypothesis is that environmental degradation increases during the initial stage of economic growth until it reached a threshold level or turning point or when a particular income is reached, after which the environmental degradation begins to decline. The theory was developed by economist Simon Kuznets in the 1950s and 1960s. The economic theory established that economic and environmental growths are well connected to each other. Many scholars have conducted research to investigate the relationship between GDP and CO_2 emissions in various econometric models. Most of the research included the CO_2 emissions variable in the model because CO_2 is a determinant in measuring the climate change. Aslanidis (2009) did a research on the EKV for CO_2 emissions. The EKC theory hypothesis and the theory of the inverted u-shaped curve cannot be applied to any situation to show the relationship between income and economic growth relationship. The EKC theory normally can be proven to a set of rich countries where the environmental protection already in a peak. He (2007) in his study for a set of developing countries found that in a given situation, the shortcomings in both the theoretical and empirical aspects of EKC theory do not fit for all to show the relationship between income and economic growth. Hence, this research only zoomed in on the relationship and causality of CO_2 and GDP.

2.1.2. Production function

In economies, the production function relates physical output of factors of production to its physical inputs. Production function are measured in order to create a framework to distinguish in what level does the economic growth attributes to change in factor allocation. From this theory, we can make a conclusion that CO_2 emissions are also connected with output. Kraft and Kraft (1978) agreed that the more production produced, the more energy will be consumed. Ang (2008) indicated that in the long-run pollution and energy use are positively related to output. Thus, the more energy used will contribute to more CO_2 emissions.

2.2. Theoretical studies on the causality between CO_2 emissions with GDP

Dinda and Coondoo (2006) investigated the causality issue of income and emission relationship and study the empirical validity of the EKC. Granger causality test were applied and the relationship between CO_2 emissions and income not support the empirical literature of EKC hypothesis. Azlina et al. (2014) try to validate the EKC hypothesis by applying a multivariate model, but that there is no causal found between incomes over emission. Halicioglu (2009) on his research for Turkey suggested that income is the most significant variables to relate the carbon emissions. Chang (2010) found CO_2 energy consumption and economic growth in China attained Granger causality. Amzath and Laijun (2014) did a study for Maldives to test the correlation and the nexus between carbon emissions and numbers of tourist receipts growth from the year of 1984 to 2010.

3. Empirical literature on the relationship between CO_2 emissions with economic growth and other determinants

We are employed a panel data approach because it provides more informative data, more degree of freedom and greater efficiency estimation. Furthermore, Augmented Dickey Fuller (ADF) test and co-integration can be distorted when the data collection is short (Johansen, 1988; Campbell and Perron, 1991). Awe (2012) using the concept of Granger causality tests that was developed by Granger (1969). Hatzigeorgiou et al. (2011) tested the causality of Gross Domestic Product, CO_2 emissions and Energy Intensity in Greece from 1977 to 2007. The method applied are co-integration tests based on Johansen test and Granger-causality tests based on a multivariate Vector Error Correction Modelling. Balcila et al. (2014) investigate the causality between economic growth and tourist receipts using ARDL-Bounds approach. Azlina et al. (2014) investigated the causal relationships between energy consumption, economic growth and pollutant emissions for Malaysia using series co-integration and vector error correction to test the causality. Co-integration analysis was conducted to see the long run relationship between CO_2 emissions and GDP, while the VECM technique was to test the short-run dynamics of the variables. Dinda and Coondoo (2006) investigated the causality issue of income and emission relationship based on the time series econometric technique of unit root test, co-integration and related error correction model applied to a panel data set.

3.1. Key variables

Panel data collected with data range from the year 1980 to 2010. The data for variables were obtained from World Development Indicator 2011 report (The World Bank, 2011).

A panel data from the annual time series of each variable has been constructed for the five selected ASEAN countries. All variables were transformed into natural logarithms as carbon dioxide (CO_2) emissions were measured in terms of metric tons per capita as a dependent variable, meanwhile real GDP per capita was expressed in constant USD at 2005 prices as an independent variable.

3.2. CO_2 emissions per kt

CO_2 are those stemming from the burning of fossil fuels. They include CO_2 produced during consumptions of solid, liquid and gas fuels and gas flaring.

3.3. Real GDP per capita

Real GDP per capita represent a gross domestic product divided by midyear population. Gross Domestic Product is the sum of gross value added by all resident producers in the economy, by adding any product taxes and minus any subsidies not included in the value of the products. Data collected were in current USD 2005 constant price.

4. Methodology

4.1. Panel unit root test

This research specifically empowered the panel unit root test because it is considered to be better compared to individual unit root tests. Panel data information is in the time series enhanced by a cross section data. In contrast, individual unit root tests consist complicated limiting distributions while panel unit root test statistics have normal limiting distributions. Complicated limiting distribution is referring to the random variables whose distributions are not known.

4.2. Panel co-integration test

Pedroni (1999) and Kao (1999) proposed panel co-integration tests which is similar to the Engle and Granger (1987) framework. The framework included the testing of stationary on the residuals from a levels regression. Kao's test is based on the following model (Eqs. 1-3):

$$Yit = \alpha i + \beta \chi it + eit \quad (1)$$
$$Yit = Yit - 1 + \upsilon it \quad (2)$$
$$\chi it = \chi it - 1 + \nu it \quad (3)$$

where i = 1,....., and t = 1,....., T, αi denotes individual intercepts, β is the common slope across i, eit is the error term and both Yit and χit contain a unit root. Kao's test is designed to find whether Yit an Pedroni (1999) and Pe d χit are co-integrated. Pedroni (2004) developed an alternative residual-based co-integration test under the null hypothesis of no co-

integration for heterogeneous panels. The difference between the Pedroni's test and Kao's test in the sense that it assumes p to be heterogeneous across cross-sections.

DOLS method was employed to estimate the long-run co-integration equation, which relates CO_2 emissions and GDP.

4.3. Panel vector error correction estimates (VECM)

Upon proving whether or not the series or variables contain unit roots and are co-integrated of order one, a long run relationship is presumed to exist between the variables. Thus, Granger (1988) argued that a proper Vector Auto regression framework must include Error Correction Model to analyze the dynamic relationship between the variables. Co-integration is a property of long-run equilibrium; meanwhile Granger causality is a short run phenomenon. A co-integrated variable contains the error term for the assessment on how the variables are adjusted, in response to short run disruptions, to re-establish equilibrium in the long run. The error term relates the variables' short run behaviour to its long run values. The representation theorem, in accordance to Engle and Granger (1987), expresses the error correction model of Eq. 4.

$$\Delta \ln CO_{2t} = \alpha + \lambda Z_{t-i} + \sum_{i=1}^{n} \beta_1 \Delta \ln GDP_{t-i} + \varepsilon_t \quad (4)$$

where Δ = the first difference operator, ε_t = random error term and Z_{t-i} one period lagged value of the error.

Through the Johansen multivariate procedure, Z_{t-1} is the generated error correction term, while λ is the error correction coefficient. This is a periodic measurement of the regression response; to its departures from equilibrium. The term Z_{t-1} reflects that the dependent variable is not directly adjusted to its long run determinants.

4.4. Panel Granger causality test based on VECM

Causality is a kind of statistical feedback concept, which is widely used in the building of forecasting models. Historically, causality has been applied formally in economics owing to Granger (1969) and Sims (1972). For this purpose, pairwise Granger causality test and Wald test based on χ2, VECM Granger Causality/Block Exogeneity are employed to determine the Granger causality. The bivariate regressions of the form:

$$Yt = \alpha 0 + \alpha 1 Yt + \cdots + \alpha l Yt\text{-}1 + \beta 1 Xt - 1 + \cdots + \beta l X\text{-}1 +$$
$$Xt = \alpha 0 + \alpha 1 Xt + \cdots + \alpha l Xt\text{-}1 + \beta 1 Yt - 1 + \cdots + \beta l X\text{-}1 + \epsilon t$$

(x, y) represent all the possible pairs of series in the group. The reported F - statistics are the Wald statistics for the joint hypothesis (Eq. 5):

$$\beta 1 = \beta 2 = \cdots \beta l = 0 \quad (5)$$

The null hypothesis for the granger causality test is:

For first regression: x not Granger-cause y
For second regression: y not Granger-cause x

5. Results and discussion

5.1. Panel unit root test

The results showed that CO_2 and GDP are non-stationary in levels. The data series contain unit root which indicate that the data do not support the rejection of the null hypothesis at the level form. The rejection of the null hypothesis can be seen in the first difference, in which all series for both variables were found stationary. Panel unit root tests confirmed and indicated that both CO_2 emissions and GDP series are I(1), which is the pre-requisite before performing co-integration analysis See Table 1.

Table 1: Panel unit root test

Unit Root	LC02	LGDP
	Level	
IPS	1.49513*	2.36314*
ADF-Fisher	2.92011*	2.23988*
LLC	1.01226*	0.92316*
PP-Fisher	1.96696*	2.82448*
	First-Difference	
IPS	1.49513***	5.72461***
ADF-Fisher	6.89617***	5.01045***
LLC	6.74884***	6.23655***
PP-Fisher	8.644301***	4.90095***

Notes: All unit root tests were performed with individual trends and intercept for each series. The optimal lag length was selected automatically using the Schwarz information criteria. The null hypothesis is a unit root for all the tests; *Statistical significance at 10% level; **Statistical significance at 5% level; ***Statistical significance at 1% level.

5.2. Long-run analysis: Panel co-integration test

Unit root test results suggested that CO_2 and GDP are stationary at first differencing. The results of stationary will allow us to test any possibility of a stationary long-run relationship that exist among these variables. In order to provide more robust evidences about the long-run relationship between CO_2 and GDP (Pedroni, 1999), seven tests were applied with the null hypothesis of no co-integration. Four out of seven of these statistics, called panel co-integration statistics, are within-dimension based statistics. These models were constructed by summing both the numerator and the denominator terms over the N dimension separately.

Table 2 tabulates the test statistics for panel and group tests. It indicates that the results were most significant in panel PP statistics with 0.0216 p value. Kao's co-integration indicated that the null hypothesis of no co-integration was rejected at 1% significant level, which implied that there exist a co-integration relation between CO_2 emission and GDP. Since the long-run co-integrating relation was found among the variables in various panel co-integration tests, this ascertained the existence of a long run equilibrium relationship between CO_2 and GDP

within ASEAN-5. The outcome of the results prompted the setup of an error-correction model.

Table 2: Pedroni's panel co-integration test results and Kao's co-integration test results

Test Statistic	LCO_2 AND LGDP
Panel V-Statistic	0.3752*
Panel rho-Statistic	0.0677**
Panel PP-Statistic	0.0216**
Panel ADF-Statistic	0.3074*
Group rho-Statistic	0.2460*
Group PP-Statistic	0.0408***
Group ADF-Statistic	0.4353**
Kao's co-integration test	0.0002***

Pedroni's panel co-integration test results and Kao's co-integration test results; Notes: (*,**,***) denotes rejection of null hypothesis of no co-integration at 10%, 5% and 1% level.

5.3. Panel DOLS results

The long-run elasticity of the impact of CO_2 on GDP for each of the selected ASEAN-5 countries based on the DOLS estimator is reported in Table 3. DOLS specified that CO_2 emissions have a positive and statistically significant impact on GDP. A 1% increase in CO_2 emissions increased the GDP by 1%. The long run coefficient on CO_2 rejected the null hypothesis at 1% with a significant p value of 0.0000. The coefficient estimated at 1.5938 indicated the elasticity of CO_2 emissions with respect of GDP and it can be interpreted such that CO_2 emissions rises by 1.5938% as the GDP increases by 1% in the long run. This test also showed that environmental pollution can affect GDP in the long run for ASEAN-5 countries. These hypotheses are useful for policy-makers to control environmental pollutions. However, to know which variables affect which, we further investigated and ran the causality test to see the short-run relationship and causality of each variable.

Table 3: Panel dynamic OLS (DOLS) estimates

Test Statistic	LCO_2 and LGDP
p-value	0.0000***
Coefficient	1.5938
R-squared	0.96

Notes: Models are estimated using fixed effects estimation. *** denotes significance at 1% level. One lags and one lead of differenced GDP are included to the long-run equation based on Bartlett Kernel, Newey-West fixed bandwidth

5.4. Panel vector error correction model (VECM)

Table 4 suggested that long-run equilibrium condition does influence the short-run dynamics in ASEAN-5. The result confirmed that the CO_2 emission of ASEAN-5 has an automatic adjustment mechanism and that the economy responds to deviations from equilibrium in a balancing manner. The -0.003241 value indicated the speed of adjustment of any disequilibrium that exist towards long run equilibrium state per year. The economy of ASEAN-5 will converge towards its long run equilibrium level by a fast pace of 3.2%. An increase in CO_2 has negative impacts on the GDP of ASEAN-5 in the short run. For instance, a 10% increase in GDP reduces 21.6% of CO_2 emissions. Meanwhile, a 10% increase in CO_2 reduces 18.7% of the GDP. This result suggested that GDP will affect CO_2 emissions greater as compared to CO_2 emission affecting GDP in the short-run. Thus, we can conclude that GDP causes CO_2 emissions to ASEAN-5.

Table 4: Panel vector error correction

VECM Statistic	Coefficient	Standard	T-Error
Co-integrating Eq. (EC(-1))	-0.003241	0.00066	-4.87433
D($LNCO_2$(-1))	-0.187933	0.09409	-1.99745
D(LNGDP(-1))	-2.16084	0.26257	2.86015
C	0.018280	0.01290	1.41762

5.5. Panel vector error correction model (VECM) based causality test result

Causality is a type of statistical feedback concept which has been widely applied during the construction of the forecast models. Causality test is basically an econometrics technique to identify whether one time-series is relevant in forecasting another, as defined by Granger (1988).

Panel VECM test suggested that a long-run equilibrium situation does influence the short-run dynamics of CO_2 and GDP in ASEAN-5. However, panel VECM test does not explain the directions of causation among the variables. In order to solve the question, Granger causality test was performed to identify the causality direction among CO_2 and GDP. The results of the causality test are presented in Tables 5 and 6.

Table 5: Panel pairwise granger causality test

Null Hypothesis	F-Statistic	Prob.
LGDP does not Granger Cause LCO_2	9.43867	0.0001***
LCO_2 does not Granger Cause LGDP	0.75140	0.4736*

Based on the results obtained from the VECM Granger Causality/Block Exogeneity Wald Test using the VECM approach, the result for causality in Table 5 indicated that GDP are the causes of CO_2 emissions. The results of causality were also supported by another causality test i.e., the panel Pairwise Granger Causality Test, which also indicated that GDP are the causes of CO_2 emissions in ASEAN-5. The results are presented in Table 6.

Table: 6: Panel VECM Granger Causality/Block Exogeneity Wald test results

Dependent Variables	Independent Variables
D(LCO_2)	1.9356* (0.3799)
D(LGDP)	18.631*** (0.0001)

6. Conclusion

This study examines the co-integration and causal relationship between GDP and CO_2 in ASEAN-5.The empirical results of this research have indicated that there are long and short run co-integrations over CO_2 emissions and GDP for ASEAN-5. The Granger causality tests have found that causality runs from GDP to CO_2 emissions. The causality results for ASEAN implied a one way

direction (unidirectional) running from GDP to CO_2 emissions with no reversed feedback. From the results, we can conclude that economic growth in ASEAN-5 is the cause of CO_2 emissions in the air. By deducing the empirical results, ASEAN-5 should implement a policy for CO_2 emissions reduction. GDP causes CO_2 emissions, thus indicating that when the government implements any new strategies and policies to control and reduce CO_2 emissions, it will not interrupt economic development but would rather give more favorable impacts to ASEAN-5. In contrast, if the empirical results showed that CO_2 emissions cause GDP, any implications to CO_2 emissions reduction will also give impacts to the economic growth of ASEAN-5.

Similar findings found by Shahbaz et al. (2013) where the linkages between economic growths to CO_2 emissions in Indonesia over the period of 1975-2011 are unidirectional. Jahangir et al. (2012) did a case study to test the causality of CO_2 emissions and GDP for Bangladesh. Bangladesh is an example of a poor country. The result of Granger Causality test found that the causality runs from GDP to CO_2 emissions. This research are important for poor and developing countries, where economic growth is still at the beginning and policy-makers can create an effective method to escape from the poverty trap that will come from environmental pollutions.

Research on developed country by Ang (2007) indicated that there is a bidirectional relationship running from CO_2 emissions and output. A bidirectional direction suggests that in both ways the variables are reacting to each other. Policy-makers are minded in adopting new policies to reduce CO_2 emissions because if the policies are not critically planned, any policies applied to reduce CO_2 emissions will lead to reduction in the numbers of output.

6.1. Implication for policy and practice

The results are sensible given that a significant amount of economic growth in ASEAN-5 have been fuelled by industrial growth, which required intensive use of energy and that CO_2 emissions are heavily released into the air.

The results have important implications for policy-makers in ASEAN-5, who aspire to transform the economy into a fully industrialized nation in the near future. A rapid industrialization requires higher and more efficient consumption of energy products. Given that over consumption of resources can have negative impacts on the environment; there is much scope for the development of energy conservation strategies. The pattern of development is nearly similar with the experiences of many developing countries. However, despite the above findings, policy-makers should be mindful that a persistent decline in environmental quality may exert a negative externality to the economy in affecting human health and thereby reducing productivity in the long-run.

6.2. Recommendations

There are various environmental policy instruments available, which have different impacts on the energy and CO_2 emission mechanisms. Below are our suggestions:

6.2.1. Information guidance

A form of information guidance to the consumers is by nurturing the community to adopt environmental friendly lifestyles. For example, reduced oil consumptions can be realized by shifting to public transport for commute; or even walking or cycling. Besides that, consumers can also purchase energy and water efficient appliances that can save energy and water usage.

6.2.2. Less carbon fuel

Government should implement a policy carbon-free to business group and individuals. Carbon-free sources of energy are environmentally friendly because the machine and technology operated without emitting CO_2 into the air. Wind power, solar power, geothermal energy, nuclear power, wave and tidal power are types of carbon-free energy sources. Another option to slower CO_2 emissions combust into the air is by switching from high utilization of carbon fuels like oil and coals to natural gas to less-carbon fuels. Chandran and Tang (2013) concluded that ASEAN-5 road energy consumption is one of the major contributors to CO_2 emissions, and the region has to focus more to energy efficient.

6.2.3. Carbon tax

Carbon tax is tax charged based on the amount of greenhouse gases generated from burning fuel and coal from in the production sector. For any businesses and production houses that can reduce fuel consumption, improve fuel efficiency, apply cleaner fuels and adopt new technologies, they are entitled for a discount in the amount they need to pay in carbon tax. According to Liang et al. (2007) in their study on the carbon policy in China, carbon tax is one of the important choices in environmental.

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