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ECONOMIC GROWTH AND AIR POLLUTION: COINTEGRATION AND CAUSALITY ANALYSIS FOR MALAYSIA

Zarul Azhar bin Nasir , Mohd Zulkifly Che Mohd Rawawi ,
Muhammad Zahidi Mohd Sharif[1] &Nur Aziera Suliman
Faculty of Business Management, Universiti Teknologi MARA (Perak), Malaysia
zarul6105@perak.uitm.edu.my[1]

Abstract
This paper investigates empirically the causal relationship between economic growth and air pollution in Malaysia over the period 1965 to 2010. To analyze the causal relationship between economic growth and air pollution, the Johansen cointegration test; Vector Error Correction Model (VECM) and Granger causality test are used. The Johansen Cointegration Test results found that these two variables are cointegrated and show the existence of short run and long run relationship. The Granger causality test suggests that there is bidirectional Granger causality among these variables with direction from CO2 to GDP and GDP to CO2.

Keywords: Economic Growth, Air Pollution, Granger Causality Test, Johansen Test.

1. Introduction

Numerous studies have been carried out over the relationship between economic growth and environment quality where economic growth came with environmental damage then. Undoubtedly, development of a country will result an external cost which affects environment quality. Malaysia as one of the developed countries which experiences rapid economic transformation, industrialization and population expansion is facing the lack of importance in environment towards economic growth in which the aim is to achieve successful socio-economic.
An increased in the full production output level of nation overtime that faced short terms ups and downs is referred as economic growth. An economic growth is determined by the annual Gross Domestic Product (GDP) of a country. The increase in economic growth is always related to the environment which mostly brings negative effects. Figure 1 shows the GDP of Malaysia from 1965 to 2010.

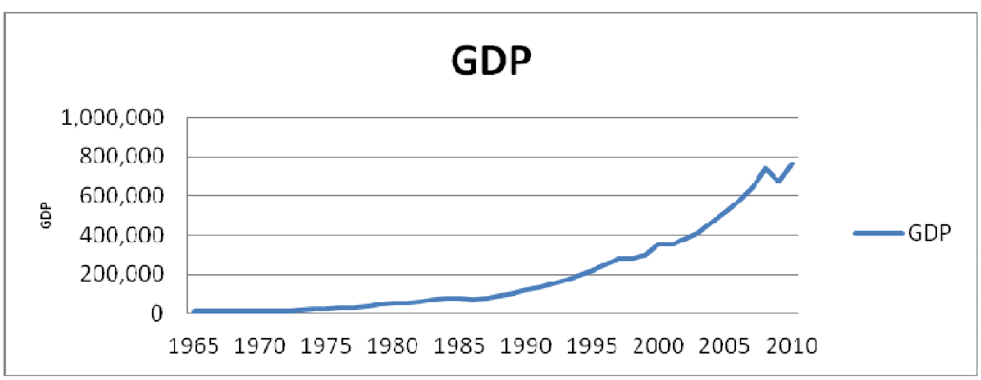

Figure 1: Malaysia GDP, 1965-2010

Malaysian economy increased consistently due to its GDP since 1965 until 2010. Due to increasing in economic growth, Malaysia's infrastructure is also growing and lots of productions are in need corresponds to the damage done to the environment. The development of Malaysia's GDP by 7.0% during the last decades has shown a rapid growth of Malaysia economic growth, despite the Asian economic downturn in the late 1990's (Wee Kean Fong, 2009).

In building economy towards social welfare, there must be a consideration of Pareto optimum which no reorganization of production or consumption can lead to an increase in the welfare of some, without at the same time reducing the welfare of others. In other words, environment and the countries development depends to one another. Failure in managing both aspects can cause eternal side effects which are harmful and destructive due to excessive used of commodities. Air pollution, water pollution, thermal pollution and garbage disposal and other environmental deterioration as such could downturn its progress. Hence, sustainable development should be adhered where the developing manufacturing will fulfill the needs of next generation in future.

Air pollution is determined by the quantity of Carbon Dioxide (CO2) emitted to the air. CO2 is not polluted since it is a natural component of the atmosphere that is needed for carbon cycle, which consists of photosynthesis. However, an excessive amount of CO2 can threaten the ecosystem and turned into toxics. In fact, scientists suggested that an increased in ocean temperature is caused by an extreme used of CO2 trapped in the oceans and thus caused the earth to heat up and the temperature rises which we commonly called global warming. The excessiveness of CO2 is caused by the energy consumed around countries either from consumer or industries. To determine the hazard level of environment, CO2 is the best indicator since it is related to global warming. Figure 2 shows CO2 emissions in tons for period since 1965 to 2010 in Malaysia. It illustrates that CO2 emissions in Malaysia increased rapidly from year to year due to the rapid economic growth and industrialization. Malaysia's total CO2 emission is highly compared to other developing Southeast Asian countries which takes place the third highest after Indonesia and Thailand. Malaysia's figure for amount of CO2/GDP is fairly high at 1.23 kgCO2/2000$ compared to the world average of 0.75kgCO2/2000$ (Wee-Kean Fong, 2009).

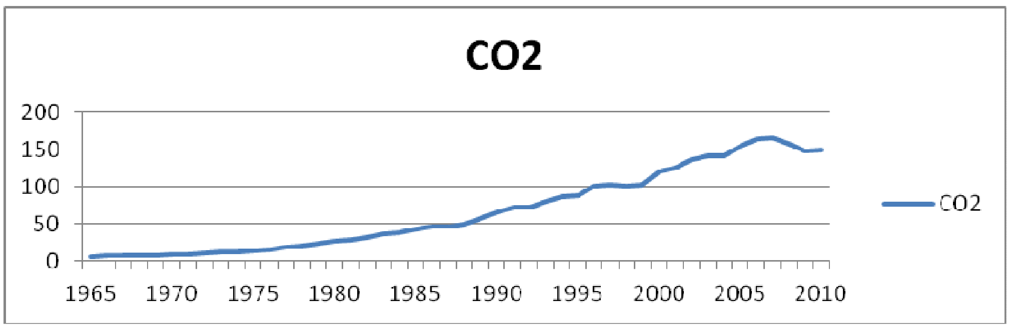

Figure 2: Malaysia Carbon Dioxide Emission, 1965-2010

The outline of the paper is structured as follow: Section 2 highlights on the empirical literature review done on CO2 emissions and economic growth; Section 3 justifies the data and methodology; Section 4 presents the results and interpretation and finally Section 5 draws a significant conclusion on the topic being discussed.

2. Literature Review

Lean, H.H. and Smyth, R. (2009) examines the causal relationship between carbon dioxide emissions, electricity consumption and economic growth within a panel vector error correction model for five ASEAN countries over the period of 1980 to 2006 by using the Granger causality tests in long-run estimates indicates that there is a statistically significant positive association between electricity consumption and emissions and a non-linear relationship between emissions and real output, consistent with the Environmental Kuznets Curve.

Acharyya, J. (2009) who examines the growth impact of FDI, and second FDI-induced growth impact on the CO2 emission during the period of 1980 to 2003 analysis finally discovered that FDI inflow in India has a positive but marginal long run impact on GDP growth.

Jaekyu, L. (1997) tested the relationship between economic growth and environmental quality in South Korea using the data from 1980 to 1997. The study revealed that Economic growth has generated environmental pressure and exists an inverted U-shaped relationship between environmental pressure measured in terms of SO2, NO2, TSP and BOD and economic growth.

Azomahou and Nguyen (1997) on the other hand investigate the empirical relationship between economic growth and greenhouse gas emissions using panel data from 1960 to 1996. Relying on nonparametric procedures, the study identified the constancy of the relationship between CO2 emissions per capita and GDP per capita.

Liu, G. (2004) conducts Granger-causality tests on real per capita GDP and four types of air emissions (CO2, CO, SO2 and NOx) by using Norwegian data covering the period 1973-2003. The test results indicate that only unidirectional causal relationships exist between GDP and air emissions. In the long-run of CO2 and CO, causal relationships run only from GDP to emissions, whereas for SO2 and NOx causal relationships are found from emissions to GDP in the short run only.

Dinda, S. (2005) and Wien, W. (1999) have made the claim that in some income ranges a positive relation between per capita income and some measure of environmental quality. By using data from UNEP and cross-country panel data on per capita GDP (measured at 1985 International Price i.e., PPP) they find the evidence of the linking of economic growth and environment.

Yuli, W et al. (2009) discuss the correlation between economic growth and environmental issues of Taiwan, Japan and Korea by using the Environmental Kuznets Curve (EKC) model. Their findings show that there is an inverse U shape in both Taiwan and Korea, while it is a flat line in Japan.

Jordi Roca et al. (2001) justify the environmental Kuznets curve hypothesis by analyzing the trends of annual emission flux of six atmospheric pollutants in Spain. The study presents evidence that there is no correlation between higher income level and smaller emissions, except for SO2.

Michael Grubb et al. (2002) study the relationships between national CO2 emissions and GDP using the data from 1950 to 2001 shows that the tendency of many advanced economies towards approximate per-capita emissions stabilization is in sharp contrast.

3. Methodology

This chapter employs several econometrics methods, such as unit root test; cointegration test; Vector Error Correction Model and causality test to examine the existence of cointegrating relationship between air pollution and economic growth from period 1965 to 2010. The variable of economic growth is measured by the real growth rate whereas the variable of air pollution is measured by the Carbon Dioxide (CO2) in Malaysia.

The models assume that Malaysian air pollution is determined by the economic growth. To test this hypothesis, a simple econometric model can be expressed as,

$$CO2_t = \alpha + \beta GDP_t + \varepsilon \qquad \text{----- (1)}$$

where CO2 is air pollution in the year *t*, α is a constant, β is slope coefficient and ε is error term.

Several econometrics tests are carried out to analyze the regression model. In the first step of the estimation process, the study examines the stationarity properties of the data series. In stationarity time series, shocks will be temporary and over time, their effects will be eliminated as the series revert to their long run mean values. On the contrary, non-stationarity series will contain permanent components (Asteriou, 2006). In fact, most of the economic variables show a trend and therefore, most cases are non-stationery. These non-stationary time series can easily lead to Ordinary Least Square (OLS) regression to incorrect or spurious conclusions. Thus, a key way to test for non-stationarity is to test for the existence of unit root. The present study employs a standard stationarity test namely, the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) test. Dickey and Fuller (1981) suggests a unit root test based on the following regression,

$$\Delta y_t = \mu + \beta_{t-1} + \delta y_{t-1} + \varepsilon_t \qquad \text{----- (2)}$$

where *t* is linear time trend, μ is intercept, β and δ are slope coefficients, and ε_t is an error term.

In those cases where the error terms are serially correlated, the method has to be modified. The simplest way to do that is to add many lags of dependent variable Δy_t to equation (2) in order to ensure that ε_t appears as white noise. This test for stationary is known as the ADF test. The ADF test is based on the following regression,

$$\Delta y_t = \mu + \beta_{t-1} + \delta y_{t-1} + \sum \gamma_i \Delta y_{t-i} + \varepsilon_t \qquad \text{----- (3)}$$

where β, δ and γ are slope coefficients, and ε_t is an error term.

The null hypothesis is that δ=0. This means that a unit roots exist in y_t. If the null hypothesis is rejected, then y_t is stationary. The current analysis also uses the Phillips-Perron (PP) test to analyze the stationary (Phillips and Perron, 1988). The PP test is based on equation (3) but it uses the modified Dickey-Fuller statistics. The PP test could be more robust in the presence of autocorrelation in the data sets.

Secondly, a cointegration test is performed to determine the nature of the long run relationship. Cointegration test is employed to analyze whether the pairs of variables are cointegrated or move jointly. An important prerequisite for the existence of a cointegrating relationship between the variables is they have the same order of integration. This means that if a variable is an integrated of order *d*, the other variables should also be an integrated of order *d*. The testing of hypothesis is null for non co-integration against the alternative hypothesis, which means the existence of co-integration. The pioneering work on co-integration analysis was done by Engle and Granger (1987). Subsequently, Stock and Watson (1988) and Johansen (1988) extended the research. This study tested the presence of co-integrating relationship between GDP and Air Pollution using the Johansen (1988) Maximum Likelihood Method within a Vector Auto Regressive (VAR) framework. This procedure has superior properties to other methods of testing co-integration (Gonzalo, 1994). A brief outline of the Johansen (1988) procedure is given below:

The notation Z_t denote a p × 1 vector of variables which are not integrated in order higher than one, then Z_t can be formulated as a VAR model of order k:

$$Z_t = \pi_1 Z_{t-1} + \pi_2 Z_{t-2} + \Lambda + \pi_k Z_{t-k} + \text{deterministic components} + \varepsilon_{1t} \qquad \text{----- (4)}$$

where ε_{1t} is independently and normally distributed and $\pi_1, \pi_2, \Lambda, \pi_{t-k}$ are coefficient matrices. The model can be reparameterized to yield a Vector Correction Model in the form of

$$\Delta Z_t = \Gamma_1 \Delta Z_{t-1} + \Lambda + \Gamma_{k-1} \Delta Z_{t-(k-1)} + \Gamma Z_{t-1} + \text{deterministic components} + \varepsilon_{2t.} \qquad \text{----- (5)}$$

Where ε_{2t} is independently and normally distributed and $\Gamma_1, \Gamma_2, \Lambda, \Gamma_{1-(k-1)}$ and Γ are coefficient matrices. Let r = rank (Γ), then if $0 < r < p$ the matrix Γ can be portioned into p x r matrices α and β such that $\pi = \Gamma\beta'$ and β' is I (0) (Johansen and Juselius, 1990). R is the number of cointegrating relationships and in each column is the cointegrating vector. In this study we used Johansen (1995) Max-Eigen and Trace Tests to determine the number of co-integrating relationships between the variables in the bi-variate model.

According to Engle Granger (1987), if the variables are cointegrated, the relationship between them can be expressed via Error correction Model (ECM). The ECM detects the long run cointegration relationship in the following form:

$$\Delta\gamma_t = \alpha_0 + \beta_1 \Delta X_t - \pi\hat{e}_{t-1} + \varepsilon_t \qquad \text{----- (6)}$$

This model includes both long run and short run information where β_1 is the impact multiplier (the short run effect) and π is the feedback effect (adjustment effect and shows number of disequlibrium being corrected). The β_2 in the equation $\hat{e}_{t-1} = \gamma_{t-1} - \beta_1 - \beta_2 X_{t-1}$ however includes the long run response.

The coefficient of Error Correction Model includes information about whether the past values of variables affect the current value of the variables under study. The size and statistical significance of the co-efficients of the Error Correction Model measures the tendencies of each variable to return to equilibrium. For example π in equation (4) is statistically significant means that y_t responds to disequilibrium in its relation with erogenous variables. According to Choudry (1995), even if the co-efficients of the lagged charges of the independent variables are not statistically significant, Granger Causality can still exist as long as π is significantly different from zero. The short run dynamics are captured through individual co-efficients of the different terms. We carefully choose the appropriate lag length of each regessor based on Akaike Information Criterion (AIC).

Finally, the Granger-causality test is run in this study to analyze the causality between Malaysia air pollution and economic growth. The Granger causality test with lag length of k is based on the following equation (Granger, 1969),

$$CO2_t = \alpha_0 + \alpha_1 CO2_{t-1} + \ldots\ldots + \alpha_k CO2_{t-k} + \beta_1 GDP_{t-1} + \ldots\ldots + + \beta_k GDP_{t-k} + \varepsilon 1 \qquad \text{----- (7)}$$
$$GDP_t = \alpha_0 + \alpha_1 GDP_{t-1} + \ldots\ldots + \alpha_k GDP_{t-k} + \beta_1 CO2_{t-1} + \ldots\ldots + + \beta_k CO2_{t-k} + \varepsilon 1 \qquad \text{----- (8)}$$

As a testing criterion the probability was used. With the probability the hypothesis of statistical significance of specific groups of explanatory variables was tested for each separate function.

4. Analysis and Findings

The stationary of the series was investigated by employing the unit root tests developed by Dickey and Fuller (1979, 1981) and Phillips and Perron (1988). The joint use of both tests attempt to overcome the common criticism that unit root test have limited power in finite samples to reject the null hypothesis of non-stationarity. Table 1 reports the Augmented Dickey-Fuller and Phillips Perron test statistics for the level and first differences of Carbon Dioxide emission and Gross Domestic Product respectively. According to the results shown in Table 1, it can be seen that GDP and Carbon Dioxide emission are not stationary at level form. However, after first differencing, all variables in the same integrated order, which is I (1), permits to test for cointegration among those two variables using the Johansen's (1998) methodology.

Table 1: Augmented Dickey-Fuller and Phillips Perron Unit Root Test at levels and first differences

	Level		First difference	
	ADF	PP	ADF	PP
GDP	1.337088	1.920518	-9.615408*	-9.584646*
CO2	-2.408565	-2.194387	-4.662103*	-4.538813*
Critical Value	-3.515523	-3.513075	-3.515523	-3.515523

Notes:

2.0 The null hypothesis of the siries is non-stationary. The (*) indicates the rejection of null hypothesis at 5 percent significance level for model with a linear trend and intercept.

3.0 The denotation: GDP-Gross Domestic Product and CO2- Carbon Dioxide

The lag length of the level vector autoregression system has been determined by minimizing the Akaike (1969) Information Criterion (AIC). Table 2 reports the cointegration result. Both Max-Eigen and Trace test suggest that there is one cointegrating equation emerged. This indicates that air pollution and economic growth are cointegrated.

Table 2 : Johansen Maximum Likelihood Cointegration Tests

Null Hypothesis	Alternative Hypothesis	Max-Eigen	95% CV	Trace	95% CV
r = 0	r = 1	29.72990*	14.26460	30.97742*	15.49471
$r \leq 0$	r = 2	1.247524	3.841466	1.247524	3.841466

Notes:

a. r is the co-integrating vector, CV is critical value at 5% level

b. * denotes rejection of the null hypothesis at 5% level of significant

The empirical results of the estimated error correction models are presented in Table 3. The results show that bi-directional causality exists between air pollution and economic growth in the case of Malaysia. This is based on the statistical significance of the error correction coefficient of the error correction terms. According to Jones and Joulfaian (1991), the error correction terms represent the long run impact of one variable while the changes of the lagged independent variable describe the short run causal impact. The results presented in Table 3 provide evidence on long run import from economic growth to air pollution as well as from air pollution to economic growth.

Table 3: Error Correction Model

Dependent Variable	**DGDP**	**DCO2**
ECT	-0.120919	-5.6205
	(0.06870)	(9.806)
	[-1.76010]	[-5.72526]
D(GDP(-1))	0.589730	-0.000242
	(0.36534)	(5.205)
	[1.61421]	[-4.63976]
D(CO2(-1))	-1171.674	-0.078991
	(1377.60)	(0.19691)
	[-1.85052]	[-0.40114]
C	22920.18	14.70233
	(16891.6)	(2.41448)
	[1.35689]	[6.08924]

Notes:

a. The denotation: GDP -Growth Domestic Product and CO2-Air Emission

b. Figure in parenthesis are standard error and figure in [ ] is t-statistics

The results of the Granger-causality test are reported in Table 4. The Chi-squared for eq(1) is 5.45858 and probability is 0.0081, which is statistically significant at the 5% level. The indication is that the null hypothesis that CO2 does not cause Granger GDP can be rejected. For eq(2), the Chi-squared and probability is 6.28445 and 0.0043, which is significant at the 5% level. This implies that the null hypothesis that GDP does not Granger cause CO2 also can be rejected. Therefore, we can conclude that environment Granger causes economic growth and vice versa in the Malaysia economy during the period studied.

Table 4: Granger Causality Tests

Null Hypothesis	Chi-squared	Probability	Eq
CO2 does not Granger cause GDP	5.45858	0.0081	1
GDP does not Granger cause CO2	6.28445	0.0043	2

5. Conclusion

The main objective of this study is to investigate empirically the causal relationship between environment and economic growth for Malaysia over the period of 1965-2010 using time series data. Several econometrics tests were carried out to determine whether a meaningful relationship between two variables in both; short run and long run exist. Before determining if the variables are cointegrated, the Augmented Dickey-Fuller and Phillips-Perron test were conducted and the results were unearthed where GDP and CO2 are all stationary after differencing once and are integrated of order one, I(1). Essentially, the Johansen cointegration test analysis was used to lead to a long run equilibrium relationship among these variables. Granger causality test found that there is bidirection relationship between variable with direction from CO2 to GDP and GDP to CO2. Consequently, economic growth in Malaysia has an impact on its environment. The study concludes that economic growth and environment in Malaysia is interrelated as economic growth of one country is increased, Carbon Dioxide emissions will also increase thus worsens the environment.

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