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A Relationship of CO2 Emission with Economic Growth, Production in Manufacturing Sector and Energy Consumption from Road Sector in Malaysia

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Abstract
This study attempts at empirically examine the relationships between CO2 emission with economic growth, road sector energy use and manufactured product in Malaysia. Using the bound testing approach to cointegration and error correction model developed within an autoregressive distributed lag (ARDL), we investigate whether a long-run equilibrium relationship exists between energy consumption from the two sectors, economic growth and CO2 emission. Results of the long-run model show a positive and significant relationship between road sector energy use and CO2 emission. This is consistent with our priori that postulates increase in energy consumption from the transportation will increase CO2 emission.

Keywords*: CO2 emission; energy consumption; economic growth; ARDL*

1. INTRODUCTION

The world is undergoing a rapid economic development and industrialization, resulting in deteriorating levels of air quality in many countries, especially in the Asia region. As the main engine of economic growth largely depends on fossil fuels consumption, its usage has rather increased tremendously for the past decades. Scientists find that emissions from carbon dioxide (CO2) and other greenhouse gases like carbon monoxide (CO) or sulfur dioxide (SO2) have contributed mainly to the global warming and greenhouse effect. However, out of all the gases being produced by human activities, the largest contributor to the greenhouse effect is CO2. As the world economy continues to grow, the amount of CO2 released into the atmosphere increase in multitude as well.

Over the course of years, the growing consumption of energy that heavily relied on limited fossil fuels had resulted significant increase of CO2 emissions in Malaysia. However, in comparison with other middle-income developing countries, Malaysia has relatively high energy consumption and CO2 emissions, which are believed to be contributed by economic growth, manufacturing industry and road sector.

This paper is therefore an attempt to extend the empirical study by considering the cointegration relationship between income, output from manufacturing and energy consumption from road transportation and CO2 emission in a multivariate framework for Malaysia during the period 1971 – 2010.To conduct the relationship analysis we employ the recently developed ARDL bound testing approach of cointegration by Pesaran and Shin (1999) and Pesaran (2001).

2. LITERATURE REVIEW

It appears from body of literatures that there are basically three well established research strands in studies on economic growth, energy consumption and environmental pollutants. The first strand of research mainly focuses on relationship between environmental pollutants and output, which is developed to test the validity of the Environmental Kuznets Curve (EKC) hypothesis. According to this hypothesis, environmental degradation tends to rise faster than income growth in the early stages of economic development. Once it reaches a certain threshold point, degradation will slows down, reaches a turning point and declines with further income growth. This phenomenon is also described as the inverted-U Kuznet curve (See Dinda, 2004).

The works on carbon dioxide (CO2) emissions however has been largely inconclusive, where some studies indicating that per capita emissions actually increase with income growth. Using panel data from Netherlands, Western Germany, UK and US for various time intervals between 1960 and 1993, De Bruyn, van den Bergh and Opschoor (1995) found out that three types of emissions (CO2, NO2 and SO2) are positively correlated with economic growth. Stern (1993) examines the relationship between GDP and energy use for the period 1947 -1990 in the US by adapting a multivariate approach of the autoregression (VAR). Results from the study, however, suggest that there is no evidence that gross energy use Granger causes GDP. Study by Dinda and Coondoo (2006) which investigated the causality issue of income-emission relationship for 88 countries in the time period from 1960 to 1990 suggests that there is more or less a bi-directional causal relationship between GDP and CO2 emission.

The second strand of research focuses on the link between economic output and energy consumption, since the pollutants are mainly caused by burning fossil fuels. Initial study by Kraft and Kraft (1978) has been done to assess the evidence of the two relationships by employing Granger causality and cointegration model. By using US data for 1947-1974, they found unidirectional Granger causality from output to energy consumption. The same study by Masih and Masih (1996) found cointegration between energy use and GDP in India, Pakistan and Indonesia, but no cointegration in the case of Malaysia, Singapore and Philippines.

Finally, the third strand of research combined the previously mentioned line of research and examined relationship between carbon emission, energy consumption and economic growth in a single framework. This combined line of approach was initiated by Ang (2007). In his study on Malaysia during the period 1971 to 1999, he employs the cointegration analysis to examine the long-run relationship between output, pollutant emissions and energy consumption. The result of the study strongly support for causality from economic growth to energy consumption, both in the short-run and long-run. In a study of Menyah and Wolde-Rufael (2010), they examine the long-run and the causal relationship between economic growth, pollutant emissions and energy consumption for South Africa for the period 1965 – 2006. They found a short-run as well as a long-run relationship among the variables with a statistically significant relationship between pollutant emissions and economic growth. Also, they found a unidirectional causality running from pollutant emissions to economic growth.

As for the nexus of manufacturing and emission, there has been a rather limited empirical study to test the relationship of the two variables. Torvanger (1991) lead the initial test to explain the changes in energy-related manufacturing CO2 emissions in nine OECD countries. Some causal factors considered under the study were fuel CO2 emission coefficients, manufacturing production structure, fuel shares and sectoral energy intensities. Result from the study suggests that the aggregate CO2 intensity, given by the ratio of total CO2 emissions to total manufacturing output, dropped by 42% from 1973 to 1987. However, no attempt has been made to empirically prove the association of manufacturing and carbon emission aside from testing its carbon intensities for manufacturing production

To the best of our knowledge, no study also has been conducted to examine direct relationship linkage between emission of CO2 and road transport. Most studies then focuses only on observation and projection of the energy usage for road transportation (See Marcotullio and Marshall, 2007; He et al, 2005; Schipper, Marie-Lilliu and Gorham, 2000). Moreover, no work has been conducted to observe the link between CO2 emission, income, manufacturing and energy use of road sector under the same framework in Malaysia. As such, this is one of the major contributions of this study to fill the gap in the energy literature. Single country study helps policy making authorities in making comprehensive policy to control environmental degradation.

The rest of the paper is outlined as follows. Section 2 will discuss on the empirical data used and the ARDL approach to cointegration as in methodology, including further inferences using variance decompositions (VDC) as well as presents the results from the empirical tests. Finally, the last section 3 will concludes this study.

3. METHODS AND ANALYSIS

3.1 Data and Methodology

The study period covers 1970 to 2010. CO2 emission (CO2) is measured in metric tons per capita. Income/economic growth is proxied by real GDP (measured in 2000 US dollars). Energy consumption from road sector is measured by the share of percentage out of the total energy consumption. On the other hand, manufacturing output is measured by annual percentage growth in value added from output. Both GDP and CO2 are expressed in natural logarithm.

To establish long-run relation among the variables we implement ARDL bounds testing approach to cointegration (Pesaran et al. 2001). By employing ARDL, it is possible to have different variables that have different optimal lags, which is impossible with the standard cointegration test. Moreover, the model could be used with limited sample data in which the set of critical values were developed originally by Narayan (2004).

A dynamic error correction model (ECM) can be derived from a simple linear transformation of a modified ARDL model which integrates the short-run dynamics with the long-run equilibrium without loss of any long-run information. This approach involves estimating the following conditional correction version of the ARDL model for CO2 emission and its determinants:

$$\Delta \ln(CO2)_t = \alpha_0 + \sum_{i=1}^{p} \phi_i \Delta \ln(CO2)_{t-i} + \sum_{i=0}^{p} \theta_i \Delta \ln(RGDP)_{t-i} + \sum_{i=0}^{p} \lambda_i \Delta MANU_{t-i} + \sum_{i=0}^{p} \varphi_i \Delta ROAD_{t-i}$$
$$+ \delta_1 \ln(CO2)_{t-1} + \delta_2 \ln(RGDP)_{t-1} + \delta_3 MANU_{t-1} + \delta_4 ROAD + \upsilon_t \quad (1)$$

where ln(CO2), ln(RGDP), MANU and ROAD are CO2 emissions, income, manufacturing growth and energy use from road sector, respectively, Δ is first-difference operator and p is the optimal lag length. Based on EKC literatures, we should expect $\theta_i > 0$ to captures in the increase in carbon emission as income increases. It is hypothesized that $\lambda_i > 0$ because higher growth in manufacturing production will result in more CO2 emission. Also, it is expected that $\varphi_i > 0$ as increase in the usage of energy by road transport will increase CO2 emission.The *F* test is used for testing the existence of long-run relationship. When long-run relationship exists, *F* test indicates which variable should be normalized. The null hypothesis for no cointegration among variables in equation (1) is H_0: $\delta_1=\delta_2=\delta_3=\delta_4=0$ against the alternative hypothesis H_1: $\delta_1\neq\delta_2\neq\delta_3\neq\delta_4\neq0$. The *F* test has a non-standard distribution which depends on (i) whether variables included in the model are I(0) or I(1) or a mixture of both. Two sets of critical values are generated which one set refers to the I(1) series and the other for the I(0) series. Critical values for the I(1) series are referred to as upper bound critical values, while the critical values for I(0) series are referred to as the lower bound critical values.

If the F test statistic exceeds their respective upper critical values, we can conclude that there is evidence of a long-run relationship between the variables regardless of the order of integration of the variables. If the test statistic is below the upper critical value, we cannot reject the null hypothesis of no cointegration and if it lies between the bounds, a conclusive inference cannot be made without knowing the order of integration of the underlying regressors. If there is evidence of long-run relationship or cointegration of the variables, the following long-run model is estimated:

$$\ln(CO2)_t = \alpha_t + \sum_{i=1}^{p} \phi_{1i} \ln(CO2)_{t-i} + \sum_{i=0}^{p} \beta_{1i} \ln(RGDP)_{t-i} + \sum_{i=0}^{p} \theta_{1i} MANU_{t-i} + \sum_{i=0}^{p} \lambda_{1i} ROAD_{t-i} + \mu_t \quad (2)$$

The ARDL specification of the short-run dynamics can be derived by constructing an error correction model (ECM) of the following form:

$$\Delta \ln(CO2)_t = \alpha_2 + \sum_{i=1}^{p} \phi_{2i} \Delta \ln(CO2)_{t-i} + \sum_{i=0}^{p} \theta_{2i} \Delta \ln(RGDP)_{t-i} + \sum_{i=0}^{p} \lambda_{2i} \Delta MANU_{t-i} + \sum \varphi_{2i} \Delta ROAD_{t-i}$$

$$+ \psi ECM_{t-1} + \upsilon_t \quad (3)$$

where ECM_{t-1} is the error correction term, defined as:

$$ECM_t = \ln(CO2)_t - \alpha_1 - \sum_{i=1}^{p} \phi_{1i} \ln(CO2)_{t-i} - \sum_{i=0}^{p} \beta_{1i} \ln(RGDP)_{t-1} - \sum_{i=0}^{p} \theta_{1i} MANU_{t-1} + \sum_{i=0}^{p} \lambda_{1i} ROAD_{t-1} \quad (4)$$

All coefficients of short-run equation are coefficient relation to the short-run dynamics of the model's convergence to equilibrium and ψ represents the speed of adjustment of the error term to long-run equilibrium.

3.2 Results and analysis

Prior to the testing of cointegration, we conducted a test of order of integration for each variable using Augmented Dickey-Fuller (ADF) and Phillip Perron (P-P) procedures to examine data stationarity. The results show that there is a mixture of I(1) and I(0) of underlying regressors and therefore, the ARDL testing could be proceeded.

We then proceeded with *F*-test to confirm the existence of the long-run or the cointegration relationship between variables. The calculated F-statistics for the cointegration test is displayed in Table 1. The critical value suggested by Narayan (2004) using small sample size between 30 and 80. The calculated F-statistic (F-statistic = 4.959) is higher than the upper bound critical value at 5% level of significance (4.088), using restricted intercept and no trend. This implies that the null hypothesis of no cointegration cannot be accepted at 5% and therefore, there is a cointegration relationship among the variables.

Table 1: *F*-Statistic of Cointegration Relationship

Test statistic	**Value**	**Lag**	**Significance level**	**Bound Critical values* (restricted intercept and no trend)**		**Bound Critical values* (restricted intercept and trend)**	
				I(0)	I(1)	I(0)	I(1)
F-statistic	4.959	2	1%	4.310	5.544	5.018	6.610
			5%	3.100	4.088	4.983	6.423
			10%	2.592	3.454	4.865	6.360

Note: * based on Narayan (2004)

The empirical results of the long-run model, obtained by normalizing on CO2 emission are presented in Table 2. The significant variables which appear to affect CO2 emission in the long-run is road transport. All signs for income, manufacturing and road sector are consistent to the inverted-U relationship hypothesis and other literatures. Higher level of economic growth would inevitably resulted in increase in manufacturing production and usage of energy from road sector. This also could be observed from the trends of growth income and CO emission experienced by Malaysia since the period of industrialization of 1960s after gaining independence. There were incremental increases in CO2 emission per capita over the years parallel with the increase in income.

Table 2: Long-run Model

Dependent Variable:	**Independent variables**		
	ln(RGDP)	**ROAD**	**MANU**
ln(CO2)	0.058648 (0.04385)	2.353093** (1.84172)	11.71144 (7.90251)

Note: standard error in parentheses
** significant at 5% level.

Results of the long-run model also show a positive and significant relationship between road transport and CO2 emission. This is consistent with our priori that postulates increase in energy consumption from the transportation will increase CO2 emission. Also, it is consistent with finding of Ang (2008) and Menyah and Wolde-Rufael (2010) that find positive relationship between energy consumption and pollutant emission.

Table 3: Error Correction Model for CO2 emission

Dependent variable: $d(lnCO2)_t$	
Independent variables	***Coefficient***
Constant	0.7998 (1.006)
$D(lnRGDP)_{t-1}$	1.0808 (0.7255)
$D(lnRGDP)_{t-2}$	-1.8043 (-1.2274)
$D(MANU)_{t-1}$	-0.0013** (-1.959)
$D(MANU)_{t-2}$	-0.0001 (-0.0371)
$D(ROAD)_{t-1}$	-0.0187 (-1.0969)
$D(ROAD)_{t-2}$	0.0258 (1.5124)
ECT_{t-1}	1.0814*** (4.9179)
R-square	0.4790
F-statistic	5.4658
DW-statistic	2.6992
RSS	0.5862

Notes: 1. t-statistic in parentheses
2. *** significant at 1% level ** significant at 5% level * significant at 10% level.

As for short-run, based on the results of error correction model on Table 3, the lagged variable for manufacturing is the only variable found to be statistically significant but negatively related to CO2 emission. This result is inconsistent with our priori. One of the possible reasons for this is over the years; the manufacturing process has reduced the sectoral energy intensities with the help of technological innovation and improved production structure. This is somehow consistent with the findings of Torvanger (1991), where it was found that aggregate CO2 emission to total manufacturing output intensity in nine OECD countries dropped by 42% from 1973 – 1987 due to reduction in energy intensities. The same can be said for the reduction in energy intensity for Malaysia, but this only can be observed in short-run period. In long-run, manufacturing continues to cause high CO2 emission in relation to higher output production.

4. CONCLUSIONS AND RECOMMENDATIONS

The aim of this paper is to investigate the relationship between CO2 emissions, income, manufacturing and energy consumption from road sector for Malaysia over the period of 1970 to 2010. The EKC hypothesis has been tested by applying ARDL model for cointegration. The result suggests that there exists long-run relationship among the variables. However, while income shows a positive relationship with CO2 emission, the estimated coefficient for income was found to statistically insignificant in both short-run and long-run. Result for manufacturing production growth suggests a negative relationship with CO2 emission in short-run while in the long-run, manufacturing production was found to be statistically insignificant. Energy consumption for road transport increases CO2 emissions significantly in long-run but it is insignificant in short-run.

Presently, there is no specific policy related to energy conservation and controlling of CO2 emissions in government plans like National Physical Plan (NPP) or Government Transformation Program (GTP) to directly deals with energy and CO2 issues. As evidenced by the current study, Malaysia, being one of the most rapidly growing countries in Asia, with the persistent consumption of energy for the purpose of economic growth especially from transportation sector would significantly contribute to air pollution in this country. The Malaysian government should establish a comprehensive policy to support and monitor environmental protection to encourage preservation of natural resources for sustainable economic development and taking into account the growing energy consumption and domestic energy supply constraints. The use of biodiesel and hybrid-cars should be promoted for the transport sector to achieve sustainable energy development rough diversification of fuel sources. Malaysia has sizable natural gas reserve which is more environmental-friendly which makes this an obvious choice over petroleum fuel. Technological innovation can help reduces the emission of pollutants and carbon intensities of manufacturing production. Otherwise, the emission of environmentally degrading CO2 into the atmosphere will increase with the continuing increasing trend of economic development for upcoming periods.

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