Economic development, pollutant emissions and energy consumption in Malaysia

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Received 1 September 2006; received in revised form 1 March 2007; accepted 1 April 2007
Available online 6 May 2007

Abstract

The objective of this paper is to examine the long-run relationship between output, pollutant emissions, and energy consumption in Malaysia during the period 1971–1999. To supplement the findings of cointegrating analysis, we assess the causal relationships between the variables using the recent causality tests available in the literature. The results indicate that pollution and energy use are positively related to output in the long-run. We found a strong support for causality running from economic growth to energy consumption growth, both in the short-run and long-run.

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JEL classification: C32; O53; Q20; Q43

Keywords: Energy consumption; Pollutant emissions; Causality; Multivariate cointegration

1. Introduction

The relationships between output and energy consumption, as well as output and environmental pollution, have been the subject of intense research over the past few decades. However, the empirical evidence remains controversial and ambiguous to date.

Economic development is closely related to energy consumption since higher economic development is expected when more energy is consumed. However, it is also equally likely that more efficient use of energy (which could lead to a reduction in energy consumption) requires a higher level of economic development. That is, better economic performance may be a catalyst for energy

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efficiency. As such, energy consumption and economic development may be jointly determined. The importance of this nexus has been well-documented in the literature. In a seminal study, Kraft and Kraft (1978) found a uni-directional Granger causality running from output to energy consumption for the United States during the period 1947–1974. The subsequent studies on this subject, which differ in terms of the time period covered, country chosen, econometric techniques employed, and the control variables used in the estimation, either confirm or contradict the results of Kraft and Kraft (1978).\footnote{See Akarca and Long (1980), Yu and Choi (1985), Erol and Yu (1987), Abosedra and Baghestani (1989), and Hwang and Gum (1991).} With the development of time series econometric techniques, more recent studies tend to focus on the cointegrating relationship between output and energy consumption.\footnote{See Masih and Masih (1996, 1997), Cheng and Lai (1997), Glasure and Lee (1998), Asafu-Adjaye (2000), Stern (2000), Yang (2000), Jumbe (2004), and Paul and Bhattacharya (2004).}

The relationship between output and pollution has also been extensively studied in the literature. Whether continued increase in national income brings greater harm to the environment is critical for the design of development strategies for developing economies. Most empirical studies in this subject mainly focus on testing the validity of the Environmental Kuznets Curve (EKC), which postulates that the relationship between economic development and the environment resembles an inverted U-curve. The findings of Hettige, Lucas, and Wheeler (1992), Cropper and Griffiths (1994), Selden and Song (1994), Grossman and Krueger (1995), and Martinez-Zarzoso and Bengochea-Morancho (2004) are consistent with the EKC hypothesis. However, increased national income level does not necessarily warrant greater efforts to contain the emissions of pollutants. The empirical results of Shafik (1994) and Holtz-Eakin and Selden (1995) show that pollutant emissions are monotonically increasing with income levels.

An assessment of the existing literature suggests that most studies focus either on the nexus of output-energy or output-pollution where little effort has been made to test these two links under the same framework. This study is an attempt to fill the gap. Malaysia appears to be an interesting case study for this subject given that it is one of the highest growth open economies in the developing world, and it has experienced a significant rise in pollutant emissions and energy consumption in recent years. The choice of this country is also motivated by the fact that no known study has been conducted to examine the relationship between output, energy consumption and pollutant emissions in Malaysia.

We prefer a country-specific case study to a cross-sectional study since empirical analyses conducted at the aggregate level are unable to capture and account for the complexity of the economic environments and histories of each individual country. Hence, any inference drawn from these studies provides only a general understanding of how the variables are broadly related, and thus offers little guidance for policy formulation. In this spirit, a country-specific in-depth case study appears to be more promising in order to find deeper answers for the issue at hand.

We formulate and estimate a vector error-correction model using the full-information maximum likelihood method by treating output, pollutant emissions, and energy consumption as endogenous variables. Unlike structural models, the proposed reduced-form model in this study does not require \textit{a priori} information on parameters. In order to supplement the findings of the long-run cointegrated relationship, we perform various causality tests to shed light on the causal relationships between output and energy use, as well as output and pollutant emissions.
The rest of the paper is organized as follows. Section 2 sets out the model, data, and estimation methodology. Section 3 presents the empirical findings. Finally, Section 4 discusses policy implications of the results and concludes the paper.

2. Model, data and methodology

Based on the theoretical arguments presented above, the relationship between output, CO₂ emissions, and energy use can be specified as follows:

\[ G_t = f(C_t, E_t) \]  

where \( G_t \) is logarithmic per capita real GDP, \( C_t \) refers to logarithmic per capita of CO₂ emissions, and \( E_t \) is logarithmic per capita commercial energy use. Following the common practice in the literature, we use carbon dioxide (henceforth CO₂) emissions as the proxy for the level of pollution.

Annual data covering the period 1971–1999 were used in this study. All data were obtained from the World Bank’s World Development Indicators (2004). The data were converted into natural logarithms so that they can be interpreted in growth terms after taking first difference. We included three dummy variables in the estimation to account for the two oil crises and the Asian financial crisis that took place in Malaysia in 1973, 1979, and 1997–1998, respectively.

In order to present the data series in the same scale, we construct an index for each series using 1971 as the base year. The diagram presented in Fig. 1 suggests that a long-run or cointegrating relationship is likely to be present in this case since all three series tend to move very closely together over time. However, casual inspection always has its perils and therefore it is necessary to perform a formal testing to confirm our belief. This simple graphical analysis also reveals that \( G_t \) and \( C_t \) have a linear relationship so that a quadratic specification is not required.

Our empirical estimation has two objectives. The first is to examine how the variables are related in the long-run. The second is to examine the dynamic causal relationships between the variables. We construct a trivariate VAR model for the estimation purpose. The testing procedure involves three steps. We begin by performing an integration analysis using three unit root tests—augmented Dickey-Fuller (ADF) test, Phillips-Perron (PP) test, and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test. The choice of the KPSS test to complement the widely employed ADF and PP tests is motivated by the argument that tests designed on the basis of the null that a series is \( I(1) \) have low power of rejecting the null. The second step is to test for cointegration using the Johansen approach for the VARs constructed in levels. Our causality tests are preceded by cointegration testing since the presence of cointegrated relationship has implications for the way in which

Fig. 1. Trends of the variables (before taking logarithms, 1971 = 100).
causality testing is carried out. If cointegration is detected, the third step is to test for causality by employing the appropriate types of causality tests.

According to Engle and Granger (1987), cointegrated variables must have an error correction representation in which an error correction term (ECT) must be incorporated into the model. Accordingly, a vector error-correction model (VECM) is formulated to reintroduce the information lost in the differencing process, thereby allowing for long-run equilibrium as well as short-run dynamics. For illustration, assuming that there is only one cointegrated relationship, the trivariate representation in which an error correction term (ECT) must be incorporated into the model.

\[
\Delta G_t = \mu_1 + \alpha_{11} ECT_{t-1} + \sum_{j=1}^{p-1} \phi_{1j} \Delta G_{t-j} + \sum_{j=1}^{p-1} \theta_{1j} \Delta C_{t-j} + \sum_{j=1}^{p-1} \psi_{1j} \Delta E_{t-j} + \varepsilon_{1t} \quad (2)
\]

\[
\Delta C_t = \mu_2 + \alpha_{21} ECT_{t-1} + \sum_{j=1}^{p-1} \phi_{2j} \Delta G_{t-j} + \sum_{j=1}^{p-1} \theta_{2j} \Delta C_{t-j} + \sum_{j=1}^{p-1} \psi_{2j} \Delta E_{t-j} + \varepsilon_{2t} \quad (3)
\]

\[
\Delta E_t = \mu_3 + \alpha_{31} ECT_{t-1} + \sum_{j=1}^{p-1} \phi_{3j} \Delta G_{t-j} + \sum_{j=1}^{p-1} \theta_{3j} \Delta C_{t-j} + \sum_{j=1}^{p-1} \psi_{3j} \Delta E_{t-j} + \varepsilon_{3t} \quad (4)
\]

where \( \varepsilon_t \)’s are Gaussian residuals and \( ECT_{t-1} = G_{t-1} + (\beta_2/\beta_1)C_{t-1} + (\beta_3/\beta_1)E_{t-1} \) is the normalized cointegrated equation. There are two sources of causation, i.e., through the ECT, if \( \alpha \neq 0 \), or through the lagged dynamic terms. The ECT shows the long-run equilibrium relationship while the coefficients on the lagged difference terms indicate the short-run dynamics. The statistical significance of the coefficients associated with the ECT provides evidence of an error correction mechanism that drives the variables back to their long-run equilibrium.

Given the two separate sources of causality, we can perform three different causality tests, i.e., short-run Granger non-causality test, weak exogeneity and strong exogeneity tests. In Eq. (2), to test \( \Delta C_t \) does not cause \( \Delta G_t \) in the short-run, we examine the statistical significance of the lagged dynamic terms by testing the null \( H_0: \theta_{1j} = 0 \) using the Wald test. Non-rejection of the null implies \( \Delta C_t \) does not Granger-cause \( \Delta G_t \) in the short-run. The weak exogeneity test, which is a notion of non-long-run non-causality test, requires satisfying the null \( H_0: \alpha_{11} = 0 \). It is based on a likelihood ratio test which follows a \( \chi^2 \) distribution. Finally, we can perform the strong exogeneity test which imposes stronger restrictions by testing the joint significance of both the lagged dynamic terms and ECT (Charemza & Deadman, 1992; Engle, Hendry, & Richard, 1983). This requires satisfying both Granger non-causality and weak exogeneity. In particular, \( \Delta G_t \) does not cause \( \Delta C_t \) if the null \( H_0: \theta_{1j} = \alpha_{11} = 0 \) is not rejected. The strong exogeneity test does not distinguish between the short-run and long-run causality, but it is a more restrictive test which indicates the overall causality in the system. It is important to highlight that this paper uses the concept of causality in the predictive rather than in the deterministic sense. As Diebold (2004) put forward, “X causes Y” is simply the abbreviated expression for “X contains useful information for predicting Y”. Hence, the causality results are interpreted in the Granger sense.

3. Empirical findings

In Table 1, it is evident that all unit root tests yield remarkably similar results——\( G_t, C_t, \) and \( E_t \) are non-stationary in their levels but become stationary after taking the first difference. Hence, we conclude that all series are \( I(1) \) at the 5% level of significance.
Table 1
Unit root tests

<table>
<thead>
<tr>
<th></th>
<th>ADFa</th>
<th>PPb</th>
<th>KPSSc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gt</td>
<td>-1.179</td>
<td>-1.138</td>
<td>0.680**</td>
</tr>
<tr>
<td>ΔGt</td>
<td>-4.187**</td>
<td>-4.158**</td>
<td>0.138</td>
</tr>
<tr>
<td>Ct</td>
<td>-0.200</td>
<td>-0.200</td>
<td>0.650**</td>
</tr>
<tr>
<td>ΔCt</td>
<td>-6.588**</td>
<td>-6.467**</td>
<td>0.093</td>
</tr>
<tr>
<td>Et</td>
<td>-0.727</td>
<td>-0.717</td>
<td>0.673**</td>
</tr>
<tr>
<td>ΔEt</td>
<td>-5.320**</td>
<td>-5.330**</td>
<td>0.094</td>
</tr>
</tbody>
</table>

(*) and (**) indicate 10% and 5% level of significance, respectively.

a $H_0 = \text{the series has a unit root. AIC is used to select the lag length. The maximum number of lags is set to be four.}$

b $H_0 = \text{the series is stationary. Barlett-Kernel is used as the spectral estimation method. The bandwidth is selected using Newey-West method.}$

Table 2
Johansen cointegration tests

<table>
<thead>
<tr>
<th>Hypothesized no. of CE(s)</th>
<th>$r = 0$</th>
<th>$r \leq 1$</th>
<th>$r \leq 2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trace statistic ($\lambda_{\text{trace}}$)</td>
<td>35.964***</td>
<td>7.027</td>
<td>0.438</td>
</tr>
<tr>
<td>Hypothesized no. of CE(s)</td>
<td>$r = 0$</td>
<td>$r = 1$</td>
<td>$r = 2$</td>
</tr>
<tr>
<td>Maximum eigenvalue statistic ($\lambda_{\text{max}}$)</td>
<td>28.937***</td>
<td>6.589</td>
<td>0.438</td>
</tr>
</tbody>
</table>

(*), (**) and (***) indicate 10%, 5% and 1% level of significance, respectively.

Given that $G_t$, $C_t$ and $E_t$ share common integration properties, we can now proceed to testing for the presence of a common trend, or equivalently, a long-run cointegrating relationship between the variables. Since the Johansen approach is sensitive to the lag length used, we conduct a series of nested likelihood ratio tests on level V ARs to determine the optimal lag length ($p$) prior to performing cointegration tests. Given the sample size, we have considered a maximum lag length of three. The optimal lag length is found to be one. We follow this lag structure for the rest of the estimations. Using likelihood ratio tests, the three dummy variables used to account for various macroeconomic shocks were found to be statistically insignificant and hence they were not included in the remaining analyses.

We perform Johansen cointegration tests to assess the evidence of cointegration. In Table 2, both the results of trace tests and maximum eigenvalue tests unanimously point to the same conclusion that there is one cointegrated relationship, at the 1% level of significance. Table 3 presents the cointegrating vector and speed of adjustment coefficient. The Lagrange Multiplier (LM) tests indicate no evidence of serial correlation in the residuals at one lag. We obtain the same

Table 3
Cointegrating vector

<table>
<thead>
<tr>
<th>LM test statistica</th>
<th>Joint Jarque-Bera test statisticb</th>
<th>Cointegrated equation</th>
<th>$\alpha_{11}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.325</td>
<td>8.486</td>
<td>$G_t = 4.475 + 0.238C_t + 0.548E_t$ (5.550***)(11.856***)</td>
<td>-0.470 (-1.761*)</td>
</tr>
</tbody>
</table>

Number of observations = 29; optimal lag length = 1; (*), (**) and (***) indicate 10%, 5% and 1% level of significance, respectively; and figures in the parentheses indicate t-statistics.

a The null hypothesis of no serial correlation at lag order 1 is not rejected at the 5% level of significance.
b The null hypothesis of residuals are multivariate normal is not rejected at the 5% level of significance.
Table 4
Causality tests

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Short-run Granger non-causality</th>
<th>Long-run weak exogeneity test</th>
<th>Overall strong exogeneity test</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H_0: \Delta G_t \not\rightarrow \Delta C_t$</td>
<td>1.664</td>
<td>0.993</td>
<td>1.289</td>
</tr>
<tr>
<td>$H_0: \Delta C_t \not\rightarrow \Delta G_t$</td>
<td>2.505</td>
<td>3.485*</td>
<td>5.717*</td>
</tr>
<tr>
<td>$H_0: \Delta G_t \not\rightarrow \Delta E_t$</td>
<td>7.935***</td>
<td>6.832***</td>
<td>10.138***</td>
</tr>
<tr>
<td>$H_0: \Delta E_t \not\rightarrow \Delta G_t$</td>
<td>0.006</td>
<td>3.485*</td>
<td>4.658*</td>
</tr>
</tbody>
</table>

(*) , (**) and (*** ) indicate rejection of the null hypothesis of non-causality at 10%, 5% and 1% level of significance, respectively; and all statistical tests are performed using Wald tests except for weak exogeneity tests which are performed using likelihood ratio tests.

Conclusion by allowing for up to four lags. Multivariate normality test shows that the residuals are Gaussian. By normalizing the coefficient of $G_{t-1}$ to one, all coefficients in the long-run cointegrated equation are statistically significant at the 1% level. It is evident that both $C_t$ and $E_t$ are positively related to $G_t$ in the long-run. The long-run elasticity of $G_t$ with respect to $C_t$ is found to be 0.238. A 1% increase in $E_t$ will result in 0.548% increase in $G_t$. Hence, the impact of $E_t$ on $G_t$ is more than twice as high as that of $C_t$. The loading factor, which measures the speed of adjustment back to the long-run equilibrium level, is statistically significant and correctly signed (negative). This implies that an error correction mechanism exists so that the deviation from long-run equilibrium has a significant impact on economic growth. This provides further support for the use of an error-correction framework. Output adjusts at the speed of 47% every year, or it takes about 2.1 years, to restore equilibrium when there is shock on the steady-state relationship. This speed of adjustment is considered relatively high for a developing country.

Evidence of cointegration implies the existence of causality, at least in one direction. However, it does not indicate the direction of the causal relationship. Hence, to shed light on the direction of causality, we perform the ECM-based causality tests. Consistent with the findings of Oh and Lee (2004) in the Korean experience, our results reported in Table 4 show strong evidence of output growth causing energy consumption growth. Some weak support for reverse causality is also found at the 10% level of significance in the long-run. Such an evidence of two-way causality is in line with the findings of Masih and Masih (1996) for Pakistan, Glasure and Lee (1998) for Korea and Singapore, Yang (2000) for Taiwan and Wolde-Rufael (2005) for the African experience. When examining the causal relationship between economic growth and CO2 emissions growth, we found some weak evidence of causality running from the latter to the former in the long-run, but no feedback relationship is observed. In cases where the hypothesis of non-causality is not rejected, the evidence is further supported by the results of strong exogeneity tests which show the overall causality for both the short-run and long-run.

4. Policy implications and conclusions

In this paper, we examine the dynamic relationships between output, CO2 emissions, and energy consumption for Malaysia during the period 1971–1999 using a multivariate vector error-correction model. To complement the findings of cointegration analysis, we perform various causality tests to throw light on the causal links of output-energy and output-pollution. The empirical results provide support for a robust long-run relationship between the variables, indicating that CO2 emissions and energy use are positively related to output in the long-run. The causality results support the argument that economic growth exerts a positive causal influence on
energy consumption growth, both in the short-run and long-run. The results also provide some support for a feedback relationship in the long-run. With regards to the output-pollution link, only a weak causality running from CO₂ emissions growth to economic growth was found in the long-run.

The finding of a bi-directional causality between output growth and growth in energy use in the long-run implies that Malaysia is an energy dependent economy. The results are sensible given that a significant amount of economic growth in Malaysia has been fuelled by industrial growth, which requires intensive use of energy. In 2000, the industry sector contributed more than 50% to the total GDP. Since energy is a stimulus for economic development, the implementation of energy conservation policies may severely affect economic performance and retard economic development. The Malaysian economy may also be subject to energy shocks in which an energy shortage may adversely affect GDP growth.

The results have important implications for policy makers in Malaysia who aspire to transform the economy into a fully industrialized nation in the near future. Economic growth is the outcome of growth in inputs and increases in the productivity of the inputs. Therefore, rapid industrialization requires higher and/or 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 evidence also suggests that degradation of the environment precedes economic growth. In Malaysia, an increase in pollution level induces economic expansion is not surprising given that much energy inputs have been consumed in the production (which have resulted in more pollution) to promote heavy industry. This pattern of development is consistent 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 through affecting human health, and thereby reduce productivity in the long-run.³

The main contribution of this paper is that for the first time an attempt is made to examine the dynamic relationships between economic development, CO₂ emissions, and energy consumption for Malaysia. Although the findings of this analysis may be unique to Malaysia due to its specific institutional and structural characteristics, the econometric techniques employed in this study can be readily extended to include other less developed countries. We subject the econometric specification to tests for serial correlation and normality. The test results support our relatively parsimonious specification. However, it is important to note that given the small sample nature of this analysis, the results must be interpreted with due caution.

References


³ Some regulatory controls can be imposed to reduce pollution and ensure sustainable development. For an assessment of the effects of different tax instruments on controlling the emissions of carbon dioxide, see Jorgenson and Wilcoxen (1993).


