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Analyzing the Relationship between GDP and CO_2 Emissions in Malaysia: A Time Series Evidence

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Abstract

The study examines the relationship between Malaysia's per capita GDP, CO2 emissions, and energy consumption from 1970 to 2008, treating CO2 emissions as a controllable variable to assess the economic impact of reducing emissions. The findings indicate that Malaysia can meet its emission reduction targets by implementing minimal yet necessary measures without severely impacting economic growth. The study uses econometric techniques to analyze long-term and short-term relationships among these variables. Results show that energy consumption is a crucial driver of economic expansion, highlighting the challenge of reducing emissions while maintaining growth. Although Malaysia's economy remains carbon-intensive, strategic policies can facilitate a shift towards sustainable development. Reducing CO2 emissions does not necessarily lead to economic stagnation. Targeted investments in renewable energy and energy-efficient technologies can help mitigate economic disruptions while ensuring environmental sustainability. The study underscores the role of government policies in balancing economic growth with emission reduction goals. Optimizing energy consumption and adopting cleaner technologies are crucial to Malaysia's strategy. The study suggests regulatory frameworks that support sustainable growth while minimizing the economic impact of emission reductions. Findings provide policymakers with insights to design effective strategies ensuring environmental sustainability alongside economic development. Achieving a balance between economic growth and environmental commitments is possible with carefully planned policy measures. This research offers guidance for Malaysia in navigating climate goals while maintaining economic stability, reinforcing the importance of integrating sustainability into national development strategies.

Keywords: Per Capita GDP, CO_2 emissions

JEL Codes: E01, Q01

1. INTRODUCTION

Climate change stands as the most pressing issue facing the world today, posing a severe and potentially irreversible threat to the planet. The only viable solution is sustainable development, which ensures the preservation of life on Earth without compromise. A substantial consensus among experts confirms that human-induced, measurable global warming is disrupting the natural balance of ecosystems, elevating environmental threats to a critical global concern. Growing awareness of the dire consequences of climate change has compelled global economies to adopt green energy solutions and significantly reduce CO2 emissions. While rapid economic growth, industrialization, and extensive energy consumption have bolstered the economies of developing nations, they have also contributed to increased CO2 emissions (Lin et al., 2008). Estimating the economic costs of reducing CO2 emissions from energy consumption is essential to balance economic growth with sustainable development. Factors such as fossil fuel usage, urbanization, and trade openness influence air pollution in both the short and long term. However, promoting renewable energy use can mitigate air pollution over time. Furthermore, financial development has shown a long-term causal relationship with reduced air pollution levels.

Economic literature suggests that implementing CO2 emission reduction measures could hinder Malaysia's economic development. Using the Environmental Kuznets Curve (EKC) theory, researchers analyzed trends in both aggregated and disaggregated energy consumption data. The empirical results revealed that the EKC hypothesis, indicating an inverted U-shaped relationship, does not hold for total energy consumption statistics. However, when disaggregating energy sources such as electricity, gas, coal, and oil, evidence supporting the EKC hypothesis emerged. Studies have also calculated the bidirectional causality between economic growth and CO2 emissions (Coondoo & Dinda, 2002; Ali & Audi, 2018). In the case of Romania, researchers examined the potential for an EKC in both the medium and long terms, confirming a long-term relationship between energy consumption, economic growth, and environmental pollution (Pieiro et al., 2008; Marc & Ali, 2018). Furthermore, while CO2 emissions were found to positively influence energy consumption and international trade, the findings rejected the existence of the EKC hypothesis in the short term (Dinda, 2004; Marc & Ali, 2018). The literature indicates that higher GDP leads to increased carbon dioxide emissions, as greater energy consumption drives higher economic output. To mitigate emissions to a certain extent, energy resource usage must be curtailed, which in turn reduces Malaysia's production levels. Given that the nonlinear EKC estimation technique is no longer suitable for analyzing the relationship between GDP and CO2 emissions to meet current reduction targets, a linear relationship approach is necessary to assess CO2 reductions in terms of output loss (Yandle et al., 2002; Ali & Audi, 2018). This study investigates the co-integration between GDP and CO2, alongside other input variables such as capital and energy consumption, to calculate the cost of reducing CO2 emissions in terms of production losses. By estimating production-related CO2 emissions and their reduction costs across varying levels of economic abatement, this research aims to contribute to the existing body of knowledge.

2. METHODOLOGY

This study aims to examine the long-term co-integration relationship between Malaysia's per capita GDP, energy consumption, capital investment, and CO2 emissions, as well as to calculate the cost of emission reduction in terms of per capita GDP loss. Based on the Cobb-Douglas economic framework, production output is determined by the amount of labor and capital invested (Miller, 2008). While the model primarily includes capital (K) and labor (L), several other factors also influence economic performance, making this approach highly accurate. In this research, we analyze the relationship between Malaysia's per capita GDP, capital, energy consumption, and CO2 emissions using the production function. CO2 emissions derived from the economy's energy

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consumption are used as a proxy for inefficient energy inputs. Prior studies suggest that the simultaneous use of additional energy inputs generates both GDP and CO2 emissions (Ramanathan, 2006). Conversely, without energy consumption, there is neither CO2 generation nor economic output. Therefore, CO2 emissions are used in this study as a representation of energy consumption. The production function used is expressed as follows:

Per Capita GDP = f (Capital, CO2 Emissions, Energy Consumption) (1)

We have applied logarithm on all variables used in our model and it follows as:

$$\ln Y_t = \alpha_0 + \alpha_1 \ln K_t + \alpha_2 \ln CO_t + \alpha_3 \ln EC_t + \varepsilon_t \qquad (2)$$

Here, *ln* denotes logarithm, *Y* is used for per capita GDP, *t* refers to the time from 1972-2008, α_0 is intercept, α_1 is the elasticity of per capita GDP with respect to capital, *K* shows capital, α_2 is coefficient the of CO_2 emissions, *CO* is used for carbon dioxide emissions, *EC* shows the energy consumption, α_3 is the elasticity of *Y* with reference to energy, and ε is the error term.

Data for per capita GDP (at constant 2008 US$), capital stock as a share of GDP (at constant 2008 US$), per capita energy use (kg of oil equivalent), and per capita CO2 emissions (metric tons) were sourced from the World Development Indicator (WDI) 2008. This study investigates the long-term relationships between the selected input and output variables. When working with time series data, there is a risk of obtaining false positives. To mitigate this, the issue of non-stationarity must be addressed. Variables may be co-integrated at level I(0), at the first difference I(1), or with a mix of some at level and others at the first difference, complicating the selection of the most reliable estimation technique for co-integration. A unit root test was employed to determine the presence of stationarity. As noted in the literature, determining unit roots involves complex methodologies (Campbell & Perron, 1991). To assess the stationarity of the variables, we utilized the ADF test and the Phillips & Perron tests (Corbae & Ouliaris, 1988). The following is the ADF test specification:

$$\Delta Y_t = \alpha + \beta t + \rho Y_{t-1} + \sum_{i=1}^{p} \Delta Y_{t-1} + \mu_t \quad (3)$$

The lagged difference is a key aspect of the ADF test, effectively addressing issues of auto-correlation. The Schwartz Information Criterion (SIC) is implicitly applied to identify the optimal number of lags. This study explores the relationship between Malaysia's per capita GDP and CO2 emissions using the Johansen co-integration method. The Johansen co-integration technique was employed to analyze the long-term relationship between per capita GDP, energy consumption, and CO2 emissions. This approach is applied when all variables are stationary at the first difference. It contains the vector autoregressive of order *p and* the VAR in the levels is as follows:

$$Y_t = \sum_{i=1}^{k} A_i Y_{t-i} + \mu_t \qquad (4)$$

When k > 1, the VAR in the levels is as follows:

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{i=1}^{k-1} \Pi_i \Delta Y_{t-i} + \mu_t \qquad (5)$$

For the simpler case k = 1, it is simply written as:

$$\Delta Y_t = \Pi Y_{t-1} + \mu_t \qquad (6)$$

Where Y_t is an *n*x1 vector of variables that are integrated of order one and μ is an *n*x1 vector of innovations.

Johansen proposes two different likelihood ratio tests of the significance of these canonical correlations and thereby the reduced rank of the Π matrix, the trace test and the maximum eigenvalue test, shown in Eq. 7 and Eq.8, respectively.

$$J\ trace = -T \sum_{i=r+1}^{n} \ln(1-\lambda_i) \qquad (7)$$

$$J\ max = -T \ln(1-\lambda_{r+i}) \qquad (8)$$

Here, *T* is the sample size and $\boldsymbol{\lambda_i}$ is the i^{th} largest canonical correlation, trace test's null hypothesis of *r* co-integrating vectors against the alternative hypothesis of *n* co-integrating vectors. The maximum eigenvalue test, on the other hand, tests the null hypothesis of *r* co-integrating vectors against the alternative hypothesis of *r* + 1 co-integrating vectors.

3. RESULTS AND DISCUSSION

The Augmented Dickey–Fuller test indicates that the natural logarithms of per capita GDP, capital, and CO_2 emissions all reject the null of a unit root at levels (their ADF statistics are more negative than the –1.95 critical value), suggesting these series are stationary in levels. This finding is consistent with the original formulation of the test and its distributional properties (Dickey & Fuller, 1979; Nelson & Plosser, 1982). The Phillips–Perron results reinforce the ADF conclusions for lnY, lnK, and lnCO, while confirming that lnEC remains non-stationary at levels but becomes stationary after first differencing. Employing both tests ensures robustness against serial correlation and heteroskedasticity in the error terms, following the enhancements proposed by Phillips and Perron (1988) and Said and Dickey (1984). By identifying a mix of I(0) and I(1) variables, these unit root outcomes set the stage for subsequent cointegration analysis under Engle–Granger or Johansen methodologies. Determining the integration order in this manner adheres to standard econometric practice for time series modeling (Enders, 2010; Gujarati & Porter, 2009). The necessity to difference the energy consumption series underscores the dynamic interplay between economic growth and environmental variables. Empirical studies in energy economics frequently encounter I(1) behavior in consumption data, highlighting the importance of long-run equilibrium modeling for policy analysis (Narayan & Narayan, 2005; Apergis & Payne, 2010).

The trace statistic for the null of no cointegration ("None") is 66.2835, exceeding its 5% critical value of 64.17, which indicates rejection of the null and suggests at least one long-run equilibrium relationship among lnY, lnEC, lnK, and lnCO in the Malaysian context. The trace test sums the log of the remaining eigenvalues and follows the asymptotic distribution derived by Johansen's procedure, which is known for its consistency in large samples (Johansen, 1988; Lütkepohl, 2005). The Max-Eigen statistic for "None" is 29.1348, also above its critical threshold of 28.68, reinforcing the presence of a single cointegrating vector. Unlike the trace test, the maximum eigenvalue test isolates the largest characteristic root and assesses it against its critical value; empirical studies have shown it to perform robustly even under small sample sizes (MacKinnon, Haug, & Michelis, 1999; Maddala & Kim, 2004). Testing for at most one cointegration vector, the trace statistic (28.4881) falls below the 5% critical value (36.19), indicating a failure to reject the null of one or fewer cointegrating relationships. However, the Max-Eigen test at this rank stage (62.7462 >

22.29) contradicts the trace outcome by suggesting two cointegrating vectors. In the presence of such discordant results, researchers often give precedence to the trace test for its superior size properties (Johansen & Juselius, 1990; Juselius, 2006). Overall, the balance of evidence—particularly the consistent rejection of no cointegration and the trace test's single-vector result—points to one stable long-run equilibrium linking per capita GDP, energy consumption, capital stock, and CO_2 emissions. This finding justifies the use of a vector error correction model to capture both short-term dynamics and long-term relationships (Engle & Granger, 1987; Stock & Watson, 1988).

Table 1: Results of ADF and PP Unit Root Test

Variables	ADF test - Levels	ADF test - First differences	ADF Critical value	PP test - Levels	PP test - First differences	PP Critical value
LnY	-2.4967	-6.0903	-1.95	-3.4126	-5.9397	-1.95
LnEC	-0.7589	-5.7633	-1.95	-1.7065	-7.0239	-1.95
LnK	-3.9419	-8.2425	-1.95	-3.02	-7.8227	-1.95
LnCO	-2.7703	-8.1345	-1.95	-2.5843	-6.8201	-1.95

Table 2: Results of Co-Integration Rank Test

Number of Co-Integrations	Eigen value	Trace stat.	critical value (trace)	Max-Eigen stat.	critical value (max-eigen)
None	1.0686	66.2835	64.17	29.1348	28.68
At most 1	1.0695	28.4881	36.19	62.7462	22.29
At most 2	0.5959	11.1068	21.26	8.0268	16.89
At most 3	1.2892	1.7896	9.16	2.8039	9.16

The long-run coefficient on carbon dioxide emissions (CO) is 2.3973, indicating that a 1 percent increase in CO_2 emissions is associated with a roughly 2.40 percent rise in per capita GDP in the equilibrium relationship, reflecting scale effects in environmental growth models as demonstrated by Banerjee, Dolado, Galbraith, and Hendry (1993). Likewise, the capital elasticity of 1.181 suggests that a 1 percent increase in capital stock (K) contributes positively to output by about 1.18 percent, consistent with Johansen's (1992) findings on efficient estimation of cointegrating vectors in multivariate systems. Energy consumption's long-run coefficient of 2.4946 underscores the pivotal role of energy inputs for Malaysian economic growth. Although this estimate does not reach statistical significance at conventional levels, its positive magnitude aligns with the dynamic energy–growth linkages identified by Gregory and Hansen (1996) and the asymptotic properties of residual-based cointegration tests discussed by Phillips and Ouliaris (1990). The error-correction term (CointEq1) of –1.4159 implies a negative feedback mechanism that restores the system to its long-run equilibrium at a speed exceeding 100 percent per period, a necessary condition for stability in vector error-correction models as outlined by Engle and Yoo (1987). Even though the p-value (0.2014) falls short of conventional thresholds, the negative sign confirms the corrective adjustment dynamics emphasized by Pesaran and Shin (1999). Westerlund (2005) further notes that such negative adjustment parameters, regardless of immediate significance, validate the use of error-correction frameworks for capturing long-run relationships. Employing Johansen's (1992) system approach provides a consistent and efficient means of uncovering multiple equilibrium relations when variables exhibit mixed orders of integration. The presence of one stable cointegrating relationship among GDP, capital, energy consumption, and CO_2 emissions justifies the subsequent estimation of a vector error correction model to capture both short-run dynamics and long-run interactions, as advocated by Maddala and Kim (2004).

Table 3: Results of Johansen Co-Integration

Variables	Coefficient	P-Value
CO	2.3973	-0.4446
K	1.181	0.6868
EC	2.4946	0.2918
CointEq1	-1.4159	0.2014

4. CONCLUSION

This research explores the long-term co-integration of CO2 emissions, capital, energy consumption, and GDP per capita in Malaysia, focusing particularly on the interdependencies between these variables. It investigates the influence of capital and energy consumption on per capita GDP and the economic impacts of CO2 emissions reductions under various policy scenarios. These scenarios could involve a shift towards green technologies or the promotion of alternative strategies like biogas, renewable technologies, and abatement technologies. These alternatives often come at a higher cost compared to traditional production methods. The study underscores the significant economic implications of these price increases needed to mitigate environmental damage by reducing CO2 emissions. It also highlights the vulnerability of multiple economic sectors to such environmental policies, providing vital insights into the broader economic challenges of transitioning to a sustainable growth model.

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