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Disclosing the Relationship among CO_2 Emissions, Energy Consumption, Economic Growth and Bilateral Trade between Singapore and Malaysia: An Econometric Analysis

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***Abstract*—**The aim of this paper is to examine the relationship among CO_2 per capita emissions, energy consumption, economic growth and bilateral trade between Singapore and Malaysia for the 1970-2011 period. ARDL model and Granger causality tests are employed for the analysis. Results of bound F-statistics suggest that long-run relationship exists between CO_2 per capita (PCO_2) and its determinants. The EKC hypothesis is not supported in Malaysia. Carbon emissions are mainly determined by energy consumption in the short and long run while, exports to Singapore is a significant variable in explaining PCO_2 emissions in Malaysia in long-run. Furthermore, we find a unidirectional causal relationship running from economic growth to PCO_2 emissions.

***Keywords*—**ADRL Bound Test, Bilateral trade, CO_2 emission, Environmental Kuznets Curve, Energy consumption, Malaysia.

I. Introduction

THE increasing threat of global warming and climate change has called for more attention and discussion of global environmental issues. There is projection of substantial increase in temperature by the end of the 21st century. It is virtually certain that increases in the frequency and magnitude of daily temperature extremes and decreases in cold extremes will occur in the 21st century at the global scale [1]. The "manmade" greenhouse effect is caused by the addition of greenhouse gases (GHG), especially carbon dioxide (CO_2). They are emitted mostly when fossil fuels, such as petroleum, coal and natural gas are burned. Global carbon dioxide emissions are set to rise again in 2012 to new record, largely as a result of the economic growth. Around 200 countries gathered in Doha, Qatar to discuss and agree a global deal climate agreement by 2015 on cutting carbon emissions [2].

It is very important to save the environment through the efficiency of energy management and consumption from the environmental preservation point of view. Developing countries like Malaysia has emerged as a robust economy and a paragon of success for the East-Asian region. Since 1957, the resource rich nation has successfully prosecuted a policy of enviable economic growth. Malaysia boasts of being among the emerging nations with the highest rates of economic growth. Due to rapid economic transformation, government has promoted the strategy to reduce the amount of energy consumption as well as to reduce CO_2 emission through energy efficiency in order to protect environmental issues as stated in the 10th Malaysia Plan [3]. Therefore, Malaysia has agreed to reduce the carbon dioxide by up to 40 percent by year 2020 in comparison to 2005 level even though Malaysia is non-annex 1 in the Kyoto Protocol but it is encourage in reducing the CO_2 emission.

Fig. 1 shows the trend of the CO_2 emissions per capita and GDP per capita in Malaysian economy for the 1970-2010 period. Both variables are showing the upward trend.

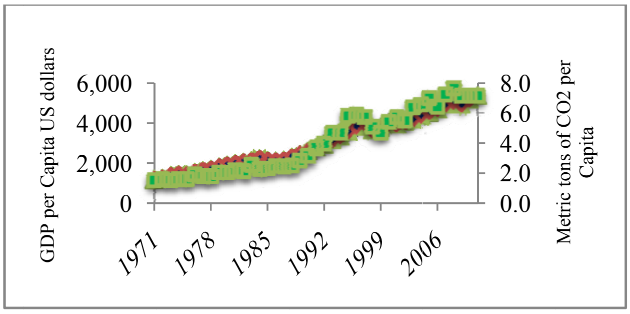

Fig. 1 Malaysian PCO_2 and GDP per capita for the 1970-2010 period [4]

The incredible economic growth of Malaysia, over the past three decades, is mainly attributed to its impressive industrial growth. Energy Information Administration (EIA) has analyzed that carbon dioxide emissions in Malaysia have increased by 221% since year 1990 to 2004 [5]. Fossil fuels contribute more than half of the total CO_2 increment. This growth rate is among the 30 biggest greenhouse gas emitters. Reference [6] has discussed that, while as a ratified the Kyoto Protocol, Malaysia put efforts to change the rapid growth in emissions. According to the Climate Change Performance Index report, Malaysia is rated as contributor of CO_2 with 49.2 scores [7]. Above all, Malaysia is an open economy which also heavily depends on external trade to achieve its economic growth. It has explained that external trade has been a catalyst in the development of the Malaysian economy contributing significantly to the Gross Domestic Product (GDP) where in 1971, the total merchandise trade to the GDP was 73 percent. It increased further by 187 percent in 2000 and recorded 142 percent in 2009 [8].

However, the main objective of the current study is to fill the gap in the energy literature by examining the equilibrium relationship between CO_2 per capita emissions and GDP per capita, bilateral trade and energy consumption in Malaysia. Single country studies help policy making authorities in making comprehensive policy to control environmental degradation. In addition, the present research has taken into account bilateral trade between Singapore and Malaysia for its impact on environmental pollution. The selection of Singapore economy is due to the largest export partner of Malaysia. Department of Statistics Malaysia (DOSM) revealed that Malaysia's comprises around 49.4% share of total exports with Singapore [9] (see Fig. 2).

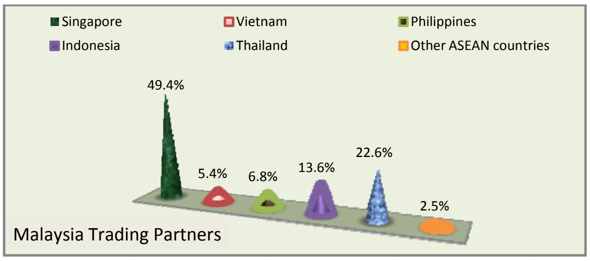

Fig. 2 Malaysia's trade with ASEAN countries for January 2012 [9]

In particular, the paper is motivated by the need to add more variables like energy consumption and trade in findings by [10]. They have suggested that the result will be more extensive by adding some other variables.

The rest of the paper proceeds as follows: Section II describes the past studies and is followed by a discussion of data and model in Section III. Section IV yields analyses of results. Finally, conclusion and policy implications are outlined in Section V.

II. Literature Review

Reference[11], in 1971, Nobel Prize winner, postulated that income inequality first rises and then falls with economic growth Ever since, the Environmental Kuznets Curve (EKC) hypothesis has become an independent research issue which has provoked a large body of theoretical and empirical literature. An inverted U-shape relationship between economic growth and environmental degradation is described by the EKC in which, environmental degradation increases with economic growth, reaches its maximum level and decreases when the economy reaches the given critical high level of income. Many related studies to EKC are available as [12]-[20].

There is another strand of literature which shows the energy consumption dependence on economic growth. One of the crucial elements for continuous economic growth is energy consumption. This highlights the importance of the link between energy consumption and economic growth. The relationship of energy consumption and economic growth has been investigated extensively as well in different countries. For example, the study by [21] for the US, [22] for Taiwan and Korea, [23] for Pakistan, [24] for EU countries, [25] for 17 African countries, [26] for six Gulf Cooperation countries, [27] for Soviet Union, [28], [29] for Malaysia, [30] for South America and [31] for Pakistan.

Trade openness is another variable which poised effect in generating CO_2 emission. It also provides a way for mobilizing factors of production freely between countries. Actually, movement of factors of production may also move dirty industries from home countries to developing economies where laws and regulations about the environment is just a formality. For example, it has documented that trade openness harms the environmental quality [32], [33]. Furthermore, it has also investigated that there is a link between trade and CO_2 emissions in Pakistan. They found a positive relationship between both of them [34]. Reference [35] added trade openness to explore the relationship between economic growth, CO_2 emissions and energy consumption in Turkey. Moreover, there was debate about the trade openness and its impacts on Chinese economy [36]. Their result showed that trade openness is one of the main contributors to economic growth while income raises the level of CO_2 emissions.

III. Data and Econometric Model

Annual time series data for the (1971-2011) period were utilized in this study. The details of variables are given in Table I:

TABLE I
VARIABLES DETAILS

Variables	Units	Sources
CO_2 per capita (PCO_2)	Metric tons per capita	[4]
GDP per capita (Y)	US dollars (constant 2000=100)	[4]
Exports to Singapore (EXS)	US dollars (constant 2000=100)	[37]
Imports from Singapore (IMS)	US dollars (constant 2000=100)	[37]
Energy Consumption (EU)	Kg of oil equivalent	[4]

Different approaches have been used to investigate the relationship between economic growth and CO_2 emissions. Reference [38] presents a comprehensive survey on the EKC literature and points out those factors as international trade, technological progress and demography may have an impact on CO_2 emissions. Based on these arguments, additionally, we also take into account trade and energy consumption. This article follows closely the methodology of the recent studies by [39], [40]. A log linear quadratic equation is specified to test the long-run relationship among PCO_2 emissions, energy consumption, economic growth and foreign trade in order to test the validity of the EKC hypothesis. The estimable econometric logarithm regression line is as follows in

$$LPCO_{2t}=\alpha_0+\alpha_1 LY_t+\alpha_2(LY_t)^2+\alpha_3 LEXS_t+\alpha_4 LIMS_t+\alpha_5 LEU_t+\varepsilon_t \quad (1)$$

where, t is the time period. While, $\alpha_1 < 0$ and $\alpha_2 > 0$ representing U-shaped relationship or if $\alpha_1 > 0$ and $\alpha_2 < 0$ indicate an inverted U-shaped relationship, hence the EKC. The expected sign of α_3 and α_4 is mixed depending on a level of a country in economic development stages. It is expected to be negative for developed countries as they specialize in clean and service intensive production and instead imports the pollution-intensive products from other countries with less restrictive environmental protection laws. On the other hand, it may be positive in the case of developing countries as they are likely to be net exporter of pollution-intensive goods mentioned [41]. Since higher level of energy consumption leading to greater economic activity and stimulates CO_2 emissions, α_5 is expected to be positive.

Various methods are available in conducting the cointegration analysis, including the residual-based approach proposed by [42], the maximum likelihood-based approach discussed by [43], the fully modified OLS procedures of [44] and the recently developed approach, Autoregressive Distributed Lag (ARDL) suggested by [45]. ARDL for cointegration analysis has a number of attractive features over the other alternatives by [46]. First, the approach avoids endogeneity problems and inability to test hypotheses on the estimated coefficients in the long-run associated with the [42]. Second, the short-run as well as the long-run effects of the independent variables on the dependent variable are assessed at the same time. Third, all variables are assumed to be endogenous. Forth the econometric methodology does not require establishing the order of integration of the variables (unit-root test). The approach is applicable regardless of whether the underlying regressors are *I(0)*, *I(1)* or fractionally integrated and finally the methodology is popular in small samples as the case of the present study .

In current study ARDL bounds testing approach is employed to examine the long-run relationship among PCO_2 emissions, economic growth, trade between Singapore and Malaysia and energy consumption. However, in matrix basis, ARDL approach could be formulated as the following form

$$\begin{bmatrix} \Delta LPCO_{2t} \\ \Delta LY_t \\ \Delta L(Y)^2_t \\ \Delta LEXS_t \\ \Delta LIMS_t \\ \Delta LEU_t \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \end{bmatrix} + \begin{bmatrix} \beta_{11} & \beta_{12} & \beta_{13} & \beta_{14} & \beta_{15} & \beta_{16} \\ \beta_{21} & \beta_{22} & \beta_{23} & \beta_{24} & \beta_{25} & \beta_{26} \\ \beta_{31} & \beta_{32} & \beta_{33} & \beta_{34} & \beta_{35} & \beta_{36} \\ \beta_{41} & \beta_{42} & \beta_{43} & \beta_{44} & \beta_{45} & \beta_{46} \\ \beta_{51} & \beta_{52} & \beta_{53} & \beta_{54} & \beta_{55} & \beta_{56} \\ \beta_{61} & \beta_{62} & \beta_{63} & \beta_{64} & \beta_{65} & \beta_{66} \end{bmatrix} \begin{bmatrix} \Delta LPCO_{2t-i} \\ \Delta LY_{t-i} \\ \Delta L(Y)^2_{t-i} \\ \Delta LEXS_{t-i} \\ \Delta LIMS_{t-i} \\ \Delta LEU_{t-i} \end{bmatrix} + \begin{bmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} & \alpha_{14} & \alpha_{15} & \alpha_{16} \\ \alpha_{21} & \alpha_{22} & \alpha_{23} & \alpha_{24} & \alpha_{25} & \alpha_{26} \\ \alpha_{31} & \alpha_{32} & \alpha_{33} & \alpha_{34} & \alpha_{35} & \alpha_{36} \\ \alpha_{41} & \alpha_{42} & \alpha_{43} & \alpha_{44} & \alpha_{45} & \alpha_{46} \\ \alpha_{51} & \alpha_{52} & \alpha_{53} & \alpha_{54} & \alpha_{55} & \alpha_{56} \\ \alpha_{61} & \alpha_{62} & \alpha_{63} & \alpha_{64} & \alpha_{65} & \alpha_{66} \end{bmatrix} \begin{bmatrix} LPCO_{2t-1} \\ LY_{t-1} \\ L(Y)^2_{t-1} \\ LEXS_{t-1} \\ LIMS_{t-1} \\ LEU_{t-1} \end{bmatrix} + \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \lambda_4 \\ \lambda_5 \\ \lambda_6 \end{bmatrix} \begin{bmatrix} ECM_{t-1} \\ ECM_{t-1} \\ ECM_{t-1} \\ ECM_{t-1} \\ ECM_{t-1} \\ ECM_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \varepsilon_5 \\ \varepsilon_6 \end{bmatrix}$$

where, Δ is the first difference operator; α_i(i =1, ….., 6) represent intercept; β_{ji}s (j,i = 1,….., 6) and n_{ji}s (j,i = 1,….,6) represent the short-run and long-run coefficients of the variables respectively; λ_i (i= 1,….., 6) represents the coefficients of ECM_{t-1} which used to link the long-run and short-run equilibrium of the variables at one period lagged; ε_is (i = 1, … . . , 6) represent the error terms.

The bounds testing procedure is based on the joint F-statistic that is tested the null of no cointegration, $H_0: \alpha_{ij} =0$, against the alternative of $H_1: \alpha_{ij} \neq 0$. The *F*-test is conducted to test the existing of long-run relationship among the variables. The critical values of the *F*-statistics in this test are available in [42]. There are two sets of critical values for a given significance level, with and without a time trend, at *I(0)* and the other at *I(1)*, which are known as lower bounds (LCB) and upper bounds critical values (UCB) respectively. The decision rule is based on compare the calculated F-statistics with the critical values tabulated at statistical tables [45]. If the calculated F-statistics are greater than the upper bounds value, *I(1),* the null hypotheses (H_0 = 0), no co-integration, will be rejected. This means that the variables included in the models share long-run relationship. Conversely, if the calculated F-statistics fall below the lower bounds value, *I(0)*, the null hypothesis (H_0 = 0), no co-integration, cannot be rejected. This means that the variables included in the models do not share long-run relationship among themselves. Moreover, if the calculated F-statistics fall in the range $I(0) \leq$ F value $\leq I(1)$ it means that the decisions are inconclusive to be either accept or reject the long-run relationship. Furthermore, in the final step, we obtain the short-run dynamic parameters by estimating ECM_{t-1} associated with the short-run estimates. That gives the adjustment speed of the disequilibrium among the variables [45]. However, it has suggested that if the co-integration exists among the variables in the long-run then, there must be either unidirectional or bidirectional causality among these variables [42].

Reference [45], [46] suggested testing the stability of estimated coefficients through cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ). In this study the stability tests are conducted to check the stability of the coefficient in estimated models.

IV. Results Analysis

Reference [47] has discussed that in time-series methodology, the regression results are likely to be spurious if the variables are non-stationary. On the other hand, it has postulated that if a time series is non-stationary, then the aim of forecasting would be cancelled out [48]. Thus, the ADF test was performed to detect the model's stationary levels (see Table II). The results show that all the models are stationary at their first differences; hence, these models are *I(1)* for the 1970-2011 period. Therefore, since all the variables are stationary at *I(1)* which enables us to proceed with the rest of the economic model.

TABLE II
ADF Test

Variables	ADF I(0)	ADF I(1)	Order of Integration
$LPCO_2$	-1.003914	-7.651692***	I (1)
LY	-1.555096	-5.462345***	I (1)
$(LY)^2$	-1.160469	-5.615044***	I (1)
LEXS	-1.531534	-6.115679***	I (1)
LIMS	-1.703011	-6.424630***	I (1)
LEU	-0.795355	-6.658566***	I (1)

Note: *** is significant at 1%.

According to the selection of lag criteria the number of lag depends on the lowest values of HQ, SBC and AIC [49]. Also, could use LR test (sequential modified) as a primary determinant of how many lags to be included (see Table III).

TABLE III
LAG SELECTION

Lag	AIC	SC	HQ
0	-7.089063	-6.835731	-6.997466
1	-16.04752	-14.27420*	-15.40634*
2	-16.28415*	-12.99083	-15.09339

Note: * is significant at 10%.

The *F*-statistics of CO_2P model was obtained 4.78 which is higher than the upper bound critical value of 3.37 at 10% significant level and supports cointegration. The other variables shows inconclusive and no cointegration result in Table IV.

TABLE IV
F-STATISTICS TEST

Models	F-statistics	Significant level	Critical value	
			Lower	Upper
LCO_2P	4.78***	10%	2.26	3.37
LY	1.53	5%	2.65	3.81
$(LY)^2$	1.68	1%	3.52	4.78
LEXS	1.85			
LIMS	2.21			
LEU	1.82			

Note: *** is significant at 1%.

The existence of cointegration among variables warrants the estimation of (1) by ARDL approach to get the long-run coefficients. The results are reported in Table V.

TABLE V
LONG-RUN CO-EFFICIENTS

Regressor	Coefficient	P-value	T-value
LY	-4.56	0.117	- 1.6103*
$(LY)^2$	0.23	0.155	1.4556*
LEXS	0.60	0.013	2.6318**
LIMS	-0.13	0.271	- 1.1199*
LEU	1.24	0.028	2.2956**
C	3.15	0.739	0.3354

Note: *, ** significant at 10% and 5%, respectively.

The negative and positive coefficient of LY and $(LY)^2$ respectively, indicate the existence of a U-shape relationship between per capita CO_2 emissions and per capita real GDP. This confirms that PCO_2 emissions declines at initial level of economic growth then reaches a turning point and increases with the higher level of economic growth. The long-run elasticity of CO_2 emissions with respect to energy consumption is 1.24 and significant at 1% level which implies that 1% increase in per capita energy consumption will lead to 1.24% increase in per capita CO_2 emissions in the long run. This positive effect of per capita energy consumption on CO_2 emissions is in line with earlier findings by [13], [36]. Similarly the coefficient of LEXS is 0.60 which is positive in sign and highly significant. It indicates that 1% increase in foreign trade will lead to 0.60% increases in per capita CO_2 emissions. The positive long-run relationship between PCO_2 emissions and trade openness is in line with [35], [40]. From the results it is apparent that the long-run effect of energy consumption on PCO_2 emissions in Malaysia is more significant than trade openness. The estimated model also passes the diagnostic tests of functional form specification and normality. Moreover diagnostic test statistics do not suggest the presence of any serial correlation and heteroskedasticity.

Hence, once we establish the long-run relationships among the series models can make a progress for analyzing the short-run relationships. Furthermore, the ECM_{t-1} and short-run results are presented in Table VI. The short-run elasticity of PCO_2 emissions, with respect to energy consumption, is 0.68. It is positive in sign and highly significant at 1% confidence level, indicating that for each 1% increase in per capita energy consumption, per capita CO_2 emissions increase by 0.68%. The coefficient of imports from Singapore is negative and insignificant. It is -0.07, suggesting that the contribution of the imports to PCO_2 emissions in the short-run is negligible in Malaysia during the estimated period while, the exports shows the positive value as 0.06. The statistical significance of ECM_{t-1} with an appropriate sign (-) is an indication of the speed towards the long-run equilibrium after dis-equilibrium in the short-run. However, the coefficient of ECM_{t-1} is fairly large, that is, -0.55. This indicates that any deviation from the long-run equilibrium between PCO_2 and other variables is corrected about 55% for each period and it takes about 1.78 year (1 divided by the estimated coefficient of ECM_{t-1}) in restoring to the long-run equilibrium level after disequilibrium in the short run.

TABLE VI
SHORT-RUN AND ERROR CORRECTION TERMS COEFFICIENTS

Regressor	Coefficient	P-value	T-Statistic
ΔLY_{t-1}	-1.23	0.457	-0.75311
$\Delta(LY)^2_{t-1}$	0.12	0.171	1.3994
$\Delta LEXS_{t-1}$	0.06	0.622	0.49804
$\Delta LIMS_{t-1}$	-0.07	0.303	- 1.0467
ΔLEU_{t-1}	0.68	0.002	3.3432**
ΔC	1.72	0.738	0.33756
ECT_{t-1}	-0.55	0.001	- 3.5853***

Note: **, *** significant at 5% and 1%, respectively.

The Granger causality has also applied to check the direction of relationship among variables[1]. However, there is unideirectional causal relationship running from economic growth to PCO_2 emissions in long-run. This result is consistent with in Tunisia [50], in Iran [51] and in Pakistan [52], the result also reveal the relationship between GDP per capita and CO_2 per capita in short run.

To check the stability of the coefficients cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) techniques were employed. Graphically, these two statistics are plotted within two straight lines bounded by the 5% significance level. If any point lies beyond this 5% level, the null hypothesis of stable parameters is rejected. As can be seen from Figs. 3 and 4, the plots of CUSUM and CUSUMSQ

[1] Results are with researchers.

statistics are well within the critical bounds, support the stability of the coefficients in estimated model.

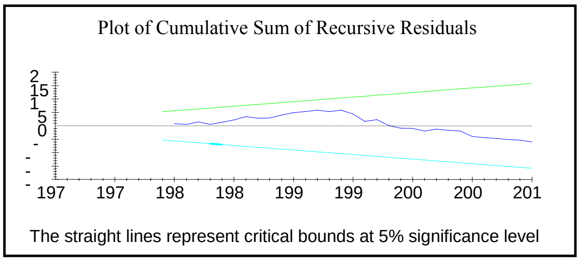

Fig. 3 Plot of cumulative sum of recursive residuals

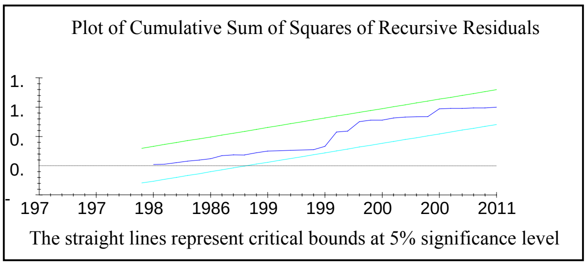

Fig. 4 Plot of cumulative sum squares of recursive residuals

V. Conclusion and Policy Implications

The current study investigated the dynamic relationship between carbon dioxide emissions and economic growth in Malaysia based on the EKC hypothesis for the period (1970–2011) by incorporating energy consumption and trade openness. Cointegration analysis was conducted using bounds testing approach developed by [45]. Negative and positive coefficient of lnY and $(\ln Y)^2$ respectively, indicating a U-shape relationship between per capita CO_2 emissions and per capita real GDP. This confirms that CO_2 emissions declines at initial level of economic growth then reaches a turning point and increases with the higher level of economic growth. Therefore, the results do not support the EKC hypothesis. The elasticity of CO_2 emissions with respect to energy consumption is 1.2430 and 0.68 in the long and short-run respectively and highly significant. This implies that for each 1% increase in energy consumption per capita CO_2 emissions will rise by 1.24% in the long-run and 0.68% in the short-run. It implies that emission reduction policies and more investment in pollution abatement will not hurt economic growth and could be a feasible policy tool for Malaysia to achieve its sustainable development in the long-run. Carbon capture and storage, carbon emissions tax and carbon-trading scheme can be performed without much concern for long-run income. Of course, these policy tools should be accompanied by other possible strategies such as increasing plant efficiency, employing fuel balancing or fuel switching and making enhanced use of renewable energy. Government of Malaysia has promoted strategies with greater emphasis given to environmental considerations which address global warming and climate change. The coefficient of exports to Singapore is positive and significant in the long-run and short-run. This is indicating that 1% increase in foreign trade will lead to 0.6% increases in per capita CO_2 emissions in the long-run while its contribution to CO_2 emissions is 0.06% in the short-run. Correctly signed and statistically significant coefficient of ECM_{t-1} supports the existence of cointegration among variables.

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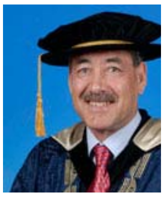

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