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The Determinants of Carbon Dioxide Emissions in Malaysia and Singapore

(Penentu-Penentu Pelepasan Karbon Dioksida di Malaysia dan Singapura)

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ABSTRACT

The focal aim of this paper is to examine the relationship between total energy consumption, Gross Domestic Product, urbanization, trade openness and financial development on carbon dioxide (CO2) emissions. The study focuses on two selected ASEAN countries namely, Malaysia and Singapore, due to their major contribution in CO2 emissions among other ASEAN countries, after Brunei. This study adopts the quarterly time series data from Q1:2010 to Q1:2020. By utilizing the linear ARDL method, the presence of a positive and long-term relationship was confirmed between the variables for both countries. The findings also validate the Environment Kuznets hypothesis namely, that CO2 emissions will continue to rise until the national income reaches optimum point and beyond this environment quality will begin to improve. The results established that financial development helps to reduce CO2 emissions in both the short- and long-run. Further, trade openness tends to reduce CO2 in Malaysia. For Singapore however, it reduces CO2 in the short-run but not in the long-run. In general the study reveals that the relationship between emissions of CO2 and economic development is U-shaped, for both countries. For future sustainable environment the study implies that specific financial planning towards green technology is necessary to sustain a better environment. Economic growth of the country is therefore more meaningful if accompanied with a sustainable environment for future generations.

Keywords: Carbon dioxide emissions; financial development; trade openness; Environment Kuznets hypothesis; energy consumption
JEL: C32, O44, P48, Q56

ABSTRAK

Fokus utama kajian ini dijalankan adalah untuk meneliti hubungan antara jumlah penggunaan tenaga, Keluaran Negara Kasar, urbanisasi, keterbukaan pasaran dan pembangunan kewangan terhadap pelepasan karbon dioksida. Kajian ini juga memfokus kepada dua negara ASEAN terpilih, iaitu Malaysia dan Singapura, kerana berbanding negera-negara lain di ASEAN, kedua-dua negara ini adalah penyumbang yang signifikan terhadap pelepasan CO2, selepas Brunei. Kajian ini menggunakan data siri masa suku tahunan dari Q1: 2010 hingga Q1: 2020. Dengan menggunakan kaedah ARDL linear, kajian ini mengesahkan adanya hubungan positif dan jangka panjang antara pemboleh ubah untuk kedua-dua negara. Penemuan ini juga mengesahkan hipotesis Environmental Kuznets. Dengan kata lain, pelepasan CO2 akan terus meningkat sehingga pendapatan negara mencapai titik optimum dan setelah titik optimum tersebut, kualiti persekitaran akan mulai meningkat. Hasil kajian mendapati bahawa pembangunan kewangan membantu mengurangkan pelepasan CO2 dalam jangka pendek dan jangka panjang. Hasil kajian seterusnya mencadangkan bahawa keterbukaan perdagangan cenderung mengurangkan CO2 di Malaysia. Namun bagi Singapura, keterbukaan perdagangan mengurangkan CO2 dalam jangka pendek tetapi tidak dalam jangka masa panjang. Secara keseluruhan, kajian ini mendedahkan bahawa hubungan antara pelepasan CO2 dan pertumbuhan ekonomi adalah berbentuk U, di Malaysia dan Singapura. Sebagai implikasi, untuk persekitaran yang lestari di masa depan, perancangan kewangan khusus ke arah teknologi hijau untuk pembangunan negara yang mampan serta *memelihara persekitaran yang lebih baik harus diutamakan. Oleh yang demikian, pertumbuhan ekonomi negara akan menjadi lebih bermakna dengan persekitaran pintar dan terpelihara untuk generasi akan datang.*

Kata kunci: Pelepasan karbon dioksida; pembangunan kewangan; keterbukaan pasaran; hipotesis alam sekitar Kuznets; penggunaan kuasa

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INTRODUCTION

The world has been embroiled with the issue of climate changes and global warming since decades ago. The success of a country in achieving sustainable economic development status is often associated with its ability to control environmental pollution as well as the ability to maintain environment sustainability. Consistent with this, some recent empirical studies have emphasized that the fall in carbon dioxide (CO2) emissions is a sign of environmental quality enhancement for the country (Rambeli et al. 2018; Harris et al. 2017; Halicioglu 2009; Green & Stern 2017; Mckibbin et al. 2017; Adamu et al. 2021). With such coverage in the literature it therefore cannot be denied that the relationship has been given attention by policymakers and researchers, ever since the achievement of sustained economic growth is gradually becoming a major global concern. However, this relationship is gradually becoming more complex than those in previous years due to the influence of other factors, while most of the earlier studies reported in the literature were theoretical in nature.

Given the importance of the CO2 emissions, international organizations around the world are continuously working to reduce the adverse side effects of global warming such as the initiatives proclaimed in the Kyoto Protocol and the United Nations Framework Convention on Climate Change (UNFCCC) (1998). These organizations are working towards reducing the level of global warming through the formalisation of several agreements including the Green Climate Fund, the European Environment Agency and the Partnerships in Environmental Management for the Seas of East Asia. The development in global concern has induced both Malaysia and Singapore to share a very close bilateral relationship on the matter. The worsening air quality and pollution in the ASEAN region could potentially be a crucial issue that can strain the relationship among ASEAN Member States (AMS). In September 2015, Malaysia and Singapore signed the United Nations (UN) Sustainable Development Goals (SDGs) which demonstrated the countries' readiness to achieve sustainable and cleaner energy growth by 2030. Both countries agreed that ambient temperature growth should be targeted at below 2°C. Under the agreement both were committed to reduce by 2030 the carbon emissions intensity to GDP by 45%, relative to 2005 levels (EPU 2017). Malaysia and Singapore were among 197 other countries that have ratified the Paris Agreement since December 2015 aimed at reducing gaseous emissions that contribute to global warming (United Nation 2016; The Paris Agreement 2016). Given the stringent target set for global warming, it was agreed at the international level that studies need to be conducted to ensure that the agreement will be successfully implemented. This necessity provides the motivation for this study which is designed to examine the relationship between economic development and the possible impact of negative external factors unleashed through macroeconomics determinants.

This study applied the theoretical perspective of the Environment Kuznets Curve (EKC) hypothesis. According to the hypothesis CO2 emissions will continue to rise until the country's average income reaches a turning point at its peak, following which environment quality will begin to improve. In other words, when the government achieves a high income level for the country, they will then be able to address the environment for better quality of life. In relation to this the EKC hypothesis accepts that the relationship between economic growth and environment exhibits the U-shape pattern (Grossman & Krueger 1995). Numerous studies have since discovered the role of macroeconomics variables in relation to CO2 emissions. Studies by Ang (2008), Kasman and Duman (2015), Keho (2017), Khoshnevis and Shakouri (2018), Rambeli et al. (2018), Chandio et al. (2019), among others, have established that energy consumption impacts CO2 emissions positively. Several studies have also explored the relationship between energy consumption (Ang 2008; Rambeli et al. 2018) and urbanization (Kasman et al. 2015; Martinez-Zarzoso & Maruotti 2011) with CO2 emissions, for developed and developing countries.

The role of trade openness and financial issue in affecting CO2 emissions is however less reported in past literature especially among developing countries (Ho & Iyke 2019). The authors also found that the effect of trade openness on CO2 emissions was dissimilar, between the short- and long-term. Furthermore, despite the empirical studies conducted, there were no firm conclusions on the relationship (Oh & Bhuyan 2018) which can either be positive or negative, in the short- and long-term. In other words, an increase in trade openness will indirectly raise or reduce CO2 emissions in the country (Bekhet & Yasmin 2013; Belloumi 2014; Ertugrul et al. 2016). For example, when import and export activities increase in the transportation sector, the volume of goods handled by logistics companies will increase accordingly. The consequent increase in shipments of these goods, will necessitate an increase in the use of vehicle oil as fuel. It is thus clear that an increase in trade may indirectly lead to increase in demand for associated commodities in the market such as fuel. In the long-run there will be a significant increase in national productivity and consequent CO2 emissions (Shahbaz et al. 2013). Ho and Iyke (2019) claimed that in the short-term there is a positive and significant relationship between trade openness and CO2 emissions. Conversely too, in the long-term the relationship between trade openness and CO2 emissions can also be positive but not significant. Nevertheless, the relationship may also be negative in the short- and long-term. This can occur when the country employs environment-friendly technology, which may increase productivity through trade openness (Shahbaz et al. 2013) but without adversely affecting the environment.

Xing et al. (2017) claimed that financial development can improve environmental quality through the reduction or control of CO2 emissions. But the effects can differ in the long- and short-term. Several studies have also explored the relationship between financial development and CO2 emissions (Bayar et al. 2020; Xiong et al. 2017; Basarir & Cakir 2015). Some of the studies found the relationship negative (Annicchiarico & Di Dio 2016; Basarir & Cakir 2015), whereas others suggested a positive relationship but only for developed countries (Manta et al. 2020). To date, there is insufficient empirical evidence to explain this relationship for the developing countries including those in ASEAN. According to Shahbaz et al. (2013) financial development can be used as tools for the government to control CO2 emissions from continuing out of control but only with incurring the requisite large expenses. As such only the developed countries that will be more capable in handling CO2 emissions in both short- and long-terms. A study is therefore necessary to examine the relationship between these two variables for developing economies.

The purpose of this study is to explore further the role of selected macroeconomics variables, namely energy consumption in industries (ENC), Gross Domestic Product (GDP), urban population (URB), trade openness (TOP) and financial development (FIN) on carbon emissions in Malaysia and Singapore. According to statistics records, a significant proportion of future escalation of CO2 emissions is likely to come from the ASEAN countries, especially from Malaysia and Singapore (IEA report, 2015-2018). Moreover, according to IEA report (2018), the ASEAN region will double its emission by 2040, with approximately more than 20 percent coming from Malaysia and Singapore. The study should thus focus on these two countries. Geographically, Malaysia and Singapore share a common international boarder. Moreover, Singapore is Malaysia's biggest trading partner in ASEAN in the period spanning 2015 to 2020, before the advent of the covid-19 pandemic (Statistical Report, 2020). Findings from this study can thus serve as example under developing situation on curbing CO2 emission to sustain environment quality.

The potential contribution from this study can be divided into two aspects. First, the study extends the existing literature through employing the linear ARDL model proposed by Shin et al. (2013) in examining the selected determinants of CO2 emissions in Malaysia and Singapore. Secondly, most of the past studies have neglected the role of trade openness and financial development in influencing CO2 emissions in ASEAN countries. The focus was mainly on Europe, United States or China. This study will therefore potentially fill the knowledge gap on the role of trade openness and financial development in affecting CO2 emissions in two ASEAN countries, namely Malaysia and Singapore, in both the short- and long-term.

The rest of the paper is structured as follows: The next section is the literature review followed by the methodology, model specifications and data employed in this study. The fourth section provides the empirical results. The conclusions and implications of the study will be included in the final section of the paper.

LITERATURE REVIEW

In this section, past reviews of the literature are discussed in terms of CO2 and its relations with several macroeconomics variables, such as gross domestic product (Ang 2008; Kasman & Duman 2015; Keho 2017; Khoshnevis & Shakouri 2018; Rambeli et al. 2018; Chandio et al. 2019), energy consumption (Basarir & Cakir 2015; Ang 2008; Rambeli et al. 2018), electricity consumption, urbanization (Shahbaz et al. 2016; Kasman et al. 2015; Martinez-Zarzoso & Maruotti 2011), trade openness (Bekhet & Yasmin 2013; Belloumi 2014; and Ertugrul et al. 2016); financial development (Jalil et al. 2009; Kakar et al. 2011; Abosedra et al. 2015; Basarir & Cakir 2015; Xing et al. 2017; Xiong et al. 2017; Economides & Xepapadeas 2018; Bayar et al. 2020) and income level (see Sharma 2011). The coverage should strengthen study findings on the relationships between macroeconomics variables and CO2 emissions.

Literature on the aforementioned compilation of variables is not only limited to Malaysia, Singapore and other ASEAN nations (Saboori & Sulaiman 2013; Fulton 2017; Chiek et al. 2021), but also sourced from other regions around the globe, namely Europe (Halicioglu 2009; Basarir & Cakir 2015; Bayar et al. 2020), North America, Asia (Kakar et al. 2011; Ab-Rahim & Xin-Di 2016; Green & Stern 2017; Xing et al. 2017; Xiong et al. 2017); and the Middle East (Chebbi et al. 2011; Abosedra et al. 2015).

In addition, studies of CO2 emissions have also examined whether the EKC hypothesis has been corroborated (Martínez-Zarzoso & Bengochea 2004; Saboori & Sulaiman 2013; Kasman & Duman 2015; Ali et al. 2017; Zhang et al. 2017; Munir et al. 2019; Ridzuan et al. 2020). Economides and Xepapadeas (2018) stressed that monetary policy was significantly affected by climate change. Kakar et al. (2011) and Abosedra et al. (2015) emphasized that higher circulation of money supply indirectly caused more carbon emissions into the environment. Greater money supply stimulates higher energy consumption, which ultimately results in intensified carbon emissions.

Xing et al. (2017) came up with new findings on carbon emissions in China. Using STIRPAT (Stochastic impacts by regression on population, affluence, and technology) model and ARDL approach, they discovered the effects of financial development on carbon emissions in the country. The impact was generally in terms of its financial size, openness and depth. They showed that efficiency and ecology in finance can reduce and improve CO2 emissions level.

Basarir and Cakir (2015) disclosed bi-directional causality between financial development and CO2 emissions in five European countries. Interestingly, they uncovered the opposite feedback effects between the two variables whereby CO2 emission would reduce by 0.12 percent with a rise in financial development by 1.00 percent. However Xiong et al. (2017) discovered contrasting results in the relationship between the two variables based on regions. Whereas financial development did increases emissions in the less developed regions it may conversely reduce these in developed ones.

In a most recent study in Europe, Bayar et al (2020) revealed that there was neither unidirectional nor bi-directional causality between financial development and carbon emissions. In contrast, Kakar et al. (2011) and Abosedra et al. (2015), had earlier maintained that financial development appeared to affect CO2 emissions positively in the long-run.

According to Fulton et al. (2017), despite the various Nationally Determined Contribution (NDC) plan submissions following the Paris agreement, all six ASEAN nations including Malaysia and Singapore, would be more likely to fail in achieving their target in reducing CO2 emissions, especially with the Paris agreement being ratified in 2016. The point being the difficulty in effectively quantifying the level of reduction in CO2 emissions, inherent in all the present and future policies that had been submitted by these countries.

DATA, MODEL SPECIFICATIONS AND METHODOLOGY

DATA

The study employed time series data spanning from Q1:2010 to Q1: 2020. The quarterly time series data included CO2 emissions (metric tons per capita), urban population (% of total), and GDP per capita and its square (local currency is constant), total primary energy consumption per capita (million Btu), trade openness (total of exports and imports of % GDP), and broad money supply, obtained from the World Development Indicators (WDI) published by the World Bank. All data were transformed into their natural logarithms due to differences in their units of measurement.

MODEL SPECIFICATION

Most past studies have adopted the cross-sectional or panel data techniques (Martínez-Zarzoso et al. 2011; Manta et al. 2020; among others studies) to estimate the relationship between CO2 emissions and various macroeconomics indicator including gross domestic product, urbanization and energy consumption. But, from econometrics perspective, some of the studies gave arguments favorable to the EKC hypothesis, yet it was not confirmed whether any particular country sampled will follow the same pollution path estimated for the panel of countries (Fodha & Zaghdoud 2010; Chebbi et al. 2011; among others studies). This study will therefore particularly estimate the CO2 model for Malaysia and Singapore.

The basic structure of the model used in this study was inspired by the model proposed by Rambeli et al. (2019). The model specification of this article also inspired by Rambeli et al. (2013) and Rambeli et al. (2014). This paper examined the role of energy consumption, Gross Domestic Product, industrial production index, and employment in influencing CO2 emissions. Additionally, the impact of trade openness (OPN) and financial development (FIN) will also be explored. As such, the multivariate framework for Malaysia and Singapore will be expressed as follows;

Malaysia

$$CO2_{Mt} = f(GDP_{Mt}, GDP_{Mt}^2, ENC_{Mt}, URB_{Mt}, OPN_{Mt}, FIN_{Mt}) \quad (1)$$

Singapore

$$CO2_{St} = f(GDP_{St}, GDP_{St}^2, ENC_{St}, URB_{St}, OPN_{St}, FIN_{St}) \quad (2)$$

The reduction for equations (1) and (2) are as follows;

Malaysia

$$CO2_{Mt} = \alpha_0 + \alpha_1 GDP_{Mt} + \alpha_2 GDP_{Mt}^2 + \alpha_3 ENC_{Mt} + \alpha_4 URB_{Mt} + \alpha_5 OPN_{Mt} + \alpha_6 FIN_{Mt} + \nu_t \quad (3)$$

Singapore

$$CO2_{St} = \beta_0 + \beta_1 GDP_{St} + \beta_2 GDP_{St}^2 + \beta_3 ENC_{St} + \beta_4 URB_{St} + \beta_5 OPN_{St} + \beta_6 FIN_{St} + \varepsilon_t \quad (4)$$

By considering the natural logs (ln), the equations (3) and (4) are transformed into linear logarithm as follows;

Malaysia

$$\ln CO2_{Mt} = \alpha_0 + \alpha_1 \ln GDP_{Mt} + \alpha_2 \ln GDP_{Mt}^2 + \alpha_3 \ln ENC_{Mt} + \alpha_4 \ln URB_{Mt} + \alpha_5 \ln OPN_{Mt} + \alpha_6 \ln FIN_{Mt} + \nu_t \quad (5)$$

Singapore

$$\ln CO2_{St} = \beta_0 + \beta_1 \ln GDP_{St} + \beta_2 \ln GDP_{St}^2 + \beta_3 \ln ENC_{St} + \beta_4 \ln URB_{St} + \beta_5 \ln OPN_{St} + \beta_6 \ln FIN_{St} + \varepsilon_t \quad (6)$$

Where $CO2_{Mt}$ and $CO2_{St}$ are carbon dioxide emissions for Malaysia and Singapore. According to equations (1) and (2), the α_0 and β_0 are constants; while, α_i (,6) are slope coefficients for Malaysia and β_i (i = 1,2,3,4,5,6) are slope coefficients for Singapore. Lastly, ν_t and ε_t are respectively the error terms for both models.

METHODOLOGY

The first step in the methodology is the unit root test. For this, the study adopted the Augmented Dickey Fuller This (ADF) unit root test (Dickey 1976; Dickey & Fuller 1979; Diebold & Kilian 2000; Aritova & Fedorova 2016; Herranz 2017). Subsequently the study employed the Akaike Information Criteria (AIC) in order to select the optimum lag-length for the estimation modelling (Akaike 1969; Akaike 1974; Ivanov & Kilian 2005; Gutierrez et al. 2009). Further, the Autoregressive Distributed Lag (ARDL) bound co-integrating testing approach was employed in order to estimate the long-term relationship between the selected variables (Pesaran et al. 2001; Babatunde 2011). For bound co-integration test, the unrestricted error correction model (UECM) of the ARDL model is expressed as follows;

ARDL Bound Co-integration Model for Malaysia

$$\Delta \ln CO2_{M1} = \alpha_0 + \alpha_1 \ln CO2_{Mt-1} + \alpha_2 \ln GDP_{Mt-1} + \alpha_3 \ln GDP_{Mt-1}^2 + \alpha_4 \ln ENC_{Mt-1} + \alpha_5 \ln URB_{Mt-1} + \alpha_6 \ln OPN_{Mt-1} + \alpha_7 \ln FIN_{Mt-1} + \sum_{i=1}^{p} \theta_i \Delta \ln CO2_{Mt-i} + \sum_{j=0}^{k} \theta_j \Delta \ln GDP_{Mt-j} + \sum_{g=0}^{g} \theta_g \Delta \ln GDP_{Mt-g}^2 + \sum_{s=0}^{b} \theta_s \Delta \ln ENC_{Mt-s} + \sum_{w=0}^{d} \theta_w \Delta \ln URB_{Mt-w} + \sum_{x=0}^{q} \theta_x \Delta \ln OPN_{Mt-x} + \sum_{f=0}^{c} \theta_f \Delta \ln FIN_{Mt-f} + \mu_t \quad (7)$$

ARDL Bound Co-integration Model for Singapore

$$\Delta \ln CO2_{S1} = \varphi_0 + \varphi_1 \ln CO2_{St-1} + \varphi_2 \ln GDP_{St-1} + \varphi_3 \ln GDP_{St-1}^2 + \varphi_4 \ln ENC_{St-1} + \varphi_5 \ln URB_{St-1} + \varphi_6 \ln OPN_{St-1} + \varphi_7 \ln FIN_{St-1} + \sum_{i=1}^{p} \delta_i \Delta \ln CO2_{St-i} + \sum_{j=0}^{k} \delta_j \Delta \ln GDP_{St-j} + \sum_{f=0}^{f} \delta_f \ln GDP_{St-f}^2 + \sum_{s=0}^{b} \delta_s \Delta \ln ENC_{St-s} + \sum_{w=0}^{d} \delta_w \Delta \ln URB_{St-w} + \sum_{x=0}^{q} \delta_x \Delta \ln OPN_{St-x} + \sum_{f=0}^{c} \delta_f \Delta \ln FIN_{St-f} + \Phi_t \quad (8)$$

The unrestricted error correction model (UECM) of the ARDL model equation (7) is for Malaysia and equation (8) for Singapore. In these equations, the long-run coefficients $\theta_i, \theta_j, \theta_g, \theta_s, \theta_w, \theta_x$, and θ_f are for Malaysia and $\delta_i, \delta_j, \delta_f, \delta_s, \delta_w, \delta_x$, and δ_f are for Singapore. Accordingly, the short-run coefficients $(\alpha_1 - \alpha_7)$ are for Malaysia and $(\phi_1 - \phi_7)$ are for Singapore. In this study the Wald-test was employed in order to perform the joint test hypothesis as follows;

Wald-test for Malaysia's ARDL Bound Co-integration Test

$$H_0 : \alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = \alpha_6 = \alpha_7 = 0$$
$$H_1 : \alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq \alpha_5 \neq \alpha_6 \neq \alpha_7 \neq 0$$

Wald-test for Singapore's ARDL Bound Co-integration Test

$$H_0 : \phi_1 = \phi_2 = \phi_3 = \phi_4 = \phi_5 = \phi_6 = \phi_7 = 0$$
$$H_1 : \phi_1 \neq \phi_2 \neq \phi_3 \neq \phi_4 \neq \phi_5 \neq \phi_6 \neq \phi_7 \neq 0$$

Under the Wald-test testing procedure, the F-statistic value produced by the estimation model was compared with the critical F-statistical value produced by Narayan (2005). This test may lead to three conclusions. Firstly, the null hypothesis can be rejected if the F-statistic value obtained from the estimation model is larger than the upper bound critical F-statistic table, which thus confirmed the co-integration between the variables. Secondly, if the F-statistic value obtained from the estimation model is less than the lower bound critical F-statistic table, the hypothesis cannot thus be rejected. Finally, the analysis is not conclusive if the F-statistic values are within the upper and lower critical values. After the variables co-integration was obtained, the next stage is the development of the long-term estimation model as follows;

ARDL Long-run Estimation Model for Malaysia

$$\begin{aligned}\ln CO2_{M1} &= \alpha_0 + \sum_{i=1}^{p}\theta_i \Delta \ln CO2_{Mt-i} \\ &+ \sum_{j=0}^{k}\theta_j \Delta \ln GDP_{Mt-j} + \sum_{g=0}^{g}\theta_g \Delta \ln GDP^2_{Mt-g} \\ &+ \sum_{s=0}^{b}\theta_s \Delta \ln ENC_{Mt-s} + \sum_{w=0}^{d}\theta_w \Delta \ln URB_{Mt-w} \\ &+ \sum_{x=0}^{q}\theta_x \Delta \ln OPN_{Mt-x} + \sum_{f=0}^{c}\theta_f \Delta \ln FIN_{Mt-f} + \mu_t \end{aligned} \quad (9)$$

ARDL Long-run Estimation Model for Singapore

$$\begin{aligned}\ln CO2_{S1} &= \varphi_0 + \sum_{i=1}^{p}\delta_i \Delta \ln CO2_{St-i} \\ &+ \sum_{j=0}^{k}\delta_j \Delta \ln GDP_{St-j} + \sum_{f=0}^{f}\delta_f \ln GDP^2_{St-f} \\ &+ \sum_{s=0}^{b}\delta_s \Delta \ln ENC_{St-s} + \sum_{w=0}^{d}\delta_w \Delta \ln URB_{St-w} \\ &+ \sum_{x=0}^{q}\delta_x \Delta \ln OPN_{St-x} + \sum_{c=0}^{c}\delta_f \Delta \ln FIN_{St-f} + \Phi_t \end{aligned} \quad (10)$$

Next, the short-term coefficients were calculated by employing the error correction (ECM) in accordance with the ARDL model;

ARDL Short-run Estimation Model for Malaysia

$$\begin{aligned}\ln CO2_{M1} &= \alpha_0 + \sum_{i=1}^{p}\theta_i \Delta \ln CO2_{Mt-i} \\ &+ \sum_{j=0}^{k}\theta_j \Delta \ln GDP_{Mt-j} + \sum_{g=0}^{g}\theta_g \Delta \ln GDP^2_{Mt-g} \\ &+ \sum_{s=0}^{b}\theta_s \Delta \ln ENC_{Mt-s} + \sum_{w=0}^{d}\theta_w \Delta \ln URB_{Mt-w} \\ &+ \sum_{x=0}^{q}\theta_x \Delta \ln OPN_{Mt-x} + \sum_{f=0}^{c}\theta_f \Delta \ln FIN_{Mt-f} + \mu_t \end{aligned} \quad (11)$$

ARDL Short-run Estimation Model for Singapore

$$\begin{aligned}\ln CO2_{S1} &= \varphi_0 + \sum_{i=1}^{p}\delta_i \Delta \ln CO2_{St-i} \\ &+ \sum_{j=0}^{k}\delta_j \Delta \ln GDP_{St-j} + \sum_{f=0}^{f}\delta_f \ln GDP^2_{St-f} \\ &+ \sum_{s=0}^{b}\delta_s \Delta \ln ENC_{St-s} + \sum_{w=0}^{d}\delta_w \Delta \ln URB_{St-w} \\ &+ \sum_{x=0}^{q}\delta_x \Delta \ln OPN_{St-x} + \sum_{f=0}^{c}\delta_f \Delta \ln FIN_{St-f} + \Phi_t \end{aligned} \quad (12)$$

Referring to these equations, the notations ω and ϑ denote the error correction terms magnitude values for Malaysia and Singapore, respectively. These magnitudes measure the speed of adjustment of the system equation. In other words, they illustrate the time taken for short-run shocks to adjust from short-run disequilibrium to long-run equilibrium. The ECT_{Mt-1} and ECT_{St-1} denote the lagged error correction terms, for Malaysia and Singapore. These values should be significant and negative. To ensure the developed model is free from biased parameters and inefficiency that can lead to spurious hypothesis, the error terms (μ_t and Φ_t) must be normally distributed with constant mean of zero value and variance without autocorrelation, homoscedasticity or multicollinearity (Knaub 2007; Rambeli et al. 2019).

As mentioned earlier this study adopted the quarterly time series data from Q1:2010 to Q1:2020. The data used included CO2 emission, gross domestic product, total energy consumption, urbanization of the country population, trade openness and financial development. These were sourced from the World Bank data base. All data were converted into natural logarithm due to the differences in their units of measurement.

EMPIRICAL RESULTS

This section comprises in-depth discussion on related research findings obtained from empirical tests conducted in this study. The focal point of this study is to investigate the short-run and long-run relationship between selected macroeconomics variables and CO2 emissions in Malaysia and Singapore. The EKC hypothesis testing was adopted and the independent variables used included trade gross domestic product (GDP), GDP^2, openness (TO), total energy consumption (ENC), urbanization (URB), trade openness (OPN) and financial development (FIN). This study adopted the linear ARDL estimating approach. Additionally, it also employed the Augmented Dickey Fuller unit root. The study also implemented the ARDL bound co-integration test, the ARDL long-run model as well as the ARDL short-run model.

TABLE 1. The results for Augmented Dickey Fuller unit root tests

Data Series	Level Form			First Difference Form		
	Pure (None)	Without Trend	With Trend	Pure (None)	Without Trend	With Trend
CO2	0.038414(18) (0.6845)	-1.786963(9) (0.3814)	-0.666596(9) (0.9688)	-4.5841***(16) (0.0000)	-6.5173***(9) (0.0000)	-7.0554***(9) (0.0000)
GDP	2.124425(9) (0.9907)	-1.814816(9) (0.3682)	-0.250037(9) (0.9895)	-4.0003***(9) (0.0002)	-4.7252***(9) (0.0005)	-4.6781***(9) (0.0031)
GDP^2	2.11383 (9) (0.7893)	-1.73621(9) (0.4891)	-0.2377(9) (0.6279)	-5.2194***(12) (0.0000)	-4.4361 ***(11) (0.0053)	-5.8921***(10) (0.0021)
ENC	3.469000(17) (0.9997)	-0.596452(9) (0.8601)	-1.875738(9) (0.6483)	-3.2270***(17) (0.0019)	-5.2806***(9) (0.0001)	-5.2153***(9) (0.0007)
URB	0.172286(9) (0.7301)	-2.922746(3) (0.0523)	1.014934(9) (0.9998)	-4.2230***(18) (0.0002)	-5.8230***(18) (0.0001)	-6.3445***(3) (0.0000)
OPN	3.252082(1) (0.9995)	-0.711613(9) (0.8317)	-2.659012(9) (0.2581)	-5.2650***(16) (0.0000)	-6.3901***(9) (0.0000)	-6.3204***(9) (0.0000)
FIN	3.245113 (3) (0.7431)	-0.64261 (9) (0.7421)	-2.4771 (9) 0.3211	-4.4361***(12) (0.0000)	-6.5231***(9) (0.0000)	-6.2153***(9) (0.0000)

Note: *** significant at 99 percent.

The Augmented Dickey Fuller Unit Root Test

Before proceeding further it is important to test the presence of unit roots in the data. As mention by Karim et al. (2017), the data series under observation must not be integrated at the I(2) level. Hence, in order to identify the stationary level of the data series, this study conducted the unit root test proposed by Dickey and Fuller (1979). Table 1, presents the unit roots tests for all data series observed in the study. The table reported at both the level form and at first different form for each data. The results also covered all three types of Autoregressive (AR) model including none, i.e with drift without time trend, and with drift and time trend. The table shows that all series from the ADF tests are statistically not significant and the null hypothesis can be rejected for all level forms. The result also indicates that these series are non-stationary at level form. It however fails to reject the null hypothesis of unit roots in their level form in the autoregressive representation of each variable, since they are all not in the I(0) level. These variables thus either contain a unit root process or share a common stochastic component. At the first difference level, the null hypothesis of non-stationary is easily rejected at 99% significance level as shown in the Table 1. Hence the data series are in the I(1) level.

Optimum lag-length Selection

This study adopts the Akaike Selection Criteria (AIC) in order to select the optimum lag for the model development in this study. Table 2 simplifies the lag optimum proposed by AIC.

ARDL Bound Co-integration Test

Having incorporated the information from the lag-length test, the next testing procedure was the ARDL bound co-integration test. Table 2 provides results from the linear ARDL bound co-integration test. The computed F-statistic for Malaysia (9.3770) and Singapore (22.3194) were analyzed in terms of the lower and upper bounds of Narayan (2005). Based on these findings, it can be concluded that in both countries all the data series under observation are co-integrated in the long-term equilibrium. In other words, there exist long-term relationships between the variables which included CO2 emissions, gross domestic product, total energy consumption, urbanization, trade openness and financial development. These findings are supported by the values of F-statistic being greater than the 1% upper bound critical values, namely 9.3770 and 22.3194 for Malaysia and Singapore, respectively.

TABLE 2. The selection of optimum lag-length by AIC

Lag Length	Akaike Information Criterion (AIC)
2	-25.16436
3	-25.46207
4	-25.14869
5	-25.83776*

ARDL Long-run Model

Once the system equations were proven to be co-integrated in the long-run, the system equation of ARDL long-term model could be generated from equations (9) and (10) for Malaysia and Singapore, respectively. Table 4 presents the ARDL long-run coefficients for the two countries. This result is based on the magnitude values and outcome of diagnostic test. For Malaysia, the ARDL long-run equations revealed that, the total energy consumption had a positive significant impact on CO2 emissions in the long-run. In other words, an increase of 1.0000% in total energy consumption raises the CO2 emissions by 0.1529%. Meanwhile, urbanization has been discovered to exert significantly and positively impacts on CO2 emissions. If urbanization increases by 1.0000%, CO2 emission will be raised by 0.4064%. An increase in trade openness leads to positive and significant impact on CO2 emission in Malaysia. If its value increases by 1.0000%, it will raise CO2 emissions by 2.3099%. Conversely, financial development exerts negative and non-significant impact on CO2 emissions in Malaysia. In other words, if financial development increases by 1.0000%, it would cause CO2 emissions to decrease by 0.3561%. In addition, CO2 emissions react positively and significantly on the GDP. In this case, a GDP increase by 1.0000%, will raise CO2 emission by 0.7366%. The analysis also verifies the EKC hypothesis which held true under this study. The argument is supported by the value of GDP^2 being less than 0, which indicates that the EKC hypothesis is valid in the long-term $(\theta_j < 0)$ and $(\theta_g > 0)$ for Malaysia. This finding also indirectly validates the U-shaped relationship of the EKC hypothesis in the case for Malaysia.

TABLE 3. Results of ARDL Bound Co-integration Test

Test statistic	Value	Significance level	Bound critical values	
			I(0)	(1)
Malaysia F-statistics	9.3770***	1.0%	2.5	3.68
		2.5%	2.24	3.35
		5.0%	2.04	2.08
		10.0%	1.8	2.8
Singapore F-statistics	22.3194***	1.0%	2.5	3.68
		2.5%	2.24	3.35
		5.0%	2.04	2.08
		10.0%	1.8	2.8

TABLE 4. ARDL long-run estimation results

Variables	Malaysia		Singapore	
	Coefficient	t-Statistic	Coefficient	t-Statistic
C	-5.1222	-1.1233	-14.7918	-1.0445
$lnGDP_t$	0.7366	3.8631***	0.3569	2.7806***
$lnGDP^2_t$	-0.5241	-3.2118**	-0.7312	-4.2511***
$lnENC_t$	0.1529	2.2144**	0.2843	3.7808***
$lnURB_t$	0.4064	1.9772*	-1.0347	-1.8528*
$lnOPN_t$	2.3099	3.0926**	-1.0553	-2.8903***
$lnFIN_t$	-0.3561	-0.6311	-0.2770	-0.5439
R-squared	0.9965		0.9773	
Adjusted R-squared	0.9958		0.9721	
F-statistic	1529.5		187.48	
Probability (F-statistic)	0.0000		0.0000	
Durbin-Watson	2.0904		1.9352	
BG-LM	1.7341 (0.3276)		1.6743 (0.1297)	
ARCH	3.2221 (0.042)		2.7862 (0.055)	
Jarque-Bera	0.3561 (0.7410)		0.7655 (0.3312)	
Ramsey-RESET	0.6723 (0.2141)		0.8651 (0.3871)	

Source: Author's estimation model using software package Eviews 9.
Note: All variables in each data set denoted by Δ are in first differences. The asterisks (***), (**), and (*) specify the significant level at 1%, 5%, and 10%.

According to Table 4, in the case of the long-run model for Singapore, the impact of total energy consumption on CO2 emissions is significantly positive. Statistically, if the total energy consumption increases by 1.0000%, then the CO2 emissions will increase by 0.2843%. Conversely, Urbanisation, trade openness and financial development influence the CO2 emissions negatively. For instance, if urbanisation rises by 1.0000%, CO2 emissions will reduce by 1.0347% at 1% significance level. Further, CO2 emissions respond positively and significantly to GDP in Singapore. Thus, a GDP increases by 1.0000%, will lead to rise in CO2 emissions by 0.3569%. In this study the EKC hypothesis also holds true for Singapore. When the GDP^2 is less than 0 the EKC hypothesis is sustained in the long-term ($\delta_j < 0$) and ($\delta_f < 0$). This finding indirectly supports the U-shaped relationship of the EKC hypothesis in Singapore.

ARDL Short-run Model

Table 5 presents the short-run coefficients based on ARDL model. In the case of Malaysia total energy consumption positively and significantly impacts CO2 emissions in the short-run. A 1.0000% increase in the total energy consumption will elevate CO2 emissions by 0.4702%. Similar relationships consistently occur for urbanisation and trade openness, with both exerting positive impacts on CO2 emissions. In other words, if urbanisation and trade openness increase, CO2 emissions will accordingly increase. Conversely however, financial development exerts significantly negative impact on CO2 emissions in Malaysia. If financial development increases by 1.0000%, CO2 emissions will reduce by 1.2614%. The GDP also significantly affect CO2 emissions in the short-term. The estimation model also confirms that the EKC hypothesis holds valid in the short-run model for Malaysia. In the case of Singapore the study confirms that total energy consumption exerts positive and non-significant influence on CO2 emissions. If the total energy consumption increases by 1.0000%, CO2 emissions will duly rise by 0.0310%. The results further shows that urbanization will impact negatively and significantly on CO2 emissions. In other words, if urbanization in Singapore increases by 1.0000%, the CO2 emissions will reduce by 3.5794%. Additionally, trade openness and financial development also impact on CO2 emissions positively and negatively. These two variables are thus important in explaining CO2 emissions in the short-run. Similarly, the GDP also significantly impacts CO2 emissions in the short-run. The study also confirms that the EKC hypothesis is valid in the case for Singapore.

The values of R^2 and adjusted R^2 were estimated to be more than 90%, which confirm that the estimated models

TABLE 5. ARDL short-run estimation results

Variables	Malaysia		Singapore	
	Coefficient	t-Statistic	Coefficient	t-Statistic
C	0.0045	0.7040	0.0076	0.8120
ΔGDP_t	0.4040	3.9686***	1.4689	8.2890***
ΔGDP^2_t	-0.1318	-2.0038**	-0.9889	-4.8676***
ΔENC_t	0.4702	2.4101**	0.0310	0.0514
ΔURB_t	5.7771	5.9412***	-3.5794	4.3019***
ΔOPN_t	0.1423	2.0140**	2.0089	4.6641***
ΔFIN_t	-1.2614	-6.3305***	-0.3768	-1.3594
ECT(-1)	-0.1203	-3.0572***	-0.0476	-3.2975***
R-squared	0.9685		0.9714	
Adjusted R-squared	0.9487		0.9493	
F-statistic	48.9592		44.0089	
Probability (F-statistic)	0.0000		0.0000	
Durbin-Watson	2.3526		2.3853	
BG-LM	2.6514 (0.2532)		1.7852 (0.3475)	
ARCH	3.0421 (0.012)		3.225(0.042)	
Jarque-Bera	0.4751(0.8352)		0.8541 (0.5955)	
Ramsey-RESET	0.7865 (0.4790)		0.7120 (0.5344)	

Note: All variables in each data set denoted by Δ are in first differences form. The asterisks (***), (**), and (*) specify the significance level at 1%, 5%, and 10% respectively.

for both countries are strongly fitted. The calculated values for F-statistic were 48.9592 and 44.0089 for Malaysia and Singapore, respectively. Further, the significant negative error correction term coefficient is also presented in Table 5. The results suggest that the error correction term (ECT_{t-1}) for Malaysia and Singapore are respectively -0.1203 and -0.0476 thus implying the respective speeds of adjustment to be 12.03% and 4.76%. It is implied that the inconsistencies between shocks and trend were corrected within more than a year. In Table 4 the diagnostic analyses of the estimated model are presented. According to all diagnostic tests, the study confirms that the ARDL model has passed all the analyses successfully.

DISCUSSIONS AND IMPLICATIONS

Results of the empirical analysis presented in the previous section has confirmed the validation of the EKC hypothesis for Malaysia and Singapore. By adopting the time series ARDL model, the study also confirms that the EKC hypothesis holds true in the short- and long-run for the estimated modelling. This finding is, among others, consistent with previous findings, including those of Ridzuan et al. (2020), Munir et al. (2019), Ali et al (2017), Ab-Rahim and Xin-Di (2016). Specifically, this study also revealed the significant role played by total energy consumption in Malaysia and Singapore. The outcome is supported by most of the past studies including Bekhet (2013), Kasman et al. (2015), Rambeli et al. (2018) and Rambeli et al. (2019). Most of these findings agreed that energy consumption impacted on CO2 emissions in both long- and short-run. They are consistent with the idea that, an increase in energy consumption will directly elevate CO2 emissions. Since the CO2 emission is known as a negative externality relative to domestic economic activity, in order to reduce its harmful impact on the environment planning is necessary to address its cross-border effect. By implication, the relevant authorities like the government and NGOs should suggest for stricter, more efficient and effective energy protection policies to be implemented in order to reduce CO2 emissions in both countries in the long- and short-term. These protection policies should be comprehensive and complied to by all levels of society including individuals and industries. At the international level, as proposed by Rambeli et al. (2017), the cap and trade mechanism within and between countries should be employed. According to the mechanism suggested, air pollution across the international border, as between Malaysia and Singapore, can be traded. Following this mechanism, at the early stage of development, each country is allowed to pollute at a certain level of gaseous air pollution. At a subsequent stage 2, if the level of emissions exceeds some allowed pollution level, the excess air pollution has to be paid for by the polluting country or alternatively taxed. With such international protection policies in place both countries will be able to reduce the cost in maintaining and controlling environmental pollution.

Additionally, this study also succeeds in documenting the role of urbanization in affecting CO2 emission for Malaysia and Singapore, in the long- and short-terms. Referring to the outcomes, results between Malaysia and Singapore are completely different. In Malaysia, urbanisation effected positive and significant impact on CO2 emissions, in the long- and short-terms. The results are also consistent with findings of Ab-Rahim and Xin-Di (2016) who suggested that a continuous growth in urbanization leads to the increase in resources and energy consumption and as a consequent, results in greater pollution. However, the impact of urbanization on CO2 emissions differ with countries which follow rigorous environmental policies (Ponce de Leon Barido & Marshall 2014). For example, Singapore shows negative and significant impact of urbanisation on CO2 emissions. As a developed nation in ASEAN, the country has less concern on pollution since it has in place stringent environmental protection measures. As such, the relationship between urbanization and CO2 emissions is negative in the long and short-term in Singapore. This finding is also supported by Martinez-Zarzoso and Maruotti (2011).

The study also documented positively significant relationship between trade openness and CO2 emissions for Malaysia in the long- and short-run. This finding is consistent with Rahman and Porna (2014) and Ab-Rahim and Xin-Di (2016). The situation is however quite different in Singapore. While the relationship is negative in the long-run, it proved positive in the short-run. A negative long-run relationship is consistent in developed countries especially those in the European Union (Iwata et al. 2012; Ho & Iyke 2019). However, a positive short-run relationship shows indirect impact of energy consumption through the rise in trade openness. Energy consumption in the short-term will automatically rise when trade openness increases, since goods need to be transported between countries. The rise in energy consumption also leads to productivity elevation and similarly so with CO2 emissions (Ab-Rahim & Xin-Di 2016). Empirical studies also suggest negative significant outcome between financial development and CO2 emissions in Malaysia and Singapore which is consistent in the long- and short- run. The result also conforms with Manta et al. (2020) who observed that a country that cares of a clean environment will always strive to spend towards the reduction of CO2 emissions gases. This consistency will eventually lead the country to achieve pollution-free status in the long-run.

This study also successfully documented the U-shaped relationship of the EKC hypothesis for both Malaysia and Singapore in the long-term. The findings concur with those of previous studies including Fodha and Zaghdoud (2010), Ridzuan et al. (2020) and Cosmas et al. (2019). However, they contradict those of Azlina et al. (2014) in the case of Malaysia and of Dogan and Ozturk (2017) for the USA. For Malaysia and Singapore in the long-term, economic growth proves to be the ultimate remedy to the environmental problem.

CONCLUSIONS

This study examined the determinants of CO2 emissions by utilising the linear ARDL model. Its specific aims were to investigate the role of selected macroeconomic variables, namely gross domestic product, total energy consumption, urbanisation, trade openness and financial development. The quarterly time series data were used spanning from Q1:2010 to Q1:2020. Through using the linear ARDL model, it was established that the EKC hypothesis was supported in both Malaysia and Singapore. Most of the variables investigated in the study produced results as anticipated. The study also validated the role played by trade openness and financial development in relation to CO2 emissions in the two countries. Even though Malaysia and Singapore are trading partners in ASEAN and share a common international border, some of the results obtained were however not parallel. In Malaysia trade openness was shown to raise the level of CO2 emissions. Conversely in Singapore, the impact was rather mixed. CO2 emissions were reduced in the long-run, but in the short-run trade openness led to greater emissions. Additionally, financial development reacts as a protector in both countries. It can thus be concluded that financial policy plays a crucial role in improving environmental pollution in the long-term (Yusoff & Darus 2012). Although most of the other variables displayed favourable impacts on CO2 emissions financial development is seen as the main catalyst in fostering a sustainable environment in the future.

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