The Determinants of CO_2 Emissions in ASEAN+3 Countries

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Abstract - This study investigates the determinants of carbon dioxide emissions in ASEAN+3 countries (Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam, China, Japan and South Korea) during the period of 1991 to 2010. The methodologies employed in this study include the Im, Pesaran, and Shin Panel Unit Root test, the Pedroni (Engle-Granger based) Cointegration Test, and the Granger-Causality based on the Vector Error Correction Model (VECM). Results from the panel unit root test show that all the variables are integrated of order one, I (1). For the cointegration test, the results indicate that there is a long relationship between carbon dioxide emissions, energy consumption, economic growth, urbanisation, trade openness, and transportation. The empirical results show that economic growth, energy consumption, and trade openness are the determinants of CO_2 emissions in ASEAN+3.

Keywords: CO_2 emission, Environmental Kuznets curve, ASEAN+3.

1. Introduction

Climate change has been the concern of researchers and policy makers and it is closely related to the long-term rise in sea levels, higher frequency of tropical storms, and the alarming rate of cardiovascular and respiratory diseases (Stocker et al., 2009). The global climate change is also expected to increase the vector-borne diseases incidences, especially malaria and dengue in Southeast Asia and Latin America (Centres for Disease Control and Prevention, 2014). The increase in the global temperature due to the increase in greenhouse gases emissions particularly carbon dioxide concentrations has become a major threat of global warming. The main causes of human-induced global warming are fossil fuels combustion and other smaller industrial sources (Oliver, Janssens-Maenhout, Munteen, and Peters, 2013). The rising concern over climate change has triggered a stream of research on the nexus between air pollution and economic growth, which can be categorised into three strands. Various studies focus on examining the validity of the environmental Kuznets curve (EKC) hypothesis such as Managi and Jena (2008), Stern (2004), as well Martínez-Zarzoso and Bengochea-Marancho (2004). On this note, past studies have also investigated the economic growth energy consumption nexus (Tang and Tan, 2013; Fallahi, 2011), and studies by Soytas and Sari (2009), Ang (2007), and Lean and Smyth (2010) have investigated the dynamic relationship between economic growth, energy consumption, and

pollution emissions.

Environmental degradation is caused by several key factors such as energy consumption, electricity consumption, economic growth, urbanization, trade openness, and transportation (Friedl and Getzner, 2003; Iwata, Okada and Samreth, 2010; Sharma, 2011).[1] Energy consumption has increased substantially due to the continuous growth in urbanization and industrialization in Association of Southeast Asian Nations (ASEAN) countries. ASEAN Centre for Energy (ACE) forecasted an increase of 4.4 percent (%) in final energy consumption among ASEAN countries in 2030, which is higher than the world's average growth of energy demand at 1.4%.

Past studies have tended to investigate the relationship between economic growth, energy consumption, and pollution emissions. Studies by Ang (2008), Zhang and Cheng (2009), and Vidyarthi (2013) suggest that carbon emissions and energy consumption are positively related to economic development in the short and long run. It is further supported by Al-Mulali and Che Sab (2013) with respect to the link between carbon emissions and economic development as well as total primary energy consumption and economic development nexus. It is noteworthy that all the above-mentioned studies do not estimate the determinants of environmental degradation. On this note, a substantial analysis of carbon dioxide emissions in ASEAN Plus Three (ASEAN+3) member countries appears to be limited. Several studies have focused on estimating the environmental degradation, the energy consumption, and the economic growth in ASEAN countries. Karki, Mann, and Salehfar (2005) and Tay, Rahman, and Labadin (2012) examined the interrelationship between CO_2 emissions and the influential factors in ASEAN countries while Borhan, Ahmed, and Hitam (2012) only focused on ASEAN 8. Lastly, Saboori and Sulaiman (2013), and Chandran and Tang (2013) assessed the impact of energy consumption, foreign direct investment, and CO_2 emissions of ASEAN-5 economies. Hence, this study attempts to fill the gap in the literature by investigating the contribution of climate change, in particular, CO_2 emissions, among ASEAN+3 countries.

According to Japan's Ministry of Economy, Trade, and Industry (2013), the sluggish growth in Japan has been absorbed by the expansion of China, Korea, and ASEAN and this has increased the share of ASEAN+3 in the global GDP. The ASEAN+3 countries' share in the global GDP overtook United State of America (US) by 2.05% and the European Union countries (EU) by 1.49% in 2012. In fact, it is forecasted that the ASEAN+3 share of global GDP would increase by 27% by 2018. The ASEAN Plus Three (APT) was institutionalised in a joint statement on East Asia Cooperation at the Third ASEAN+3 Summit in Manila, in 1999 (Association of Southeast Asian Nation, 2014). Thereafter, the APT Cooperation Work Plan 2013-2017 was adopted at the 14th APT Foreign Ministers' Meeting on 30 June 2013. One of the outline of the APT Work Plans is to strengthen the cooperation in environment and sustainable development and to address the impact of climate change. The rest of this article is organised as follows. The next section provides a discussion on previous studies follows by the methodology section. The subsequent section presents the empirical results and the paper ends with the conclusion in the last section.

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[1] There are other determinants of CO_2 emissions such as cold climate, hot climate, and availability of renewable energy sources (Neumayer, 2004). However, this study only focuses on energy consumption, electricity consumption, economic growth, urbanization, trade openness and transportation.

2. Literature Review

Economic growth hampers the income equality between the rich and poor people in the least developed countries and it narrows the income disparity gap in wealthier countries (Kuznets, 1955). Grossman and Krueger (1991) incorporated the levels of environmental quality in the relationship with economic growth and the environmental Kuznets curve (EKC) was further improved by Panayotou (1993). Shafik and Bandyopadhyay (1992), and Grossman and Krueger (1995) postulated an inverted U-shaped relationship between income and environmental pollution. An inverted U-shaped relationship between economic growth and environmental degradation refers to the worsening of pollution levels at the initial point and subsequently, it improves after some threshold income point.

The majority of past studies on the nexus between economic growth and environmental degradation are centered on the validity of the EKC. At very low levels of economic growth, low levels of pollution are emitted because people tend to rely primarily on subsistence activity that has little impact on the environment (Stern, 2004). As the countries become industrialized, they tend to use dirtier or cheaper technologies, which emit large amounts of pollution. Initially, the amount of CO_2 emitted increases rapidly as poor countries develop. When a certain level of economic growth is reached, people start to value the environment more and choose to use affordable, cleaner, and effective technologies. Past studies have examined the dynamic relationship between output, CO_2 emissions, and energy consumption; the results indicate that CO_2 emissions are positively related to output (Ang, 2008; and Du, Wei, and Cai, 2012). In addition, Puzon (2012) and Friedl and Getzner (2003) confirm the validity of the EKC relationship in 8 East Asian countries and Austria, respectively. The above-mentioned studies postulate that apart from gross domestic products (GDP) per capita as the determinant for per capita CO_2 emissions, there are other determinants such as energy consumption, urbanization, trade openness, and transportation.

2.1 Energy Consumption

Recent studies by Ang (2008), Hossain (2011), Sharma (2011), and Leitão and Shahbaz (2013) confirm that energy consumption has a positive impact on carbon dioxide emissions as the energy is used in the production processes, which involve the burning of fossil fuels. Moreover, energy consumption is also related to economic growth since higher economic development demands higher energy consumption. Earlier studies by Kraft and Kraft (1978) found unidirectional causality running from GNP to energy consumption for the US; nevertheless, Yu and Hwang (1984) ruled it out in the US context. Hossain (2011) examined the dynamic causal relationship between CO_2 emissions, energy consumption, economic growth, trade openness, and urbanization for newly industrialized countries (NICs) and the findings show that NICs' high energy use has led to higher CO_2 emissions. Other studies confirm the positive nexus between the energy consumption in high income, middle income, and low-income panel of 69 countries (Sharma, 2011), Organization for Economic Cooperation and Development (OECD) countries as well as ASEAN countries (Iwata, Okada and Samreth, 2010).

2.2 Urbanization

Continuous growth in urbanization leads to the increase in resources and energy consumption and consequently, to greater pollution; however, the impacts of urbanization

on CO_2 emissions are less severe in countries with stringent environmental policies (Ponce de Leon Barido and Marshall, 2014). It is supported by Chikaraishi et al. (2014) whereby in countries where the GDP per capita and the percentage share of service industries with respect to GDP are sufficiently high, the urbanization progress has resulted in more environmentally friendly countries as postulated by the ecological modernization theory. Based on the three categories of income levels, Martínez-Zarzoso and Maruotti (2011) suggested the emission-urbanization elasticity is more elastic in the low-income country; on the contrary, the elasticity is negative in the context of the upper-income countries. Other studies such as Hossain (2012) discovered urbanization has a positive impact on CO_2 emissions in Japan while Sharma (2011) confirmed the significance of urbanization as one of the determinants of CO_2 emissions across 69 countries. It is further supported by Leitão and Shahbaz (2013) that urbanization improved the quality of the environment by lowering CO_2 emissions in eighteen countries (Australia, Belgium, Brazil, Canada, China, Denmark, France, Germany, Netherlands, Spain, Portugal, Japan, Korea, Thailand, Italy, United Kingdom, US, and Russia).

2.3 Trade Openness

Energy consumption rises with the development of trade openness, as goods need to be transported from one country to another. The Heckscher and Ohlin model postulate that free trade encourages specialization in production using the countries' abundant and cheap factors of production and export. The theory of comparative advantage by the great Ricardo predicts patterns of commerce and production based on the technological progress or factor endowments of a trading region. Past studies show that there is a long-term equilibrium relationship between trade liberalization and carbon dioxide emissions in China (Gu, Gao, & Li, 2013) and Bangladesh (Rahman, 2013). However, Iwata, Okada, and Samreth (2010) argue that the impact of trade is not statistically significant in eleven OECD countries except for Belgium and Switzerland. In addition, Hossain (2012) states a negative relationship between trade openness and CO_2 emissions in Japan while Naranpanawa (2011) finds that there is neither a long run equilibrium relationship nor a long-term causality between CO_2 emissions and trade openness in Sri Lanka.

2.4 Transportation

As the major user of energy, transportation utilizes a bulk share of the world's petroleum. Neumayer (2004) suggested that big countries have higher transportation requirements as goods and people are typically moved over longer distances; thus, the total length of the road network, both paved and unpaved, is used as an alternative proxy variable. Benestad (1994) proposed an 'equal burden' formula for CO_2 emissions based on Rawl's (1971) theory of justice. Lin (2010) applied a bottom-up approach to determine the amount of CO_2 emissions and found that transport (private car) accounts for the most CO_2 emissions in the tourism industry in Taiwan's national parks.

3. Research Methodology

3.1 Data

Annual data for CO_2 emissions (metric tons per capita), trade (% of GDP), urban population (% of total), the length of the road network (km), and GDP per capita (constant

2005 US$) over the period of 1991 to 2010 were obtained from the World Development Indicators (WDI) published by World Bank. Data for total electricity net consumption (billion kWh) and total primary energy consumption per capita (million Btu) were obtained from the Energy Information Administration (EIA). The ASEAN+3 countries consist of Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, Philippine, Singapore, Thailand, Vietnam, Japan, People's Republic of China, and South Korea. The relationship between the carbon dioxide (CO_2) emissions and its explanatory variables, which are energy consumption, economic growth, urbanisation, trade openness, and transportation are expressed in Equation 1:

$$CO2_{it} = \beta_0 + \beta_1 ENE_{it} + \beta_2 ELE_{it} + \beta_3 GDP_{it} + \beta_4 URB_{it} + \beta_5 TOP_{it} + \beta_6 TRA_{it} \tag{1}$$

where *i* represents country (ASEAN+3 countries); *t* represents time (1991 - 2010); $CO2_{it}$ represents carbon dioxide emissions (metric tons per capita); ENE_{it} represents total primary energy consumption per capita (million Btu per person); ELE_{it} represents total electricity net consumption (billion kWh); GDP_{it} represents GDP per capita (constant 2005 US$); URB_{it} represents urban population (% of total); TOP_{it} represents trade (% of GDP); and TRA_{it} represents length of road network (km).

3.2 Methodology

This study conducted a few tests such as the panel unit root test to examine whether the variables contain a panel unit root; the Pedroni (Engle-Granger based) cointegration test to explore long-term relationship; and the Granger-causality based on the vector error correction (VECM) to measure the short and long run causal relationships between the variables.

Panel Unit Root Test

The Im, Pesaran, and Shin test was applied in this study as it allows individual unit root processes. This test is basically characterised by a combination of individual unit root tests to derive a panel specific result. It specifies a separate ADF regression for each cross section as in Equation 2:

$$\Delta y_{it} = \alpha y_{it-1} + \sum_{j=1}^{p_i} \beta_{ij} \Delta y_{it-j} + X'_{it} \delta + \varepsilon_{it} \tag{2}$$

where *y* is the dependent variable, *X* is the independent variable, α and δ are individual entity and time effect, respectively, *t* is time, *I* is the cross section, and ε is the residual. The null hypothesis can be written as:

$$H_0: \alpha_i = 0 \text{ for all } i \tag{3}$$

while the alternative hypothesis is given by:

$$H_1: \begin{cases} \alpha_i = 0 & \text{for } i = 1, 2, \dots, N_1 \\ \alpha_i < 0 & \text{for } i = N + 1, N + 2, \dots, N \end{cases} \tag{4}$$

where *i* may be reordered as necessary. This may be interpreted as a non-zero fraction of the individual processes that are stationary. After estimating the separate ADF regressions, the average of the t-statistics for α_i from the individual ADF regression $t_{iT_i}(p_i)$:

$$\overline{t_{NT}} = \left(\sum_{i=1}^{N} t_{iT_i}(p_i)\right)/N \tag{5}$$

is then adjusted to arrive at the desired test statistics in the case where the lag order is always zero ($p_i = 0$ for all *i*). In the general case where the lag order in Equation (2) may be non-zero for some cross-sections, a properly standardised $\overline{t_{NT}}$ has an asymptotic standard normal distribution:

$$W_{\overline{t_{NT}}} = \frac{\sqrt{N}(\overline{t_{NT}} - N^{-1}\sum_{i=1}^{N} E(\overline{t_{iT}}(p_i)))}{\sqrt{N^{-1}\sum_{i=1}^{N} Var(\overline{t_{iT}}(p_i))}} \to N(0,1) \tag{6}$$

The expressions for the expected mean and variance of the ADF regression t-statistics, $E(\overline{t_{iT}}(p_i))$ and $Var(\overline{t_{iT}}(p_i))$, are provided by Im, Pesaran, and Shin (2003) for various values of *T* and *p* and differing test equation assumptions.

Pedroni Cointegration Test

If the variables contain a panel unit root, the Pedroni test is applied to examine the long-run relationship between the variables. Pedroni (1999) proposed several tests for cointegration that allow for heterogeneous intercepts and trend coefficients across cross-sections. Consider the following regression:

$$y_{it} = \alpha_i + \delta_i t + \beta_{1i} x_{1i,t} + \beta_{2i} x_{2i,t} + \cdots + \beta_{Mi} x_{Mi,t} + e_{i,t} \tag{7}$$

where $t = 1, \dots, T$; $i = 1, \dots, N$; $m = 1, \dots, M$; and *y* and *x* are assumed to be integrated of order one, I(1). The parameters α_i and δ_i are individual and trend effects which may be set to zero if desired, *M* is the number of regresses, *t* is the number of observations, and β_1, β_2, and β_K are slope coefficients. Under the null hypothesis of no cointegration, the residuals $e_{i,t}$ will be I(1). The general approach is to obtain residuals from Equation 7 and then to test whether residuals are I(1) by running the auxiliary regression:

$$e_{it} = \rho_i e_{it-1} + u_{it} \tag{8}$$

or $\quad e_{it} = \rho_i e_{it-1} + \sum_{j=1}^{\rho_i} \psi_{ij} \Delta e_{it-j} + v_{it} \tag{9}$

for each cross-section. Pedroni (1999, 2004) describes various methods of constructing statistics for testing the null hypothesis of no cointegration ($\rho_i = 1$). There are two alternative hypotheses: the homogenous alternative, ($\rho_i = \rho$) < 1 for all *i* (which Pedroni terms the within-dimension test or panel statistics test), and the heterogeneous alternative, $\rho_i < 1$ for all *i* (also referred to as the between-dimension or group statistics test). The Pedroni panel cointegration statistic $\aleph_{N,T}$ is constructed from the residuals from Equation 8 or Equations 9. A total of eleven statistics with varying degrees of properties (size and power for different *N* and *T*) are generated. Pedroni shows that the standardized statistic is asymptotically normally distributed,

$$\frac{\aleph_{N,T} - \mu\sqrt{N}}{\sqrt{v}} \Rightarrow N(0,1) \tag{10}$$

where μ and *v* are Monte Carlo generated adjustment terms.

Granger-Causality based on the Vector Error Correction Model (VECM)

Engle and Granger show that non-stationary variables are cointegrated in the model. Therefore, the vector error-correction model is used to investigate the temporal short-run causality between the variables. Short-run Granger causality, which is based on the F-test and χ2-test, can be established by conducting a joint test of the coefficients. On the other hand, the long-run causal relationship is applied through the significance of the lagged error correction term in the VECM, based on the *t*-test. The Granger causality model with uniform lag length is introduced by the following equation:

$$\Delta DEP_{it} = \alpha_{it} + \beta_{it} ect_{it-1} + \sum_{i=1}^{l} \xi_{it} \Delta DEP_{it-1} + \sum_{i=1}^{l} \varphi_{it} \Delta \log (INDP)_{it-1} + \mu_{it} \quad (11)$$

where *DEP* is the dependent variable, *INDP* is the independent variable, Δ is the first difference operator, α_{it} is the constant term, β_{it}, ξ_{it} and φ_{it} are the parameters, ect_{it-1} is the lagged error correction term obtained from the cointegrating equation, and μ_{it} is the white noise error.

4. Data Analysis

The variables that have been used in this study include carbon dioxide emissions (CO2), economic growth (GDP), total primary energy consumption (ENE), total electricity net consumption (ELE), urbanization (URB), trade openness (TOP), and transportation (TRA).

Table 1: Empirical Results of Pedroni (Engle-Granger based) Cointegration Test

	Statistic	Weighted Statistic
Individual intercept		
Panel v-statistic	-2.543(0.995)	-3.183(0.999)
Panel ρ-statistic	3.032(0.999)	3.322(0.999)
Panel PP-statistic	-5.129(0.000)*	-8.149(0.000)*
Panel ADF-statistic	-4.818(0.000)*	-5.568(0.000)*
Group ρ-statistic	4.596(1.000)	
Group PP-statistic	-12.094(0.000)*	
Group ADF-statistic	-6.462(0.000)*	
Individual intercept and individual trend		
Panel v-statistic	-1.354(0.912)	-3.661(0.999)
Panel ρ-statistic	4.179(1.000)	4.156(1.000)
Panel PP-statistic	-7.125(0.000)*	-8.295(0.000)*
Panel ADF-statistic	-5.143(0.000)*	-4.938(0.000)*
Group ρ-statistic	5.079(1.000)	
Group PP-statistic	-15.084(0.000)*	
Group ADF-statistic	-6.655(0.000)*	
No intercept or trend		
Panel v-statistic	-191.978(1.000)	-3.035(0.998)
Panel ρ-statistic	2.857(0.998)	2.343(0.990)
Panel PP-statistic	-2.630(0.004)*	-4.456(0.000)*
Panel ADF-statistic	-2.541(0.005)*	-4.367(0.000)*
Group ρ-statistic	4.113(1.000)	
Group PP-statistic	-6.246(0.000)*	
Group ADF-statistic	-4.732(0.000)*	

Notes: * denotes the significance at 1 percent level. Figures in parentheses are the *p*-value. The automatic selection based on the Schwarz is used to choose the optimal lag length.

The results of unit root test show that all panel variables (CO₂ emissions, energy

consumption, economic growth, trade openness, and urbanization) are integrated of order 1 using four different panel unit root tests (Levin, Lin, and Chu; Im, Pesaran, and Shin; Maddala and Wu; and Choi). Next, the presence of cointegration in the model is decided by the significance of the Pedroni panel cointegration statistics. These are the panel v-statistic, panel ρ-statistic, panel PP-statistic, panel ADF-statistic, group ρ-statistic, group PP-statistic, and group ADF-statistic. The results in Table 1 show that six out of eleven test statistics are significant for every deterministic trend specification, so the null hypothesis that the series are not cointegrated can be rejected at 1 percent significance level. There is a long run relationship between carbon dioxide emissions, energy consumption, economic growth, urbanization, trade openness, and transportation, consistent with Hossain (2011; 2012). Besides, Hossain (2012) also indicated that CO_2 emissions, energy consumption, economic growth, foreign trade, and urbanization are cointegrated in Japan for the period of 1960 to 2009. Naranpanawa (2011) added that there is a cointegrating vector among the variables, capital stock, trade openness, CO_2 emissions, and GDP.

Next, Table 2 presents the results of the short and long run causal relationship as well as the causality effects between the variables using Granger-causality to study the dynamic relationship between the variables.

Table 2: Results of Granger Causality Test

Variable	ΔLCO_2	$\Delta LENE$	$\Delta LELE$	$\Delta LGDP$	$\Delta LURB$	$\Delta LTOP$	ΔTRA	ECT
$\Delta LCO2$	-	16.941*	0.802	12.579*	1.474	10.477*	1.497	0.157*
$\Delta LENE$	6.594*	-	2.448	12.190*	4.943	9.806*	3.735	-0.010
$\Delta LELE$	0.994	0.228	-	4.131	7.630**	0.346	1.209	-0.008
$\Delta LGDP$	0.074	0.253	7.823**	-	8.463**	4.555	5.249	-0.058*
$\Delta LURB$	0.338	0.221	0.303	1,115	-	3.390	0.282	0.000
$\Delta LTOP$	0.270	2.646	3.507	9.951*	0.760	-	0.973	0.011
ΔTRA	4.538	4.332	4.158	0.146	2.103	0.019	-	-0.016

Note: CO_2- carbon dioxide emissions (CO2); GDP - economic growth; ENE - total primary energy consumption; ELE - net consumption of total electricity; URB – urbanisation; TOP - trade openness; and TRA - transportation. The χ^2-statistic tests the joint significance of the lagged values of the independent variables and the significance of the error correction term(s) while Δ is the first different operator.
* denotes significance at 1 percent level; and ** denotes the significance at 5 percent level.

Table 2 shows the results of the Granger-Causality test in a VECM framework and Error Correction Term (ECT). Based on the table, the results show that there is only one bi-directional relationship between LENE and LCO_2; thus, energy consumption can influence the increase in CO_2 emissions and vice versa. Ang (2008) and Shahbaz (2013) also found that energy consumption has a positive impact on CO_2 emissions. Next, LGDP is found to have a unidirectional causality with LCO_2, LENE, and LTOP; the findings imply that further economic development can increase CO_2emissions, energy consumption, and trade openness. It is supported by Chang (2010), who claimed that high economic growth increases both energy consumption and CO_2 emissions in the short and the long run in China. The third factor, namely transportation has unidirectional causal relationships with LENE and LCO_2; thus, increases in trade openness will result in the increase of energy consumption and CO_2 emissions. This finding is consistent with the Hecksher-Ohlin trade theory that trade can lead to greater consumption and production of goods and services and eventually greater pollution. Besides, there is also a unidirectional causality from LURB to LELE and LGDP. The results indicate that the fourth factor, i.e. urban population results in positive electricity consumption and economic growth. According to Li and Yao (2009), the big volume and high speed of building construction can cause large pressure on resources and the environment. If one observes further, the causal relationship is also

present from LELE to LGDP; thus, consuming more electricity can lead to further economic development. Nevertheless, there is no short-run relationship between LTRA and any of the other variables.

From the ECT column in Table 2, the coefficient of the error-correction term (ECT) takes a negative sign when LENE, LELE, LGDP, and LTRA are the dependent variables, respectively. However, ECT for LGDP (-0.058) is the only one that possesses all the 3 conditions of ECT, which has the coefficient of less than one, negative, and significant at the 5 percent level. This implies that there is a long-run relationship among the variables and that LGDP solely bears the brunt of the short-run adjustment to bring about the long-run equilibrium in ASEAN+3. The ECT coefficient measures the speed of adjustment towards the long-run equilibrium. The coefficient of ECT corresponds to the speed of adjustment, which is 5.8% adjustment; thus, ASEAN+3 needs approximately 17 years and 3 months in order to return to the long-run equilibrium level. In short, Figure 1 provides the idea of the causal relationship between all the variables in the short run.
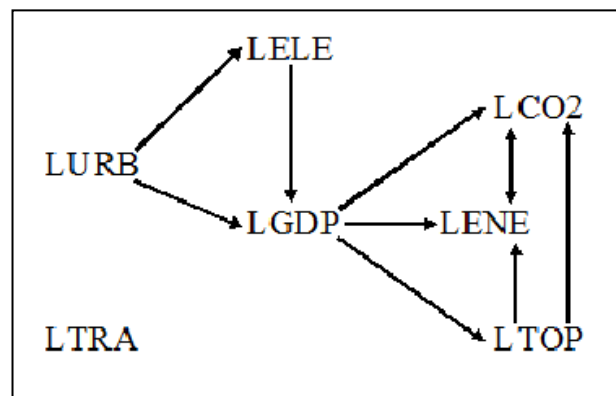

Figure 1: Short-run Causality Direction

5. Conclusion

This study examined the determinants of carbon dioxide emissions using the panel unit root test, the Pedroni (Engle-Granger based) cointegration test, and the Granger-Causality based on the VECM for 13 countries (Brunei, Cambodia, China, Indonesia, Japan, Korea, Lao, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam) from the period of 1991 to 2010. The results from the cointegration test indicated that the series are cointegrated and there is a long run relationship between carbon dioxide emissions, energy consumption, economic growth, urbanization, trade openness, and transportation. Hence, the Granger-Causality test based on the Vector Error Correction Model (VECM) was carried out. The Granger-Causality test results showed a bi-directional causality between carbon dioxide emissions and energy consumption; short-run unidirectional causalities running from economic growth to carbon dioxide emissions, energy consumption, and trade openness; from urbanization to electricity consumption and economic growth; from trade openness to energy consumption and carbon dioxide emissions; and from electricity consumption to economic growth. However, transportation does not have any causal relationship with any variables. These indicate that in the short-run, further economic development, an increase in energy consumption, and trade openness lead to an increase in CO_2 emissions in ASEAN+3. In short, economic growth, energy consumption, and trade

openness are the determinants of CO_2 emissions in the ASEAN+3. Empirical results further suggested that there are causal relationships between economic growth, energy consumption and trade openness, and carbon dioxide emissions in ASEAN+3.

The results suggest that stricter, efficient, and effective energy conservation policies need to be implemented in order to decrease carbon dioxide emissions. Without the energy conservation policies, the countries are developing their countries at the cost of environmental pollution. Besides, since a unidirectional causality was found from urbanization and electricity consumption to economic growth, any policy in respect to reduction of urbanization and electricity consumption may be risky for further developing the economy in ASEAN+3. Governments should implement policies to increase urban population and control electricity consumption in order to develop the economy.

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