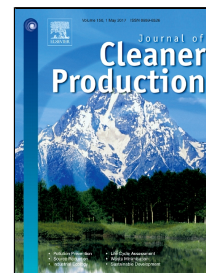


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Impact of Urbanization Growth on Malaysia CO<sub>2</sub> Emissions: Evidence from the Dynamic Relationship

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**HIGHLIGHTS:**

- The Ecological Modernization and Augmented Cobb-Douglas production theories are utilized.
- Inverted U-shaped relationship between CO<sub>2</sub> emissions and urbanization is revealed in the long-run.
- Significant unidirectional causality from urbanization to CO<sub>2</sub> emissions is found in short-run.
- The role of urbanization to stimulate the CO<sub>2</sub> reduction target is confirmed.
- Managing urban infrastructure, transportation, residential and commercial building are crucial.

# Impact of Urbanization Growth on Malaysia CO<sub>2</sub> Emissions: Evidence from the Dynamic Relationship

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## Abstract

Urbanization is a phenomenon of economic and social modernization. Investigating the link between urbanization growth and CO<sub>2</sub> emissions is necessary and helpful for Malaysia to achieve its pollution reduction targets. Ecological modernization and augmented Cobb–Douglas production theories are used in order to gain the best understanding of interaction between CO<sub>2</sub> emissions and urbanization for the 1971–2015 period. This study aims to examine the relationships among CO<sub>2</sub> emissions, urbanization growth, energy consumption, GDP, domestic investment, and financial development. The F-bounds test and VECM Granger causality are utilized. The dynamic relationship among variables and the inverted U-shaped relationship between CO<sub>2</sub> emissions and urbanization in the long run are examined. The elasticity of CO<sub>2</sub> – urbanization is found positive elastic in the early stage of urbanization, but it turns to negative inelastic at the higher urbanization stage. Furthermore, the unidirectional causality from urbanization to CO<sub>2</sub> emissions in the short run are at a 1 percent level of significance, and the bidirectional causality between CO<sub>2</sub> emissions and urbanization is at a 5 percent level of significance in the long run. Also, we captured bidirectional causality among energy consumption, domestic investment, GDP, CO<sub>2</sub> emissions, and unidirectional causality from financial development to CO<sub>2</sub> emissions at least at a 5 percent level of significance. These findings could support policymakers in managing urbanization development and considering clean investment and other green aspects for urban sustainable development, which can save many people from natural disaster.

**Keywords:** *ARDL, CO<sub>2</sub> emissions, Urbanization, Elasticity, Granger causality, Malaysia*

## 1. Introduction

Sustainable development, which is defined as development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs (Jalil, 2010), is an important concept in the present day. This concept first emerged in the 1970s, and it concerns not only economic development but also social and environmental development. Climate change is one of the consequences of unsustainable development because humans have overexploited natural resources (fossil fuels) to generate electricity by cutting down forests (Quahrani et al., 2011), thus ignoring the impact of such development on the environment and future generations. For instance, the world's CO<sub>2</sub> emissions grew from 17.78 billion tons in 1980 to 32.1 billion tons in 2015 (International Energy Agency [EIA], 2016), and the resulting warming has had an influence on human health, agriculture, economic activities, biodiversity, and ecosystem functioning. Stern (2007) reported that, if no action is taken to reduce such emissions, the concentration of greenhouse gas (GHG) in the atmosphere could double its preindustrial levels by as early as 2035.

Urbanization is a dynamic moderation for social and economic capabilities from rural to urban areas. Presently, almost half the world's population live in urban areas; by 2050 approximately 64% of developing countries' population will be urbanized (Shahbaz et al., 2016; He et al., 2016). This phenomenon has contributed to higher energy consumption and CO<sub>2</sub> emissions from production and other economic activities because almost all of these activities take place in urban areas. Furthermore, most rural residents have changed their lifestyles in certain ways and improved their living standards during the urbanization process. In pace with the improvement of living conditions and income levels, urban residents' consumption levels also continue to increase, while their consumption patterns have gradually shifted from survival mode to development mode and even enjoyment mode, which may directly or indirectly increase urban energy use (Ji & Chen, 2015). Many previous studies (Liddle & Lung, 2010; Sadorsky, 2014; Wang et al., 2016) have demonstrated the positive relationship between

urbanization and CO<sub>2</sub> emissions, with residential household, transportation, and building material industries being the major CO<sub>2</sub> emitters in urban areas (Li & Lin, 2015; Yang & Li, 2013). According to Zhu and Peng (2012), urbanization generally affects CO<sub>2</sub> emissions in three ways: first, residential and industrial energy consumption; second, energy used by the construction sector for the purpose of building better infrastructure, transportation, and residential dwellings; and third, the conversion of grasslands and woodlands to allow for urban development. Furthermore, increased use of residential home appliances (e.g., air-conditioning, water heater) has consumed high electrical power and indirectly affects CO<sub>2</sub> emission levels.

Malaysia is a developing country that has significantly transformed itself from a predominantly agriculture-based country to manufacturing and, now, toward modern services and modernization. Within that transformation process, Malaysia's GDP has grown by 3.4 percent for the 1971–2015 period (see Figure 1). Malaysia's development policy (New Economic Policy [NEP: 1970–1990], the National Development Policy [NDP: 1990–2000], and Vision 2020) was recognized as one of the important drivers of economic transformation, modernization, and it was accompanied by rapid urbanization growth (Siong, 2008). Figure 1 significantly shows urbanization growth by 1.8 percent for the 1971–2015 period, and it has moved in the same direction with GDP growth.

Figure 1:

The shrinking of the agriculture sector, which is rural based, has moved most of people to urban areas for brighter economic prospects, and it was in line with the Malaysian economy's policies on poverty eradication. In the early 1980s, Malaysia had four major urban cities located in developing states consisting of more than 50 percent of the country's population; this amount is expected to grow, and it is estimated that, by 2030, almost 80 percent of overall population will be living in urban cities (Shahbaz et al., 2016). Furthermore, the World Bank (2015) has acknowledged Malaysia as one of the urbanized countries in East Asia as well as a high middle-income country. On top of that, the government of Malaysia set a target to become a high-income nation by 2020 and to achieve a GDP growth of 6 percent annually over the subsequent five years in the 11<sup>th</sup> Malaysia Plan (11MP) and Vision 2020. Thus, urbanization is expected to grow along with this economic performance.

In this regards, more energy is needed to support Malaysia's industrial development as well as to enhance the productivity of capital, labor, and other factors to production (Shafie et al., 2011). Unfortunately, Malaysia struggles with an overdependence on nonrenewable energies (fossil fuels and coal) to generate electricity and other production activities. Accordingly, the growth of energy consumption has, in turn, increased CO<sub>2</sub> emissions. Figure 2 illustrates the time trend of Malaysian CO<sub>2</sub> emissions and energy consumption growth by 7.1 and 6.7 percent respectively for the 1971–2015 period, and it has moved in the same direction with GDP and urbanization.

Figure 2:

In 2009, recognizing the importance of sustainability, Malaysia established a voluntary target of reducing the GHG intensity of its GDP by up to 40 percent compared with 2005 levels by 2020 (Begum et al., 2015). Under the 10<sup>th</sup> Malaysia Plan (2011–2015), the energy intensity had decreased by 33 percent by the end of 2013; however, it was below the reduction target. The crucial challenge faced by Malaysia today is supporting economic development by keeping its GDP up and bringing CO<sub>2</sub> emissions down (CO<sub>2</sub> accounted for three quarters of GHG emissions). Solid policies and strategy to reduce dependencies on fossil fuel resources, energy intensity, and CO<sub>2</sub> emissions are needed to achieve sustainable development, specifically with the force of urbanization growth.

In view of these considerations, the aim of this study is to assess the link between urbanization growth and CO<sub>2</sub> emissions. Thus, the major challenge that needs to be addressed is how to reduce the gap between Malaysia's economic development and CO<sub>2</sub> emissions—specifically, how to reduce CO<sub>2</sub> emissions and maintain sustainability in a rapid urbanization and modernization scenario. Specifically, to assess the existence of a long-

run relationship between them, to determine whether there is a monotonically positive or negative relationship, U-shaped or inverted U-shaped relationship between urbanization growth and CO<sub>2</sub>, and finally to assess the direction of causal relationship between urbanization growth and CO<sub>2</sub> emission in a multivariate framework. This study utilized the F-bounds test to assess the long-run relationship among variables and to determine the relationship between CO<sub>2</sub> emission and its determinants as well as the elasticity of CO<sub>2</sub> emissions with respect to the changes in urbanization, domestic investment, energy consumption, FDI, and GDP growth. Also, the vector error correction model (VECM) is used to determine the direction of causal relationship among variables. This study focuses on CO<sub>2</sub> emissions, utilizing them as a proxy for GHG emissions because they are the main source of GHG and account for three quarters of GHG emissions (Nejat et al., 2015). This study contributes to the literature in three ways: (1) many of the previous study that utilized IPAT and STIRPAT models to assess the link between CO<sub>2</sub> emissions and urbanization (Shahbaz et al., 2016; Liddle & Lung, 2010; York et al., 2005; Dietz & Rosa, 1994). However, this study uses ecological modernization (EM) and augmented Cobb–Douglas production (AC-D) theories in order to do the similar task (see details in the next section); (2) it employs nonlinearity and a dynamic model to follow the concept of environmental Kuznet curve (EKC); (3) the EKC hypothesis built the link between CO<sub>2</sub> emissions and GDP. Thus, this study investigates the existence of EM theory by regressing the urbanization (U) and urbanization square (U<sup>2</sup>) on CO<sub>2</sub> emissions. By examining the dynamic relationship between CO<sub>2</sub> emissions and urbanization, this study yields powerful recommendations for urban planning, national energy, and climate change mitigation policies, exactly at the time when Malaysia is pursuing the transition into a low carbon society.

The structure of this study is as follows. Section 2 reviews the Malaysian urbanization sector. Section 3 provides a theoretical background and critical review of the literature related to urbanization and CO<sub>2</sub> emissions. Section 4 contains data sources and methodology employed. Section 5 analyzes the empirical results, while section 6 presents the conclusion and discuss the policy implications.

## 2. Malaysian Urbanization Sector

Figure 1 shows a significant relationship between economic growth and urbanization, which are substantially increasing and moving together in the same direction. Urbanization started to increase after 1970 (Yaakob et al., 2010) exactly after the implementation of National Energy Policy (NEP). In the 1990s, this trend continued, and now it is more rapid due to the extensive rural migration, high intensity of industrial development (Shahbaz et al., 2016), and diversification of economic activities (Aziz et al., 2012). As a result, many cities, especially in the west peninsular of Malaysia, have been developed such as Kuala Lumpur, Penang, Johore Bahru, Shah Alam, Kuching, Kota Kinabalu, and Ipoh (Bekhet & Othman, 2016; Shahbaz et al., 2016; Shahbaz et al., 2015; Yaakob et al., 2010). Most of the cities, which are the hub of government and businesses, are where the population was concentrated (Ministry of Housing and Local Government [MHLG], 2006), as well as the centres of government and business activities.

Notably, urbanization is an increasing concentration of people in cities (Dao, 2002) and a dynamic moderation phenomenon on social and economic capability. Until now, urbanization remains one of the important agendas for Malaysian economic development because the urbanization level of a country will reflect its level of economic performance. Besides, urbanization plays an important role in attracting local and foreign investors in Malaysia (MHLG, 2006). Figure 3 shows the urbanization level for each region in Malaysia; the figure also reveals the central regions (Kuala Lumpur, Putrajaya, Selangor, and Negeri Sembilan) as the most urbanized region in Malaysia.

Figure 3:

Many people prefer to live in urban areas for brighter economic prospects. This is because most infrastructures are built in urban areas to cater to the needs of industries, shelter, recreation, and other services (Yaakob et al., 2010; KeTTHA, 2011). The urban cities also are where new job opportunities are created (Aziz et al., 2012)

and high-skill manpower is available (Shahbaz et al., 2016). Indeed, the urban sector serves as an important catalyst toward Malaysian economic growth and a vital investment center for the nation. Also, the urbanization was a mandatory step toward modernization and development for developing countries.

Urbanization, which includes transportation, is considered a driving force. Figure 4 shows that the time trend of total number of vehicles registered growth for Malaysia was 5.3 percent and its increased from 20.1 million in 2010 and to 26.3 million in 2015; these vehicles consists of commercial, public, motorcar, motorcycles, etc. The flexibility and comfortability of private vehicles are the main reason for the growing number of private vehicles in the urban areas (Bekhet & Othman, 2016). The World Bank (2015) estimated an average of two cars for each resident in Kuala Lumpur. The large number of private vehicle ownership puts pressure on the capacity of the existing road network, especially for larger conurbations such as Kuala Lumpur and George Town (MHLG, 2006).

Figure 4

Furthermore, the number of commercial and business set up in the urban area is increasing. The commercial sector (the demand for a well-planned commercial center and shopping complexes) is growing as a consequence of the increasing capacity of purchasing power among urban population (Ahmad et al., 2009). Figure 5 shows the time trend (1.8 percent) and the number of local and foreign companies increased from 41.6 thousand in 2009 to 49.2 thousand in 2014. Then, due to the depletion of Malaysian currency, the number of companies registered dropped to 45.6 thousand in 2015.

Figure 5:

In addition, the increased of urban population requires additional space for housing. Figure 6 reveals the number of living quarter (housing) consistently increased from 4 million in 1991 to 5.6 million in 2000 and then 7.4 million in 2010, and it was dominant by Johore, Selangor, Perak, Penang, Sarawak, and Kuala Lumpur. This is because of more than 50 percent of the Malaysian population live in these six major cities.

Figure 6:

Above all, the rapid urbanization brought together the residential, commercial, office, and retail space in a single development. In order to cater to the need of the urban population, the government spent a huge investment on construction of residential and commercial buildings, infrastructures, and social amenities (Yaakob et al., 2010). Figure 7 reports construction projects to develop social amenities (SA), infrastructure (I), and residential building (Re) have grown by 13.4, 13.6, and 4.9 percent, respectively, for the 2006–2014 period. While the construction of nonresidential buildings declined 1.8 percent for the same period. Furthermore, the Malaysian government consistently put a priority to build and improve social amenities and infrastructure to provide a good quality and competitive environment, complemented with all forms of urban activities, which was in line with the Malaysian Urbanization Policy (2006).

Figure 7:

Based on the growth of urban development (see Figure 1), accordingly the demand for energy increased with the transport and industrial accounting for 50 to 60 percent of energy use in urban cities (Shahbaz et al., 2016). Because Malaysia is still relying on fossil fuel as a source of energy, the CO<sub>2</sub> emissions also moved in an upward trend for the 1971–2015 period (see Figure 2). All these factors highlight that urbanization is the main GHG contributor, accounting for 50 percent of all GHG specifically in Malaysia (KeTTHA, 2016).

### 3. Theoretical Background and Literature Review

Rapid increase in urbanization, especially in the new industrialized and developing countries, has caused a number of challenges to improve environmental quality and to create a sustainability energy supply. Thus, investigating the linkage between CO<sub>2</sub> emissions and urbanization growth has become a vital concern because,



based on the results of the analysis, the researcher can detect how urbanization can influence CO<sub>2</sub> emissions. This is one of the reasons why, recently, a number of studies investigated the impact of urbanization on emissions.

Many theoretical attempts have been made to address the linkage between urbanization and urban energy consumption as well as energy-related CO<sub>2</sub> emissions. Poumanyong and Kaneko (2010) presented three theories that describe the mechanisms that link urbanization, energy consumption, and emissions: (1) ecological modernization theory (EMT); (2) environmental transition theory (ETT); and (3) compact city theory (CCT). The EMT creates a link between CO<sub>2</sub> emissions and urbanization at the national level and assumes the movement of societies from low to the middle stage of development may increase environmental problems because societies typically place more emphasis on improving their income level instead of focusing to environmental sustainability. However, after reaching a higher stage of development, with a promising income status, they will change their prominence in order to improve environment sustainability (Sadorsky, 2014). Different from ETT and CCT, these theories links CO<sub>2</sub> emissions and urbanization at the city level. The ETT assumes the environmental pressure is different, and that it is based on the level of affluence (measured by income level) (Sadorsky, 2014; Miao, 2017). As income increases and cities become wealthier via growth of the manufacturing base, the demand for electricity, heating, transportation and construction will increase as well, which will lead to industrial pollution. However, the use of energy and environmental pollution may be lessened through government intervention (national regulation and policies), technology advancement, and change of economic structure. On the other hand, the CCT emphasized the importance of urban design in realizing sustainable urban development. Sustainable urban design is high density, offers convenient public transport, and accessibility of local services and job (Miao, 2017). Through convenient public transports, the dependency on private motor vehicles and traffic congestion and environmental pollution will be reduced.

A number of studies have explored the linkage between CO<sub>2</sub> emission and urbanization. The review of the past literature was divided into two strands: (1) the impact of urbanization to CO<sub>2</sub> emissions; and (2) the relationship between urbanization and CO<sub>2</sub> emissions within a Granger causality framework. York et al. (2003) found that urbanization had a significant impact in increasing CO<sub>2</sub> emissions and energy consumption in the world. Utilizing time-series econometrics and panel data econometrics methodology, Liddle and Lung (2010); Kasman and Duman (2015); Wang et al. (2016); and Wang et al. (2016b) revealed similar results. Also, studies by Sadorsky (2014) and Rafiq et al. (2016) found the relationship between CO<sub>2</sub> emissions and urbanization to be insignificant positive. Conversely, for the case of China, He et al. (2016) found that urbanization had a significant impact on CO<sub>2</sub> emissions. A common assumption held by all of these empirical studies is that the relationship among the variables is linear, but this assumption may not always be realistic.

Poumanyong and Kaneko (2010) investigated the impact of urbanization on CO<sub>2</sub> emissions in 99 countries and revealed the effect varies across the different stages of development. This finding supports the argument that could be the existence of a nonlinear relationship between CO<sub>2</sub> emissions and urbanization. Martinez-Zarzoso and Maruotti (2011) revealed an inverted U-shaped relationship in 88 of developed countries. Al-Mulali et al. (2012) investigate the relationship for seven regions in the world (East Asia and Pacific, East Europe and Central Asia, Latin America and the Caribbean, Middle East and North Africa, South Asia, Sub-Saharan Africa, and Western Europe) and revealed that 84 percent of countries have a positive relationship between CO<sub>2</sub> emissions and urbanization, and most of the low income countries showed the opposite result. Then, Al-Mulali et al. (2013) investigated the relationship between the aforementioned variables for MENA (Middle East and North Africa) countries and found the positive relationship between CO<sub>2</sub> emissions and urbanization in upper-middle-income countries and a negative relationship in the low-income countries. Recently, Shahbaz et al. (2016) indicated a U-shaped relationship for Malaysia, and Zie et al. (2016) revealed the inverted U-shaped relationship between a similar variable in China. From all the above literature, the results were found mixed and inconsistent. One of the reasons is that most of the countries faced different stages of development. At the early

stage of development, societies put more intention to improve their income level instead of focusing on environmental sustainability. However, after reaching the higher stage of development, with a promising income status, they will change their prominence to improve environmental sustainability. Also, this phenomenon could be due to different types of countries, different proxies to measure environmental pollutants, and different frameworks used to capture the linkage between CO<sub>2</sub> emissions and urbanization.

The second strand of the empirical literature is to probe the relationship between urbanization and CO<sub>2</sub> emissions within a Granger causality framework. Historically, results from previous studies can be categorized into three types (Akinlo, 2008; Bekhet & Othman, 2011): unidirectional causality, bidirectional causality, and finally, no causality. The causality results are useful in determining the appropriate strategies to achieve sustainable development. Al-Mulali et al. (2013) utilized DOLS and VECM Granger causality to MENA countries in order to reveal long- and short-run bidirectional causality between CO<sub>2</sub> emissions and urbanization. A similar result was found by Al-Mulali et al. (2013) who employed FMOLS to the seven regions in the world. Instead of CO<sub>2</sub> emissions, Solarin and Shahbaz (2013) tested the causality relationship between energy consumption and urbanization by using the ARDL model and revealed the bidirectional causality relationship between the aforementioned variables.

However, Kasman and Duman (2015) tested new EU member and candidate countries; Wang et al. (2016) tested ASEAN countries and revealed a short-run unidirectional causality running from urbanization to CO<sub>2</sub> emissions. However, Shahbaz et al. (2016) tested Malaysia; Wang et al. (2016) tested ASEAN countries; and Wang et al (2016) tested BRIC (Brazil, Russia, India and China) countries and revealed unidirectional causality running from urbanization to CO<sub>2</sub> emissions in the long run. Moreover, Kasman and Duman (2015) found the long-run causality relationship from the opposite direction, and Ghosh and Kanjilal (2014) failed to detect any causality relationship between urbanization and CO<sub>2</sub> emissions in India. The causality results provide fruitful ideas and strategies for policymakers in creating the best strategy for sustainable development. If the direction of causality is coming from urbanization to CO<sub>2</sub> emissions, the strategy to slow urbanization growth will improve the environmental condition with the assumption *ceteris paribus*. Alternatively, the policymaker has to consider the role of technology and innovation in order to improve environment conditions, which depends on which variables present a significant negative relationship with CO<sub>2</sub> emission in a multivariate framework. This is because any increase in those particular independent variables will induce the process to reduce the CO<sub>2</sub> emissions. Table 1 yields a summary of empirical literature findings on the link between CO<sub>2</sub> emissions and urbanization.

Table 1:

The empirical analyses of previous research enriches our knowledge on how urbanization influences the environment quality that is presented by CO<sub>2</sub> emissions. However, due to the nature of the available data, not many studies consider the roles of urbanization for a Malaysia time series. Although some of the previous studies did not focus on Malaysia as a single country, they utilized panel data and grouped Malaysia in emerging countries (Sadorsky, 2014) and ASEAN countries (Wang et al., 2016). Moreover, some studies utilized different theories and models to develop a link between CO<sub>2</sub> emissions and urbanization (Shahbaz et al., 2016). Thus, there is still additional room to expand upon the recent literature by testing the nonlinear and dynamic relationship between CO<sub>2</sub> emissions and urbanization by combining the EMT and augmented C-D theories in one multivariate framework; at the same time this strategy can avoid the possibility of omitted variable bias. Based on the above and to achieve the objectives of the current paper, the hypotheses are formulated as shown below:

- H<sub>1</sub>: Significant dynamic relationship exists between CO<sub>2</sub> emissions and its determinants in Malaysia
- H<sub>2</sub>: CO<sub>2</sub> emissions has a significant inverted U-shaped relationship with urbanization growth
- H<sub>3</sub>: Significant long-run causality exists between CO<sub>2</sub> emissions and urbanization in Malaysia
- H<sub>4</sub>: Significant short-run causality exists between CO<sub>2</sub> emissions and urbanization in Malaysia



## 4. Data Sources and Methodology

### 4.1 Data sources

The annual data of the CO<sub>2</sub> emissions (C), energy consumption (E), domestic investment (K), financial development (F),<sup>1</sup> gross domestic product (Y), and urbanization (U) are used. The sources have mainly taken from World Development Indicator (WDI), published by World Bank and covering the 1971–2015 period. Table 2 present the details of the variables.

Table 2:

All the data are converted to natural logarithms. This is necessary in order to eliminate the influence of the variable's dimension (Wang et al., 2017), to induce the stationary process (Narayan & Smyth, 2005; Lau et al., 2014), and to reduce the possibility of heteroscedasticity and autocorrelation to exist (Bekhet & Othman, 2014). Also, it could reduce the sharpness of data and provide reliable empirical finding (Shahbaz et al., 2014). Table 3 presents the behaviour and relationship matrix of the variables at level.

Table 3:

Table 3 shows that all variables are normally distributed, and the interrelationship coefficients between the variables are significantly positive correlated to each other. Also, it is not too surprising that the coefficient of the partial Pearson correlation among LC, LE, and LY is highest. It denotes how important the energy to economic development, and how strong the dependency on fossil fuel resources for 1971-2015 period that in turned create higher pollution. Likewise, these results indicate the data being employed is significantly moved together in a positive direction and are ready to be used in the next step.

### 4.2 Model construction

Because the goal of this study is to evaluate the link between CO<sub>2</sub> emissions and urbanization, the work of Grossman and Krueger (1991; Martinez-Zarzoco and Maruotti, 2011; Saboori and Sulaiman, 2013, Al-Mulali et al., 2015; Shahbaz et al., 2016; and Miou, 2017 are followed. The CO<sub>2</sub> emission was underpinned by GDP growth, and it was assumed they have a linear relationship. However, the ecological modernization (EM) theory was utilized to make a link between CO<sub>2</sub> with urbanization and GDP. Urbanization is a demographic indicator that increases urban density and transform the organization of human behavior, thereby influencing household energy consumption pattern (Poumanyvong & Kaneko, 2010; Sadorsky, 2014). In the current era, the linear relationship between CO<sub>2</sub> emissions and urbanization is not realistic; an inverted U-shape or U-shape could happen and is highly dependent on the stage of development. For this purpose, Shahbaz et al. (2016) used a simple quadratic function to measure the changing of relationship between CO<sub>2</sub> emissions and urbanization as urbanization rises. Thus, the baseline model for the current study is presented as in Equation [1]:

$$C_t = Y_t^{\alpha_1} U_t^{\alpha_2} U_t^{2\alpha_3}, \quad [1]$$

where C, Y, U, and U<sup>2</sup> represent CO<sub>2</sub> output emissions, GDP, urbanization, and urbanization square. The  $\alpha_1$ ,  $\alpha_2$ , and  $\alpha_3$  represent coefficients of the relationship among CO<sub>2</sub> and GDP, urbanization, and urbanization square, respectively. Then, Equation [1] needs to be expanded with the inclusion of the augmented Cobb–Douglas (AC-D) production function to avoid omitted variable bias. Also, the inclusion of AC-D production theory enables us to capture the link between the output and the input used [see Equation 2] and to capture the scale, composition, and technique effect that leads to a nonlinear relationship between CO<sub>2</sub> emissions and urbanization:

<sup>1</sup> Domestic credit to the private sector, as shares of GDP are used to measure FD. Domestic credit obtained from the banking sector, includes gross credit to various sectors, with the exception of credit to the central government, which is net. Banking sector includes monetary authorities and deposit money with banks and other banking institution for which data are available. Also included are the institutions that do not accept transferable deposits but incur liabilities such as time and saving deposits. This provides a reasonably good measure for the development of the financial sectors (Islam et al., 2013). Example: Loan, purchases of nonequity securities, trade credits, and other account receivable (Bautabba, 2014).

$$Q_t = A_t K_t^{\alpha_4} L_t^{\alpha_5} E_t^{\alpha_6} e^v, \quad [2]$$

where  $Q_t$  is output, and  $K$ ,  $L$ , and  $E$  denote capital, labor, and energy consumption, respectively.  $e^v$  refers to the random error term; it is assumed to be normally distributed.  $\alpha_4$ ,  $\alpha_5$ , and  $\alpha_6$  represent the returns to scale linked with  $K$ ,  $L$ , and  $E$ , respectively.  $K$  enters the production function directly and influences the multifactor productivity.  $L$  mainly deals with the skills and qualifications of people, which are acquired through explicit training and on-the-job experience (Omri et al., 2015). Nowadays, energy has been identified as an indispensable force that spurs aggregate output with the inclusion of  $K$  and  $L$  to act as a complement (Lean & Smyth, 2010). “ $A$ ” indicates the technological parameter. This technology is measured by financial development (Shahbaz et al., 2012; Shahbaz, 2012; Islam et al., 2013; Hamdi et al., 2014) due to its capability to boost domestic investment and encourage FDI inflow inter alia, which brings both superior technology and know-how (Islam et al., 2013). Also, it leads to the improvement of energy efficiency through the technology effect and by upgrading the industrial structure (Islam et al., 2013; He & Wang, 2012). The technology function ( $A_t$ ) is expressed as in Equation [3]:

$$A_t = \theta F_t^{\alpha_7}, \quad [3]$$

where  $\theta$  is the constant,  $F$  represents financial development, and  $\alpha_7$  represents the coefficient of the relationship between outputs with financial development. Equation [3] is substituted into Equation [2] to produce Equation [4]:

$$Q_t = \theta K_t^{\alpha_4} L_t^{\alpha_5} E_t^{\alpha_6} F_t^{\alpha_7} e^v. \quad [4]$$

Following Sueyoshi and Goto (2011, 2013), output can be classified into two types: desirable output (good output) of GDP and undesirable output (bad output) of  $CO_2$  emissions. The desirable output contributed to GDP growth, while undesirable output could harm environmental condition, human health, and the socio-ecological system. Consequently, this study focuses on the production of  $CO_2$  emission ( $C$ ), and thus the  $Q_t$  is substantial by  $C_t$  as in Equation [5]:

$$C_t = \theta K_t^{\alpha_4} L_t^{\alpha_5} E_t^{\alpha_6} F_t^{\alpha_7} e^v. \quad [5]$$

By combining Equations [1] and [5], Equation [6] represents the framework for  $CO_2$  emissions function to be employed in this study:

$$C_t = \theta Y_t^{\alpha_1} U_t^{\alpha_2} U_t^{2\alpha_3} K_t^{\alpha_4} L_t^{\alpha_5} E_t^{\alpha_6} F_t^{\alpha_7} e^v. \quad [6]$$

Then, following Hamdi et al. (2014) and Shahbaz (2014), both sides of Equation [6] were divided by population and obtains each series in per capita but leaves the impact of labor constant. Also, the elimination of  $L$  from [Equation 6] can lessen the problem of multicollinearity. Next, to make a meaningful interpretation, the consistent and efficient model of the nonlinear production function [Equation 6] is converted to a linear logarithmic quadratic specification by taking the natural logs ( $L$ ) as in equation [7]:

$$LC_t = \delta + \alpha_1 LY_t + \alpha_2 LU_t + \alpha_3 LU_t^2 + \alpha_4 LK_t + \alpha_6 LE_t + \alpha_7 LF_t + v_t, \quad [7]$$

where  $\delta = L\theta$ , after taking the natural logs. The relationship coefficients  $\alpha_i$  [ $i= 1, \dots, 7$ ] are interpreted as elasticities. The details of the interpretation are summarized in Table 4.

Table 4:

#### 4.3 Estimation Procedure

In order to test the hypothesis and to achieve the objectives of this study, the econometric procedures are used, as shown in Figure 8.

Figure 8:

A macroeconomic variable is usually nonstationary and possesses a trend over time. Evidence from past studies suggests the presence of a unit root in most of the financial and economic variables (Bekhet & Mugableh, 2012). Many econometric scholars define stationarity as a condition when the mean and variance of the variables in a time series are constant over time, and the covariance between the two values from the series depends only on time separating observations, not the time at which they are observed. Researchers use many econometric methodologies to test stationarity (ADF test [Dickey Fuller, 1979], PP test [Phillips & Perron, 1988], KPSS test [Kwiatkowski, Phillips, Schmidt, & Shinb, 1992], N-P tests [Ng & Perron, 2001]). The main reason why it is important to observe the stationarity condition for each variable before embarking on OLS is to avoid spurious regression results. Other than that, the results from the stationarity test could give the researcher an idea of what is a suitable model that can be used in a future step (see Figure 8). It will also alert the researcher of the presence of a shock or structural break in the time series.

This study utilized an N-P test due to its ability to overcome the problem of low power and size distortion.<sup>2</sup> It utilized the idea of a generalized least squares (GLS) detrending to improve the power of the test and to improve the procedure for choosing the truncation lag by modifying the lag selection (e.g., the AIC to become a modified AIC @ MAIC) to create an additional size distortion in the unit root test (more detail about this test, see Ng & Perron, 2001).

The F-bounds test within the ARDL framework is utilized due to its ability to eradicate the incapacity of other techniques of co-integration (Engle & Granger [E-G], 1987, test, Johansen & Juselius, 1990, test). Likewise, a number of advantages exist with this technique as listed in many studies (Bekhet et al., 2017; Shahbaz et al., 2016; Begum et al., 2015; Ivy-Yap & Bekhet, 2015; Bekhet & Matar, 2013). Thereby, it can be used to simultaneously estimate the short- and long-run relationship. The combination of short- and long-run components, along with the appropriate number of lags, able to solve the autocorrelation and endogeneity problem lead to bias in parameter estimation. According to Narayan (2005) and Farhani et al. (2014), the F-bounds test is appropriate for small sample sizes ( $30 \leq n \leq 80$ ) and is far superior to that of the multivariate co-integration. Equation [8] formulated the dynamic relationship among CO<sub>2</sub> emissions and their determinants:

$$\Delta \begin{bmatrix} LC \\ LY \\ LU \\ LU^2 \\ LK \\ LE \\ LF \end{bmatrix}_t = \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \\ \delta_6 \\ \delta_7 \end{bmatrix} + \begin{bmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} & \alpha_{14} & \alpha_{15} & \alpha_{16} & \alpha_{17} \\ \alpha_{21} & \alpha_{22} & \alpha_{23} & \alpha_{24} & \alpha_{25} & \alpha_{26} & \alpha_{27} \\ \alpha_{31} & \alpha_{32} & \alpha_{33} & \alpha_{34} & \alpha_{35} & \alpha_{36} & \alpha_{37} \\ \alpha_{41} & \alpha_{42} & \alpha_{43} & \alpha_{44} & \alpha_{45} & \alpha_{46} & \alpha_{47} \\ \alpha_{51} & \alpha_{52} & \alpha_{53} & \alpha_{54} & \alpha_{55} & \alpha_{56} & \alpha_{57} \\ \alpha_{61} & \alpha_{62} & \alpha_{63} & \alpha_{64} & \alpha_{65} & \alpha_{66} & \alpha_{67} \\ \alpha_{71} & \alpha_{72} & \alpha_{73} & \alpha_{74} & \alpha_{75} & \alpha_{76} & \alpha_{77} \end{bmatrix} \begin{bmatrix} LC \\ LY \\ LU \\ LU^2 \\ LK \\ LE \\ LF \end{bmatrix}_{t-1} + \sum_{m=1}^k \Delta \begin{bmatrix} \theta_{11} & \theta_{12} & \theta_{13} & \theta_{14} & \theta_{15} & \theta_{16} & \theta_{17} \\ \theta_{21} & \theta_{22} & \theta_{23} & \theta_{24} & \theta_{25} & \theta_{26} & \theta_{27} \\ \theta_{31} & \theta_{32} & \theta_{33} & \theta_{34} & \theta_{35} & \theta_{36} & \theta_{37} \\ \theta_{41} & \theta_{42} & \theta_{43} & \theta_{44} & \theta_{45} & \theta_{46} & \theta_{47} \\ \theta_{51} & \theta_{52} & \theta_{53} & \theta_{54} & \theta_{55} & \theta_{56} & \theta_{57} \\ \theta_{61} & \theta_{62} & \theta_{63} & \theta_{64} & \theta_{65} & \theta_{66} & \theta_{67} \\ \theta_{71} & \theta_{72} & \theta_{73} & \theta_{74} & \theta_{75} & \theta_{76} & \theta_{77} \end{bmatrix}_m \begin{bmatrix} LC \\ LY \\ LU \\ LU^2 \\ LK \\ LE \\ LF \end{bmatrix}_{t-m} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \varepsilon_5 \\ \varepsilon_6 \\ \varepsilon_7 \end{bmatrix}_t \quad [8]$$

where  $\Delta$  is the first difference operator,  $\delta_{is}$  represent the intercepts, and  $\alpha_{ijs}$  and  $\theta_{ijs}$  denote the long- and short-run coefficients of the variables, respectively.  $\varepsilon_{it}$ s represent the error terms,  $k$  is the utmost lag length, and  $m$  indicates the optimal number of lag. Two options to determine the optimal lag length, Akaike information

<sup>2</sup> ADF, PP, and KPSS tests suffer from the problem of low power and size distortion (Ng & Perron, 2001)

criterion (AIC) and Schwarz's Bayesian criterion (SBC). Usually, these two methods might provide different lag structures for the ARDL model. The AIC tends to select maximum relevant lag length, whereas SBC tends to select the smallest possible lag length (Sugiawan & Managi, 2016). However, to prevent the model from being under-fit, this study prefers to use AIC instead of SBC. For testing the existence of a long- and short-run relationship among variables, the hypothesis was formulated as  $H_0: \alpha_{ij}s = 0$  against  $H_1: \alpha_{ij}s \neq 0$ , and  $H_0: \theta_{ij}s = 0$  against  $H_1: \theta_{ij}s \neq 0$ , respectively.

F-statistics could be used to highlight the long- and short-run relationship, and the decision to reject or accept the  $H_0$  will be based on the following procedure (Pesaran et al., 2001; Shahbaz & Lean, 2012; Bekhet et al., 2017):

- If F-statistics > I(1) critical value,  $H_0$  will be rejected for long run relationship exist;
  - If F-statistics < I(0) critical value,  $H_1$  will be rejected for no long run relationship exist; and
  - If  $I(0) \leq \text{F-statistics} \leq I(1)$  critical value, then the decision is inconclusive.
- where the F-statistic is taken from Narayan (2005)<sup>3</sup> table.

However, in case of inconclusive, the stationarity of the residuals will be tested. If the residuals are stationary, the variables are co-integrated and vice versa (Ivy-Yap & Bekhet, 2015). Once the dynamic relationship among the aforesaid variables has been confirmed, the long-run  $\text{CO}_2$  elasticity toward the changes in its determinants can be estimated (Dogan & Turkekul, 2016; Ivy-Yap & Bekhet, 2015; Begum et al., 2015). Then, the direction of the causality relationship among  $\text{CO}_2$  emissions, GDP, urbanization, domestic investment, energy consumption, and financial development can be assessed by applying the VECM (restricted VAR model) framework (Bekhet & Al-Smadi, 2015 & 2017). Thus, Equation [9] is formulated to measure long- and short-run causality among the variables of the current study.

$$\Delta \begin{bmatrix} \text{LC} \\ \text{LY} \\ \text{LU} \\ \text{LK} \\ \text{LE} \\ \text{LF} \end{bmatrix}_t = \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \\ \delta_6 \end{bmatrix} + \sum_{j=1}^m \Delta \begin{bmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} & \alpha_{14} & \alpha_{15} & \alpha_{16} \\ \alpha_{21} & \alpha_{22} & \alpha_{23} & \alpha_{24} & \alpha_{25} & \alpha_{26} \\ \alpha_{31} & \alpha_{32} & \alpha_{33} & \alpha_{34} & \alpha_{35} & \alpha_{36} \\ \alpha_{41} & \alpha_{42} & \alpha_{43} & \alpha_{44} & \alpha_{45} & \alpha_{46} \\ \alpha_{51} & \alpha_{52} & \alpha_{53} & \alpha_{54} & \alpha_{55} & \alpha_{56} \\ \alpha_{61} & \alpha_{62} & \alpha_{63} & \alpha_{64} & \alpha_{65} & \alpha_{66} \end{bmatrix} \begin{bmatrix} \text{LC} \\ \text{LY} \\ \text{LU} \\ \text{LK} \\ \text{LE} \\ \text{LF} \end{bmatrix}_{t-j} + \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \\ \delta_6 \end{bmatrix} \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \varepsilon_5 \\ \varepsilon_6 \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \varepsilon_5 \\ \varepsilon_6 \\ \varepsilon_7 \end{bmatrix}_t \quad [9]$$

The  $\text{ECT}_{t-1}$ s are lagged error correction terms derived from the long-run relationship. According to Masih and Masih (1996), the long-run causality relationship (unidirectional, bidirectional, and neural) can be identified through coefficient  $\theta_{is}$  of  $\text{ECT}_{t-1}$  by using t-test. On the other hand, the significance of the coefficient ( $\alpha_{ij}$ ) for each explanatory variable by joint Wald F or  $\chi^2$  test indicates the short-run causality relationship (unidirectional, bidirectional, and neural). Then, the  $\varepsilon_i$  ( $i=1, \dots, 6$ ) are the white noise error terms, and they should be normally distributed with zero mean and constant variance,  $\varepsilon_i \sim N(0, \sigma^2)$ , homoscedastic, free from autocorrelation problems, and have no multicollinearity. If one of the aforementioned criteria is not met, the model could encounter bias in the parameters, become inefficient, and yield an invalid hypothesis. Thus, to ensure that the estimated model is free from the above-mention problems, the Arch, Breusch–Godfrey, Breusch–Pagan–Godfrey, and RAMSEY tests were employed. Furthermore, to assess the stability of the model, the CUSUM and CUSUMQ tests (Brown et al., 1975) are applied. The model is stable if the plot of the CUSUM and CUSUMQ tests is placed inside the critical bounds of the 5 percent significance level (Bekhet & Matar, 2013; Abid, 2015). If not, there is a possibility of a structural break within the estimation period or the coefficient of regression is not stable (Abid, 2015).

<sup>3</sup>The reason for choosing critical value provided by Narayan (2005) instead of critical value provided by Pesaran (2001) is because the critical value provided by Narayan (2005) is most sensitive to the small sample size.

## 5. Results and Discussion

Table 5 shows that only LU is significantly stationary at level  $I(0)$  at the 5 percent level, while the others are significantly stationary  $I(1)$  at the 5 percent level. These results are consistent with the notion that most of the financial and macroeconomics variables are nonstationary at level (contain unit root), but they would become stationary after the first or second difference (Bekhet & Othman, 2011; Bekhet & Mugableh, 2012).

Table 5:

Because there is a mixed stationary  $I(0)$  and  $I(1)$ , and the sample size is 45, which is relatively small, the F-bounds test is the most suitable approach to run the co-integration test. However, before carrying on with the co-integration test, it is crucial to determine the optimal lag length to be used in the F-bounds test (Sugiawan & Managi, 2016; Matar & Bekhet, 2015). Based on the Akaike information criterion (AIC), the optimal lag length is 4 (details are presented in the appendix).

The long-run relationships among variables have been found for the 1971–2015 period at least at a 5 percent significant level (see table 6). A similar finding exists in other literature (Arvin et al., 2015; Kasman & Duman, 2015; Shahbaz et al., 2016; Sodri & Garmiwa, 2016; Wang et al., 2016; Wang et al., 2016) but is inconsistent with Jafari et al. (2012).

Table 6:

Based on the above findings, the long-run elasticities and the existence of inverted U-shaped relationship between CO<sub>2</sub> emissions and urbanization are measured (see Figure 9). The coefficient of LU is found significantly positive at a 1 percent significance level, and LU<sup>2</sup> is found significantly negative at a 10 percent significant level, which supported the inverted U-shaped relationship between CO<sub>2</sub> emissions and urbanization in the long run. This is in line with the findings of Martinez–Zarzoco and Maroutti (2011) for the case of 88 developing countries and the findings of Zi et al. (2016) for the case of China. However, the result contradicts that of He et al. (2016) for the case of China and Shahbaz et al. (2016) for the case of Malaysia. These evidences propose that CO<sub>2</sub> emissions increase in the initial stage of urbanization and suddenly decrease at higher stage of urbanization; also it supports the ecological modernization (EM) and environmental transition (ET) theory. The negative relationship between the aforementioned variables at the higher level of urbanization is a result of government intervention through Malaysia's energy and environment policies. Subsequently, this study reveals the significant negative relationship between CO<sub>2</sub> emissions and energy consumption and the significant positive relationship between CO<sub>2</sub> emissions and domestic investment at a 1 percent significant level.

Figure 9:

Furthermore, the elasticities present the degree of sensitivity or responsiveness of the CO<sub>2</sub> emissions due to the changes in its determinants. The long-run CO<sub>2</sub> emissions – urbanization elasticity was found elastic; a 1 percent increase in urbanization will increase the CO<sub>2</sub> emissions by 11.32 percent. This finding implies that the rapid urbanization in Malaysia led an increased energy demand that was dominated by fossil fuel resources, which, in turn, increased CO<sub>2</sub> emissions for the 1971–2015 period. This is not a surprising result for CO<sub>2</sub> emissions to respond that much because the sources of CO<sub>2</sub> emissions are coming from three channels (transportation, construction of commercial and residential building, and the demand for electrical appliances). In the earlier stage of urbanization development, societies are typically looking for flexibility and comfortability when using private vehicles instead of environmental sustainability; thus, the number of vehicles registered increased by 30.84 percent within the five years since 2010. Then, to cater to the needs of commercial and urban dwellers, the construction of social amenities, infrastructure, and residential building grew by 13.4, 13.6, and 4.9 percent, respectively for the 2006–2014 period (see Figure 7). Also, as one of the most electricity-consuming sectors in an economy (Dergiades & Tsoulfidis, 2011), the growth in urban population, increase the demand for electrical appliances (cooling, ventilation, lighting, appliance, etc.) contributed to higher CO<sub>2</sub> emissions. After the threshold level, this long-run CO<sub>2</sub> emissions – urbanization elasticity turned to inelastic, 1 percent increase in

urbanization, decrease the CO<sub>2</sub> emissions by 0.79 percent. This result (U<sup>2</sup>) shows that Malaysian energy-efficient (EE) and renewable energy (RE) strategies have moved their environment in a positive direction. To date, the EE strategy has successfully reduced Malaysia's energy consumption by 306.9 gigawatt hours (GWh) and avoided 208,705 tons (tCO<sub>2</sub>) of CO<sub>2</sub> through the Sustainability Achieved via EE (SAVE) program between 2011 and 2013 (Bekhet & Othman, 2016). Meanwhile, the retrofitting of four government buildings also successfully reduced energy consumption by at least 19 percent per month (EPU, 2015).

In addition, the CO<sub>2</sub> function via ARDL framework passed the diagnostic tests of serial correlation, heteroscedasticity, and normality test, which indicates the model-free misspecification problem. Also, it can confirm the CO<sub>2</sub> model (Equation 7) is reliable and stable, covering the sample period (1971–2015). This is because the plot of CUSUM and the CUSUMQ tests fall inside the critical bound of the 5 percent significant level (see Figure 10) (Bekhet et al., 2017; Matar & Bekhet, 2015).

Figure 10: Plots of CUSUM and CUSUMQ

Source: Output of EVIEWS package version 9.

Furthermore, causality information is essential for policymakers to recognize the directions of causality among the variables to regulate suitable policies. Table 7 shows the multivariate causal relationship among variables. The results indicate the long-run bidirectional causality relationship between CO<sub>2</sub> emissions and the independents variables (urbanization, energy consumption, GDP and domestic investment) and unidirectional causality running from financial development to CO<sub>2</sub> emissions, urbanization, energy consumption, and domestic investment at different significance levels. The bidirectional causality relationship between urbanization and CO<sub>2</sub> emissions is consistent with Al-Mulali et al. (2012) for the case of seven regions, and Al-Mulali et al. (2013) for the case of MENA countries. However, the result is inconsistent with the studies of Wang et al. (2016), Wang et al. (2016), and Shahbaz et al. (2016) for the case of BRIC countries, ASEAN, and Malaysia, respectively.

Table 7:

On the other hand, the result of the  $\Delta LC_t$  model indicates significant unidirectional short-run causality running from domestic investment, financial development, urbanization, and GDP to CO<sub>2</sub> emissions at 1 percent. Also, the  $\Delta LE_t$  model implies significant unidirectional short-run causality from urbanization to energy consumption. Furthermore, the  $\Delta LY_t$  model suggests significant unidirectional short-run causality from CO<sub>2</sub> emissions, domestic investment, and urbanization to GDP. The unidirectional causality from urbanization to CO<sub>2</sub> emissions is consistent with the study by Wang et al. (2016) for the case of ASEAN countries and is in contrast with that of Al-Mulali et al. (2013) for the case of MENA countries. However, Figure 11 is summarized the long- and short-run causality.

Figure 11:

## 6. Conclusions and Policy Implications

Unlike in the previous studies, this study combined the ecological modernization and augmented Cobb–Douglas theories to acquire the best understanding of interaction between CO<sub>2</sub> emissions and urbanization growth for the 1971–2015 period. This study scrutinize to what extent urbanization can influence the level of CO<sub>2</sub> by examining the dynamic relationships between CO<sub>2</sub> emissions and urbanization with the involvement of other possible determinants (energy consumption, GDP, domestic investment, and financial development). The F-bounds test and VECM Granger causality are utilized for that particular purpose. The results reveal the existence of dynamic relationship among variables and the inverted U-shaped relationship between CO<sub>2</sub> emissions and urbanization in the long run. Also, the CO<sub>2</sub> emissions – urbanization elasticity is found positive elastic in the initial stage of urbanization; after achieving the threshold level, it's turned to negative inelastic. In term of causality relationship, it found a significant unidirectional causality from urbanization to CO<sub>2</sub> emissions in the short run at 1 percent, and bidirectional causality between CO<sub>2</sub> emissions and urbanization at 5 percent in the



long run. Moreover, this study has captured significant bidirectional causality from energy consumption, domestic investment, and GDP to CO<sub>2</sub> emissions and unidirectional causality from financial development to CO<sub>2</sub> emissions at least at 5 percent. These results could help policymakers in managing urbanization development, considering the clean investment and other green aspects, thus the economic development and environmental quality can be balanced. However, the findings can be accompanied by existing policies for several reasons:

**First:** The inverted U-shaped relationship between urbanization and CO<sub>2</sub> emissions indicates that urbanization will be the remedy for environmental pollution soon. As a middle-income country, the priority of urban societies is to achieve a larger income, profitability, and to improve living conditions, instead of environmental sustainability. This is because most societies originate from rural areas and move to urban areas for better job opportunities. As a hub of government, businesses, and other economy activities, expansion of the urban population requires better transportation development, more industrial, business, and residential building and space, and better urban infrastructure. So far, Malaysia has shown the growing number of urban infrastructures, and expected to provide a continuous improvement in the future. Accordingly, demand for energy increased with transportation and industry accounted for 50 to 60 percent of energy use in urban cities, and the majority of energy comes from fossil fuel sources, which, in turn, increased CO<sub>2</sub> emissions. This condition has been supported by elasticity of CO<sub>2</sub> emissions – urbanization measure that equal to 11.32. Recently, Malaysian urban societies have adopted the implementation of energy efficiency and renewable energy mechanism such as solar PV, energy efficiency appliances, which can reduce CO<sub>2</sub> emission levels. However, the result shows that the magnitude of CO<sub>2</sub> emissions reduction is smaller than the magnitude of urbanization growth, presented by the inelastic elasticity of CO<sub>2</sub> emissions – urbanization.

**Second:** With respect to the long-run causality, the results indicate bidirectional causality between CO<sub>2</sub> emissions and urbanization. All these results (relationship, elasticity, and causality) imply that urbanization is an important factor to be considered when developing CO<sub>2</sub> emission functions for Malaysia, and it cannot be omitted from the CO<sub>2</sub> emissions model. Slowing down or lowering urbanization growth *ceteris peribus* could be a government option to meet an environmental target of 40 percent reduction of CO<sub>2</sub> intensity by 2020. Unfortunately, it may not be a brilliant option because the urbanization level of Malaysia reflects the country's level of economic performance, modernization, and industrialization. It will waste previous government efforts (through NEP, NDP, NVP, and ETP) to ensure urbanization moves smoothly with a sustainable environment protection. The existing energy and environmental policies (National Environment Policy, National Policy of Climate Change, National Green Energy Policy, and National Renewable Policy) have shown a positive result, but movement is too slow, and this phenomenon is very common to a new industrialized country like Malaysia.

Above all, this study has confirmed the role of urbanization to provide a new insight into the CO<sub>2</sub> emissions – urbanization relationship. In order to keep the GDP up and bring down the carbon and energy intensity, this study recommends the following strategies/ policies:

1. Effective planning of comprehensive land use and proper infrastructure with efficient utilization of energy through technology innovation should be implemented. By 2020, the urban population is estimates to make up 80 percent of the total population; thus the application of compact city theory, which emphasizes urban design, convenient public transport, and accessibility of local services and jobs, are needed to reduce dependencies on private motor vehicles and traffic congestion that contributed to higher CO<sub>2</sub> emissions. Likewise, with a convenient urban infrastructure and layout, it is possible to encourage societies to use public transportation or walking and cycling.
2. Transportation is a major energy user and CO<sub>2</sub> emitter in urban areas. The Federal Territory of Kuala Lumpur has an estimated average of two cars for each resident. Moreover, the usage of public transport in Malaysia has been reported to be 16 percent, which is the lowest among the Asian peers. For the purpose of CO<sub>2</sub>

reduction, Green Technology Malaysia has encouraged the use of electricity vehicles and the deployment of 2000 electrical busses by the year 2020.

3. Green vegetation in the form of tree planting is another approach to fight CO<sub>2</sub> emissions and cooling the urban environment due to its ability to absorb approximately 1000 kg of CO<sub>2</sub> per tree.
4. Building (including residential, office, and commercial building) is another element to be consider when developing urban areas. It accounts for approximately 40 percent of global energy consumption and 25 percent of GHG emissions with a large portion being used for cooling, ventilation, lighting, appliances, etc. Additionally, it offers promising opportunities for saving energy and CO<sub>2</sub> emissions. In Malaysia, it approximately consumes 14.3 percent of the overall energy and 53 percent of electrical energy being consumed in residential and commercial sectors. Thus, utilizing renewable energy and energy-efficiency appliances and office equipment can reduce energy consumption and CO<sub>2</sub> emissions. Thus far, KeTTHA's Low Energy Office (LEO) building, the Malaysia Green Technology Corporation (MGTC) Zero Energy Office (ZEO), and Diamond building are three examples of building with energy efficiency and renewable energy. For developing residential buildings, the installation of a PV system is another practical strategy for reducing CO<sub>2</sub> emissions.
5. To build all of the above will require a large amount of investment. In this case, the policymaker should focus on the investment on green technology instead of dirty and obsolete technology, which could harm current and future generations. Thus far, through the Government Transportation Program and the 10<sup>th</sup> Malaysia Plan, the Malaysian government has initiated the adoption of green mobility by improving public transportation such as LRT, buses, and mass rapid transit (MRT).
6. The government must work hand in hand with local entities such as nongovernmental organization and educational institutions to increase public awareness on renewable energy and clean environments
7. Financial institutions have to play their role by (i) providing financial assist to the building developer to construct green buildings, thus such building should be widely available in the market; (ii) providing financial assist to private dwellers to renovate their house and change the existing building envelope with green criteria.
8. Finally, another practical way is to implement carbon tax due to its ability to shift relative price, stimulate the economic and urbanization development, and substitution of fossil fuels with renewable energy.

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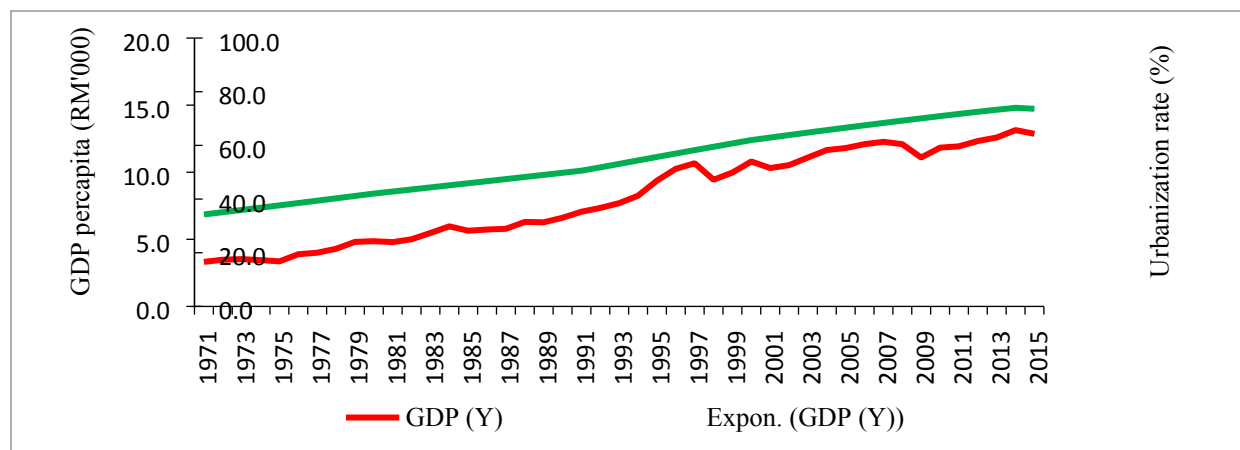


Figure 1: GDP per capita and urbanization trend for 1971–2015.

Sources: The World Bank (2016) (<http://data.worldbank.org/>)

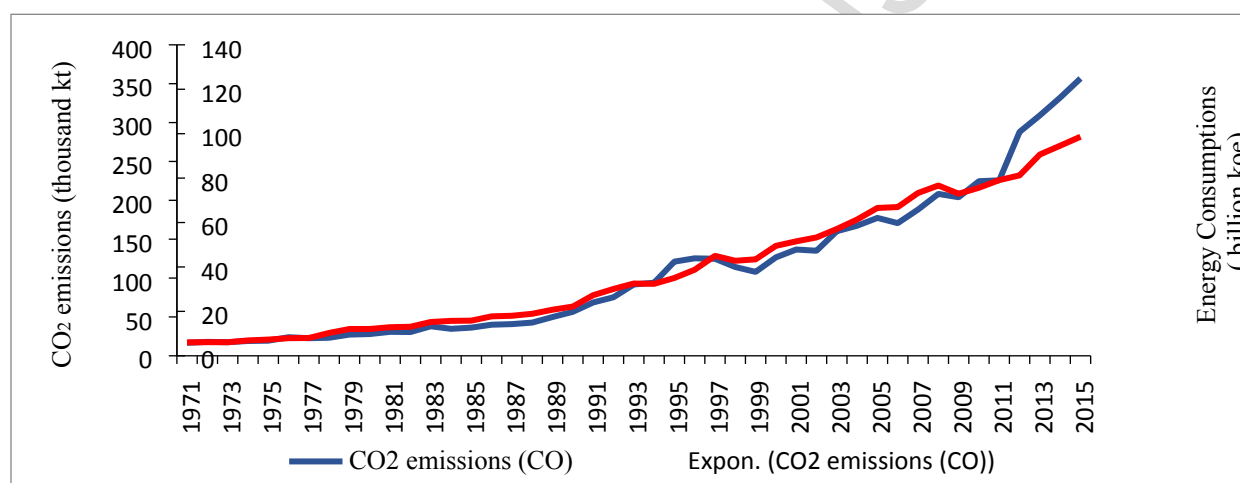


Figure 2: CO<sub>2</sub> emissions and energy consumption trend for 1971–2015

Sources: The World Bank (2016) (<http://data.worldbank.org/>)

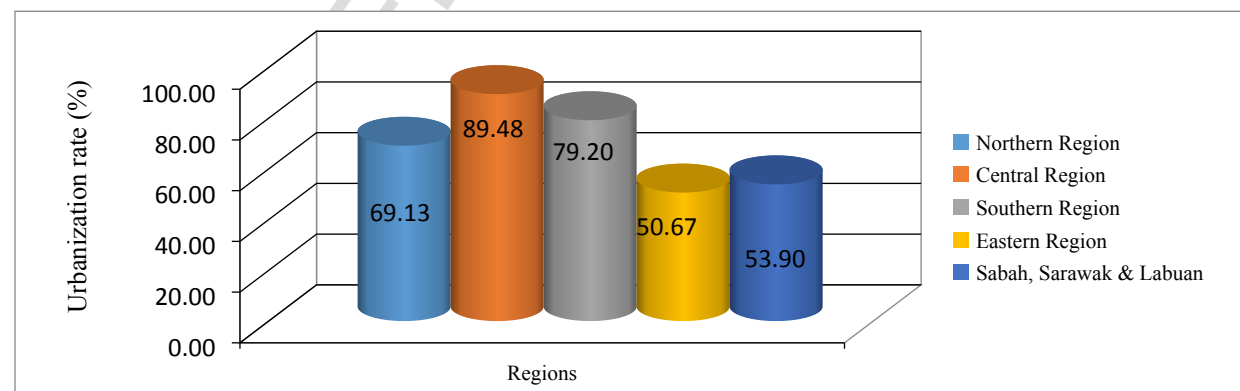


Figure 3: Level of urbanization in Malaysia

Source: Department of Statistic Malaysia (DOSM) (<https://www.statistics.gov.my/index>)

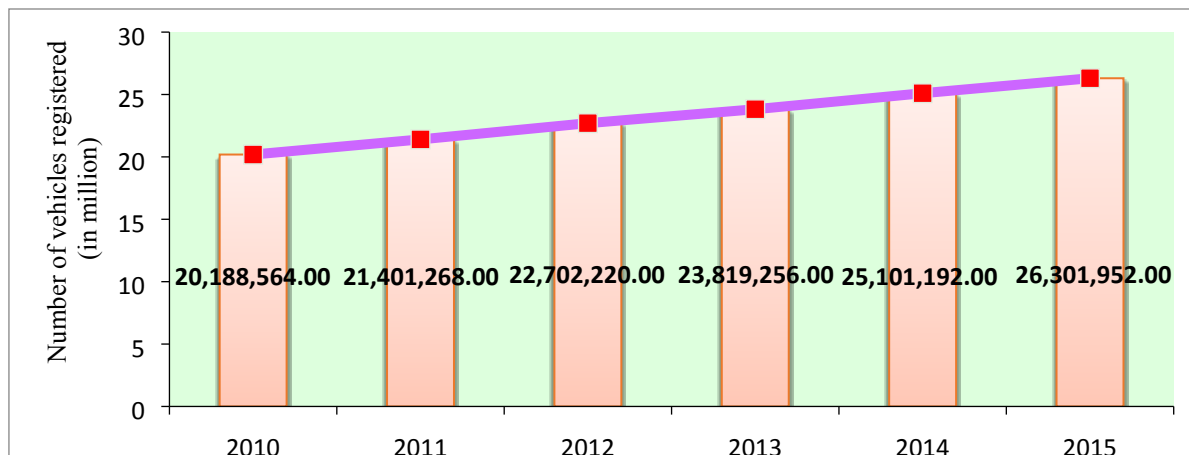


Figure 4: Trend and Number of vehicles registered in Malaysia.

Source: Road transport Department Malaysia (<http://www.jpj.gov.my>)

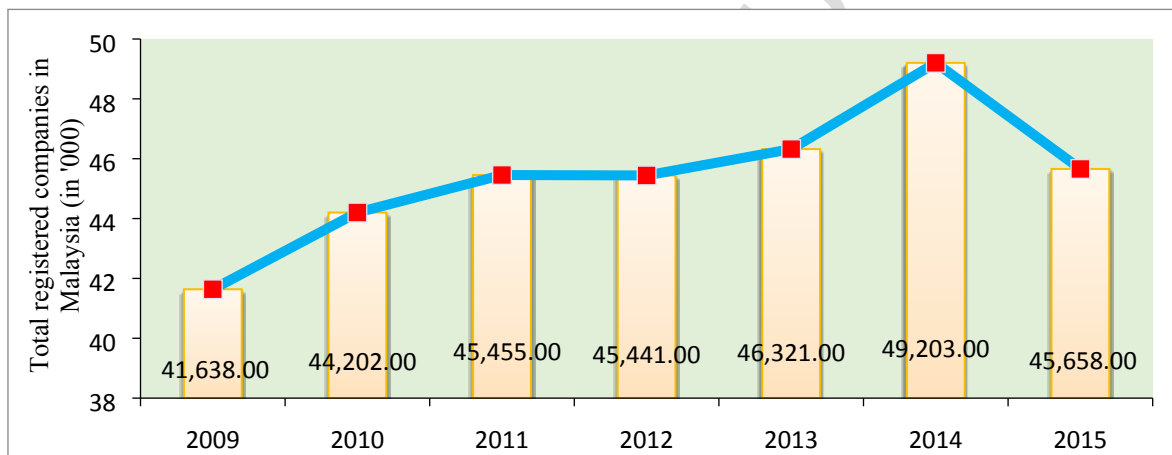


Figure 5: Trend and Total number of companies registered in Malaysia

Source: Company commission of Malaysia. Annual Report (<http://www.ssm.com.my>)

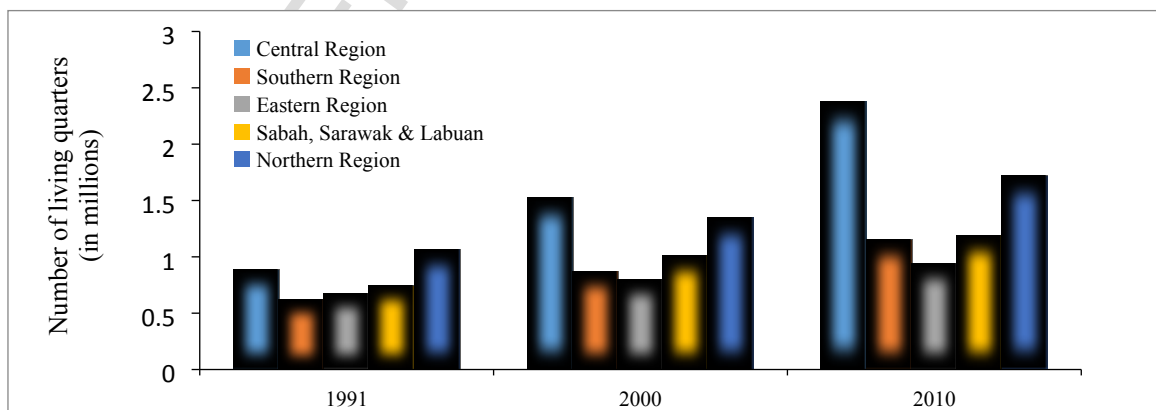


Figure 6: Number of living quarters in Malaysia

Source: Department of Statistic Malaysia (DOSM) (<https://www.statistics.gov.my>)

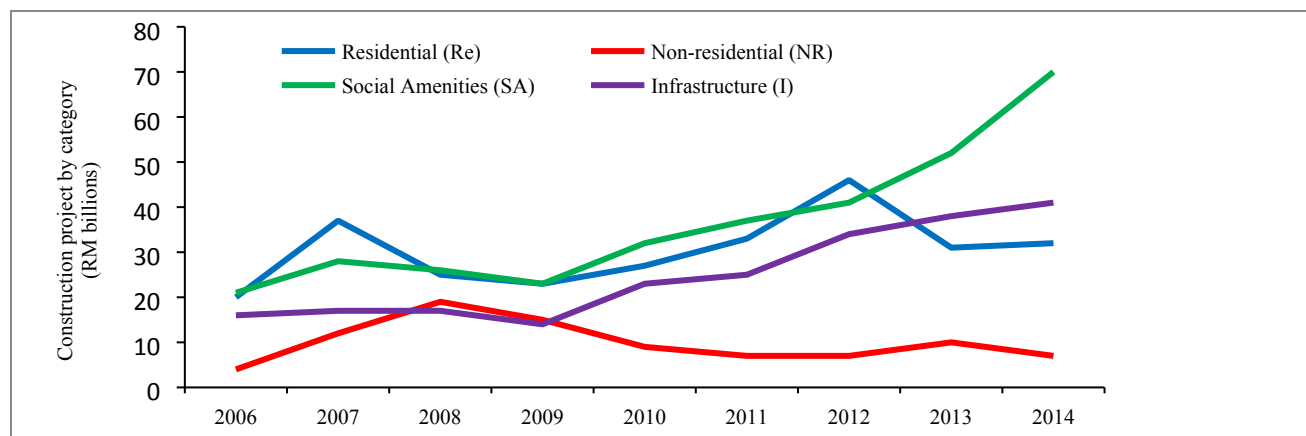


Figure 7: Value of construction project by categories in Malaysia

Source: Construction Industry Development Berhad (CIDB) Malaysia (2014) Annual Report (<http://www.cidb.gov.my>)

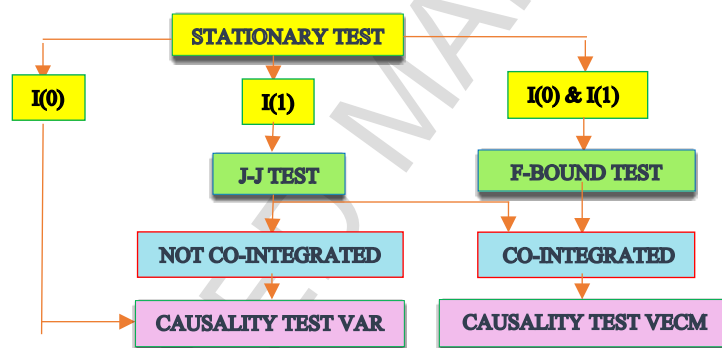
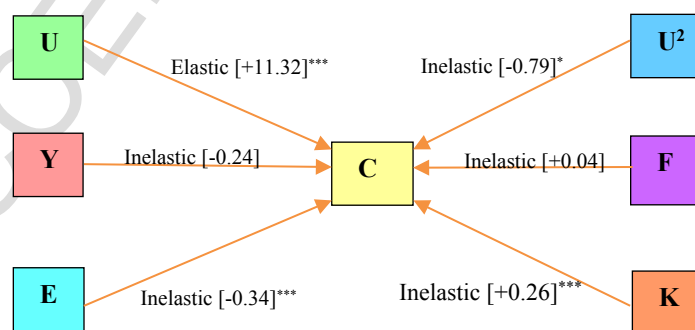
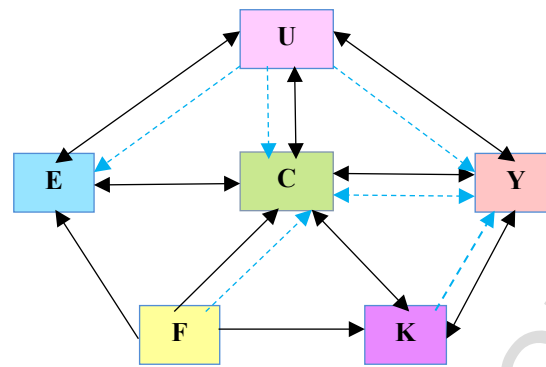


Figure 8: Estimation Procedure



Notes: (1)\*\*\*, \*\*, and \* as defined in table 5. (2) Diagnostic test: Jarque-Bera = 1.02 (0.59); Breusch-Godfrey Serial Correlation = 6.65 (0.08); Breusch-Pagan-Godfrey = 25.23 (0.50); ARCH = 2.45 (0.11); Ramsey RESET = 0.45 (0.51); (3)  $ect_{t-1} = -3.39$  (0.00).

Figure 9: Long-run elasticity of CO<sub>2</sub> emissions toward its determinants



Note: —> long-run causality; - - -> short-run causality

Figure 11: Direction of causality relationship among variables

Table 1: Summary of Literature Review

Authors	Countries	Variables Employed	Results		
			Impact of U to CO <sub>2</sub> / Relationship	Short-Run Causality	Long-Run Causality
Liddle & Lung (2010)	17 developed countries	C, Po, U, Tec, Y	[+]	n/a	n/a
Sadorsky (2014)	16 emerging countries	C, U	[+]	n/a	a/a
Wang et al. (2016)	BRIC	C, U	[+]	n/a	U → C
Wang et al. (2016b)	ASEAN	C, E, U	[+]	U → C	U → C
Poumanyvong & Kaneko (2010)	99 countries	C, Y, U, In, E, EI	[+]	n/a	n/a
Martinez-Zarzoso & Maruotti (2011)	88 developing countries	C, U, EE, E, In.	∩	n/a	n/a
Al-Mulali et al. (2012)	7 regions	C, U, E	n/a	n/a	C ↔ U
Al-Mulali et al. (2013)	MENA countries	C, U, E	[+] in UMIC [-] in LIC	C ↔ U	C ↔ U
Shahbaz et al. (2016)	Malaysia	C, U, E, K, To	U	n/a	U → C
He et al. (2016)	China	C, Y, Po, U, EI In	[-]	n/a	n/a
Zi et al. (2016)	China	C, U, Y	∩	n/a	n/a

Notes: CO<sub>2</sub> emissions = C; Energy consumption = E; GDP = Y; Urbanization = U; Population = Po; Capital = K; Trade Openness = TO; Energy Efficiency = EE; Energy Intensity = EI; Industrialization = In; Technology – Tec  
 → unidirectional; ↔ bidirectional; n/a= neutral; ∩ = inverted U-shaped; U= U-shaped; [+] = positive; [-] = negative; UMIC = upper middle income countries; LIC = low income countries.

Table 2: Variables Details

Variables	Proxy	Unit of measurement	Source	Used by
C	CO <sub>2</sub> Emissions	Mt per capita	WDI	Sugiawan & Managi (2016) Brown & McDonough (2016)
	Total population			
Y	Gross Domestic Product	RM per capita (2010 =100)	WDI	Sugiawan & Managi (2016) Brown & McDonough (2016)
	Total population			
U	Urban population	Percentage	WDI	Wang et al. (2017) Rafiq et al. (2016) Al-Mulali et al. (2013)
	Total population X 100			
K	Domestic Investment	RM per capita (2010 =100)	WDI	Shahbaz et al. (2016) Saidi & Hammami (2015)
	Total population			
E	Energy Consumption	Ktoe per capita	WDI	Sugiawan & Managi (2016) Brown & McDonough (2016)
	Total population			
F	Domestic Credit to private sector	Percentage	WDI	Islam et al. (2013) Omri et al. (2015)
	GDP X100			



Table 3: Results of Data Quality Tests

	LC	LY	LU	LK	LE	LF
Mean	8.25	9.70	3.96	8.26	7.72	4.39
Median	8.44	9.77	3.97	8.48	7.83	4.62
Maximum	9.28	10.43	4.3	9.08	10.54	5.06
Minimum	7.30	8.78	3.53	6.98	8.71	3.11
Std. Dev	0.62	0.48	0.23	0.61	0.57	0.54
Skewness	-0.04	-0.20	-0.17	-0.47	-0.30	-0.96
Kurtosis	1.59	-1.79	1.74	2.04	1.81	2.72
J-B	3.74	3.04	3.17	3.39	3.30	7.19
P-Value	0.15	0.22	0.20	0.18	0.09	0.03
Observation (n)	45	45	45	45	45	45
LC	1					
LY	0.99	1				
LU	0.98	0.99	1			
LK	0.94	0.94	0.91	1		
LE	0.98	0.99	0.99	0.93	1	
LF	0.83	0.86	0.85	0.88	0.87	1

Note: All inter-relationship between the variables are significant at 1 percent level.

Source: Output of EVIEWS package version 9.

Table 4: Types and Interpretation of Elasticities

Coefficients	Type	Interpretation
$ \alpha_i  < 1$	Inelastic	1% increase in IVs, increase* CO <sub>2</sub> emissions less than 1%
$ \alpha_i  = 1$	Unitary elastic	1% increase in IV, increase* CO <sub>2</sub> emissions with the same percentage
$ \alpha_i  > 1$	Elastic	1% increase in IV, increase* CO <sub>2</sub> emissions more than 1%

Adapted from Ivy-Yap and Bekhet (2015); IVs = independent variables (E, K, L, F, Y and U); \* = Decrease if the original  $\alpha_i$  in negative; i = 1, ..., 7

Table 5: Stationary Test Results

Variables & Stationary level		M <sub>za</sub> statistics	Critical Value			Decision
			1%	5%	10%	
LC	I(0)	-10.60	-23.80	-17.30	-14.20	I(1)
	I(1)	-20.80**				
LE	I(0)	-8.36				I(1)
	I(1)	-21.25**				
LF	I(0)	-1.67				I(1)
	I(1)	-20.77***				
LK	I(0)	-12.89				I(1)
	I(1)	-19.63**				
LU	I(0)	-43.69***				I(0)
	I(1)	-5.26				
LY	I(0)	-5.22				I(1)
	I(1)	-21.26**				

Note: \*\*\*, \*\*, and \* indicate 1%, 5%, and 10% level of significant respectively.

Source: Output of EVIEWS package version 9.

Table 6: Results of F-Bounds Test

Estimated Models	F-statistic	Critical Value for I(0)			Critical Value for I(1)			Decision (√ / X)
		1%	5%	10%	1%	5%	10%	
LC   LE, LF, LK, LU, LU <sup>2</sup> , LY	12.04***	3.80	2.79	2.35	5.64	4.21	3.59	√
LE  LC, LF, LK, LU, LU <sup>2</sup> , LY	5.23**							√
LF  LC, LE, LK, LU, LU <sup>2</sup> , LY	8.85**							√
LK  LC, LF, LE, LU, LU <sup>2</sup> , LY	6.89***							√
LU  LC, LE, LF, LK, LY	2.68							X
LY  LC, LE, LF, LK, LU, LU <sup>2</sup>	8.78***							√
Include observation (n) = 43;      K= 6;      H <sub>0</sub> : No long run relationship exist								

Note: (1) \*\*\*, \*\*, and \* as define in table 5. (2) Critical value obtained from Narayan (2005) for unrestricted intercept and no Trend (case III); (3) [√] represent co-integrated; [X] represent not co-integrated.

Source: Output of EVIEWS package version 9.

Table 7: VECM Granger Causality Results

Model	Chi-Square Statistics						Coefficient	t-Statistic
	$\sum \Delta LC_{t-j}$	$\sum \Delta LY_{t-j}$	$\sum \Delta LU_{t-j}$	$\sum \Delta LK_{t-j}$	$\sum \Delta LE_{t-j}$	$\sum \Delta LF_{t-j}$	$E_{ct,t-1}$	
$\Delta LC_t$		7.99***	12.80***	2.30	1.34	6.65***	-0.71***	-5.98
$\Delta LY_t$	4.68**		7.39***	3.34**	0.90	1.29	-0.18**	2.69
$\Delta LU_t$	0.23	1.33		1.86	3.28	1.98	-0.01**	-2.57
$\Delta LK_t$	1.38	4.46**	1.52		2.10	0.13	-0.48*	-1.83
$\Delta LE_t$	1.74	1.18	5.27**	0.06		0.11	-0.29**	-2.60
$\Delta LF_t$	0.22	0.38	0.03	1.75	0.05		0.19	0.85

Note: \*\*\*, \*\*, and \* as defined in table 5.

Source: Output of EVIEWS package version 9.

## Appendix:

### Lag length selection for co-integration

Lag	AIC	SC
0	-11.40	-11.15
1	-22.31	-20.55*
2	-23.30	-20.04
3	-23.00	-18.23
4	-23.33*	-17.06

Notes: \*\* indicates lag order selected by the criterion. (each test at 5% level);

AIC: Akaike information criterion; SC: Schwarz information criterion;

Source: Output of EVIEWS package version 9.

Co-integration test via Engle Granger 2 steps procedure:

H<sub>0</sub> : The long run relationship among variables exist.

Exogenous: None

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-4.42	0.00
Test critical values:		
1% level	-2.61	
5% level	-1.94	

10% level

-1.61

\*MacKinnon (1996) one-sided p-values.

ARDL Cointegrating And Long Run Form

Dependent Variable: LC

Selected Model: ARDL(3, 4, 4, 4, 3, 2, 2)

Date: 11/28/16 Time: 07:42

Sample: 1971 2015

Included observations: 41

## ECM

Variable	Coefficient	Std. Error	t-Statistic	Prob.
$\Delta LC$	1.56	0.21	7.38	0.00
$\Delta LY$	1.96	0.49	4.00	0.00
$\Delta LU$	-101.92	126.93	-0.80	0.43
$\Delta LU^2$	16.96	15.98	1.06	0.30
$\Delta LK$	-0.56	0.13	-4.16	0.00
$\Delta LE$	0.70	0.12	5.53	0.00
Constant	-71.87	6.39	-11.24	0.00
$ECT_{t-1}$	-3.39	0.30	-11.24	0.00

$$ECT = LC - (-0.2394*LY + 11.3173*LU - 0.7949*LU^2 + 0.2595*LK - 0.3388*LE + 0.0428*LF)$$

## Long Run Elasticities

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LY	-0.23	0.38	-0.61	0.54
LU	11.32	3.90	2.89	0.01
$LU^2$	-0.79	0.42	-1.88	0.08
LK	0.26	0.09	2.85	0.01
LE	-0.34	0.10	-3.31	0.00
LF	0.04	0.04	0.88	0.39