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Muhammad Shahbaz and Nanthakumar Loganathan and  
Ahmed Taneem Muzaffar and Khalid Ahmed and  
Muhammad Ali Jabran

COMSATS Institute of Information Technology, Lahore Campus,  
Pakistan, Universiti Sultan ZainalAbidin, University of Western  
Sydney, Sukkur Institute of Business Administration , Pakistan,  
COMSATS Institute of Information Technology, Lahore Campus,  
Pakistan

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## **How Urbanization Affects CO<sub>2</sub> Emissions in Malaysia? The Application of STIRPAT Model**

**Muhammad Shahbaz**

Energy Research Centre  
COMSATS Institute of Information Technology,  
Lahore Campus, Pakistan  
Email: shahbazmohd@live.com

**Nanthakumar Loganathan**

Faculty of Economics and Business Management  
Universiti Sultan ZainalAbidin  
21300 Kuala Terengganu, Terengganu, Malaysia  
Email: n4nantha@yahoo.com

**Ahmed Taneem Muzaffar**

School of Business  
University of Western Sydney  
Locked Bag 1797, Penrith, NSW 2751, Australia  
School of Business, University of Notre Dame, Australia  
Email: taneemm@gmail.com

**Khalid Ahmed**

Sukkur Institute of Business Administration (Sukkur-IBA)  
Airport Road, Sukkur 65200, Pakistan  
Email: khalid.ahmed@iba-suk.edu.pk

**Muhammad Ali Jabran**

Department of Management Sciences  
COMSATS Institute of Information Technology, Lahore, Pakistan  
Email: majqamar@ciitlahore.edu.pk

**Abstract:** We investigate the impact of urbanisation on CO<sub>2</sub> emissions by applying the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) in the case of Malaysia over the period of 1970Q1-2011Q4. Empirically, after testing the integrating properties of the variables using unit root test, we applied the Bayer-Hanck combined cointegration approach to examine the cointegration relationship between the variables. Further, we tested the robustness of long-run relationship in the presence of structural breaks using ARDL bounds testing approach. The causal relationship between the variables is investigated by applying the VECM Granger causality test. Our results validate the existence of cointegration in the presence of structural breaks. The empirical results exposed that economic growth is a major contributor to CO<sub>2</sub> emissions. Besides, energy consumption raises emissions intensity and capital stock boosts energy consumption. Trade openness leads affluence and hence increases CO<sub>2</sub> emissions. More importantly, we find that the relationship between urbanisation and CO<sub>2</sub> emissions is U-shaped i.e. urbanisation initially reduces CO<sub>2</sub> emissions, but after a threshold level, it increases CO<sub>2</sub> emissions. The causality analysis suggests that the urbanization Granger causes CO<sub>2</sub> emissions.

**Keywords:** Urbanisation, Energy, Malaysia

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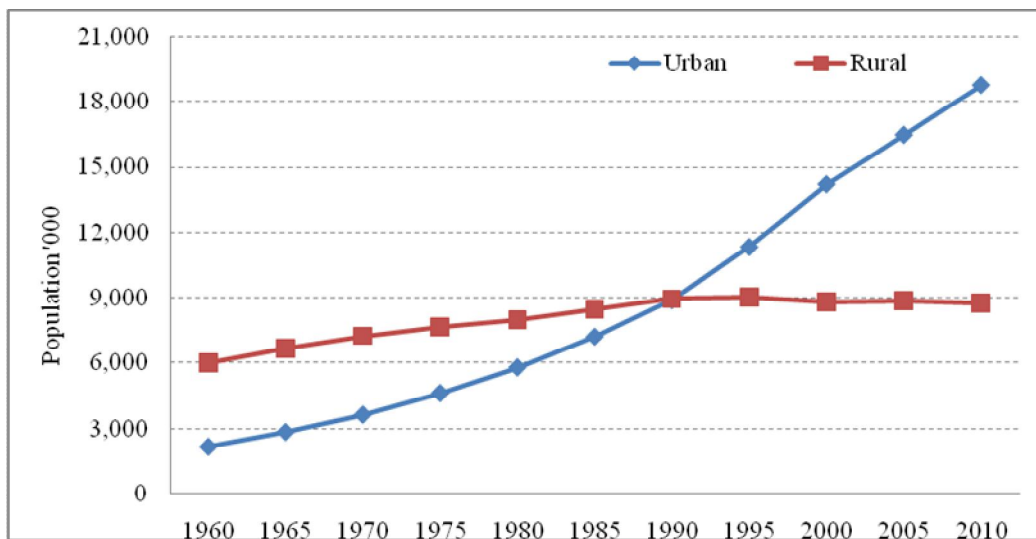
## **1. Introduction**

Urbanisation is a dynamic moderation phenomenon on social and economic capability from the rural areas (agrarian economic base) to urban areas (industrial economic base). Indeed, urbanisation with high urban densities also able to structure out the economic patterns of resource use and global environmental quality (Parikh and Shukla, 1995). In recent decades, due to economic globalization, many of the developing countries are undergoing economic transformation that is ultimately resulting in the physical expansion of urban areas. Currently, half of the world's population lives in urban areas and United Nations roughly estimates that the 64% of developing countries' population will be urbanized by 2050. However, the rapid wave of urbanisation in recent decades foresees high potential for increasing energy demand and severe environmental concerns, simultaneously. The rate of urbanisation in Africa and Asia regions is observed relatively fast, where the percentage of urban population is projected to be doubled between the year 2000 and 2030. Overall, the global urban population, which was 1.52 billion in 1970, is projected to reach 4.6 billion people by 2030, and much of its proportion will be in the Asian and African cities (UNDP, 2011). Urban areas may also be expected to be energy intensive with high tendency of economic activities (i.e. industrial manufacturing and transportation) that are mainly fossil fuel driven and cause environmental degradation.

Malaysia is a resource rich and culturally diverse country of East Asia. For past three decades, urban growth has been one of the important agenda of country's economic development. Since 1990s, Malaysia archived an average of 4.5% economic growth; meanwhile, urbanisation is also substantially increased, stimulating upward pressure on energy demand. According to Malaysia's census report, the rate of urbanisation has increased from 25% to 65% from 1960 to 2005, respectively. Furthermore, it is expected that by 2020, 3 quarters of the Malaysian population will be living in the urban areas (Tenth Malaysia Plan,

2010). In early 1980s, Malaysia has 4 major urban cities located in developing states consisting of more than 50% of the country's population, i.e. Klang Valley, Ipoh, Johor Bahru and Penang. On the contrary, the less developed states such as Terengganu, Kedah, Kelantan, Sabah and Sarawak have a low percentage of population living in the urban areas. This rural-urban driven migration also transformed the economic base of the country from agriculture to industrial. Most of rural people move to urban areas for seeking lucrative jobs and better living standard. Figure-1 shows the rural-urban divide of total population in Malaysia over the period of 1960-2010. It is estimated that by 2030 almost 80% of overall population will be living in urban cities (Population Distribution by Local Authority Areas and Mukim, 2010). Rapid urbanisation occurred in 1990s and this mainly caused by rural-urban migration activities along with high intensity of industrial development in the west coast of Malaysian Peninsula.

**Figure-1: Rural and Urban Population in Malaysia, 1960-2010**



In terms of rural township and regional land development in Malaysia, several other rural areas are proposed to develop such as DARA, KEJORA, KETENGAH and KESEDAR.

These rural areas are basically supported with rubber and oil palm agricultures without high demand for energy resources. Majority of the population living in urban settlement relatively enjoy high standards of living with quality infrastructure, electricity, telecommunication and clean water supply facilities. Although resource rich states such as Terengganu, Sabah, Sarawak and Pahang attract resource based industries, but most of the export based industries are located in the Malay Peninsula. Besides, this urban area is advantaged with accessibility, infrastructure, transportation and high skilled manpower. The recent study of Shahbaz et al. (2015) found strong causal links between urbanization and energy consumption in Malaysia. Therefore, there is a possibility that the urbanization also have direct or indirect relation with Carbon dioxide emission.

During the Malaysia's ninth five-year plan period (2010-2015), the government promotes 5 regional developments and accelerates growth in designated geographic areas. Meanwhile, it is being targeted under the tenth five-year plan for Malaysia that the role of regional development in country economic development will be accelerated by focusing around a limited number of high-density clusters in the corridors based on the sectoral and geographical advantages. The five corridors being developed in Malaysia are Iskandar Malaysia (Southern Peninsular Malaysia), Northern Corridor Economic Region (NCER), East Coast Economic Region (ECER), Sarawak Corridor Renewable Energy (SCORE) and Sabah Development Corridor (SDC). All these urban areas surely increase demand for energy and it leads to CO<sub>2</sub> emissions due to intense economic activities. That is the main interest of the authors to investigate the environmental impact of urbanisation in case of Malaysia.

The study contributes to the existing literature by investigating the relationship between urbanization and CO<sub>2</sub> emissions by using the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) function in case of Malaysia. We have applied the structural break unit root test to test the unit root problem. The Bayer-Hanck

(2013) cointegration approach is applied to test the existence of cointegration among the series and long run results are validated by using the ARDL bounds testing approach to cointegration. We note that cointegration is present among the variables. Furthermore, the relationship between urbanization and CO<sub>2</sub> emissions emerges as nonlinear, taking an inverted U-shaped characteristic<sup>1</sup>. Economic growth and energy consumption add in CO<sub>2</sub> emissions. Trade openness increases CO<sub>2</sub> emissions. The causality results expose that CO<sub>2</sub> emissions is Granger cause of urbanization.

## **2. A Review of Literature**

The theory of urban environmental transition reveals that how environmental aspects are related to urban development at the city level. As industrialization takes place within urban areas, cities accumulate wealth. This also leads to the higher level of atmospheric pollution. The growing numbers of wealthier citizens push demand for energy intensive products. However, with the help of awareness campaigns along with the astringent environmental regulations, the citizens may concern about the environmental issues. Nonetheless, the decreasing environmental quality and its negative impacts also urge affluent population to increase the use of environment friendly technology. Therefore, it is not clear whether the wealth effect would increase or decrease the pollution problem. Finally, the theory of compact city explains the advantages of urbanisation in which it claims that it leads to less environmental damage. The higher density of urbanisation helps to achieve the economies of scale thus leads to lower level of pollution. For example; Poumanyvong and Kaneko (2010) examine the dataset of 99 countries for the period of 1975-2005, and find a positive impact with the higher impact for the middle income group of the countries. Their

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<sup>1</sup> The inverted-U shaped between urbanization and CO<sub>2</sub> emissions reveals that urbanization is positively with CO<sub>2</sub> emissions and urbanization declines CO<sub>2</sub> emissions after a threshold level of urbanization.

findings show higher coefficient for urbanisation in the case of low income group countries compared to the high income group countries.

Urbanisation is defined as a process regrouping large permanent residents in moderately small areas and as results forming crowded metropolises. Further, urbanisation is migration of people from the agricultural area to non-agricultural area. Physical accumulation of people in urban areas generates a critical increase of costs, social disparities and negative impact on environment. Further urbanisation has a wide effect on energy consumption due to massive housing rate and growth of investment and industrialization among other factors. Dhal and Erdogan (1994), when investigating the relationship between urban population and oil consumption, found that the rise of urbanisation has a positive effect industrialization which raises oil demand. On the other hand, Solarin and Shahbaz (2013) also analyzed the relationship between economic growth, urbanisation and electricity consumption for Angola using several econometric estimation techniques and concluded long-run association among the variables and also found bidirectional Granger causality between urbanisation and electricity consumption in case of Angola.

These are different theories, i.e. ecological modernization theory, urban environmental transition theory and compact city theory (for details see, Sadorsky, 2014). The theory of ecological modernization states that, at low stages of development societies give priority to economic growth over environmental sustainability. As the societies become more affluent they become more concerned with environmental damage and try to find out ways in which the damage could be reduced. As a result transformation within an economy and society takes place through technological innovation, urbanisation, and move from secondary sector to tertiary sector (see, for instance, Crenshaw and Jenkins, 1996; Gouldson and Murphy, 1997; Mol and Spaargaren, 2000; Ahmed and Long, 2013; and Ahmed, 2014).



A number of cross-country studies empirically investigated the relationship between urbanisation and carbon emissions over the last few decades. Most of the earlier studies show that increase in urbanisation leads to higher level of carbon emissions. For instance, Parikh and Shukla (1995) found that urbanisation has positive impact on greenhouse gases in case of 83 developed and developing countries. Their estimate of carbon emissions elasticity of urbanisation is 0.036. Similar result is found by York et al. (2003) with a much larger dataset of 137 countries. Cole and Neumayer, (2004) utilize data of 86 countries and show that a 10% increase in urbanisation leads to 7% increase in carbon emissions. However, some of the studies carried out in recent years contradict with these findings. For example, in the context of developing countries, Fan et al. (2006) claim that there is a negative relationship between urbanisation and CO<sub>2</sub> emissions. In the case of 17 developed countries, Liddle and Lung (2010) conclude that the positive impact of urbanisation on carbon emissions is insignificant when carbon emissions are used in aggregate. A sectoral analysis using carbon emissions from transport sector, however, shows a positive and significant impact of urbanisation on carbon emissions.

Kalnay and Cal, (2005) put forward that urbanisation generates pressure on agriculture sector to overproduce. It has negative effects such as massive land use and raise of energy demand in agriculture sector. Bryant, (2005) found out that urbanisation is related to industrialization, technological involvement, globalization and migration. All these variables contribute to increasing energy demand. Hemmati, (2006) studied the impact of income and urbanisation on energy demand for Iran using annual data. He stated that urbanisation leads industrialization and commercialization that result of rising raw material demand and consumer goods which by the way affect energy demand. Halicioglu, (2007) used the vector error correction method Granger causality technique to determine the causal relationship between economic growth, energy prices, urbanisation and energy consumption in Turkey.

He pointed out that urbanisation Granger causes energy consumption in the long run but not vice versa. By examining the impact of demographic factors on energy consumption in European Union countries, York (2007) found that energy demand is source of fast urbanisation and industrialization in these economies. Taking Iran as country case, Abouie-Mehrzi et al. (2012) used energy demand function to explore the impact of population growth, urbanisation and affluence on energy consumption. The empirical results exposed that population growth, urbanisation and affluence on energy consumption have long run relationship and these variables raise energy demand.

Ren et al. (2014) employs the input-output (IO) approach to analyze the scale and structure of CO<sub>2</sub> emissions of several industrial sectors in China by establishing the relationship between energy intensity, per capita output, trade openness, foreign direct investment (FDI), trade comparative advantage, environment regulation, technology, and CO<sub>2</sub> emissions intensity. The relation between per capita output and CO<sub>2</sub> emissions is inverse N-type, and FDI and trade comparative advantage are two main elements increase CO<sub>2</sub> emissions in China. Meanwhile, Yazdi and Shakouri (2014) used cointegration analysis to capture the dynamic relationship between CO<sub>2</sub> emissions, energy consumption, economic growth, financial development and trade openness in Iran over the period of 1975-2011. The results confirm the existence of environmental Kuznets curve (EKC) hypothesis and Granger causality estimates indicate the unidirectional causality running from per capita real income, per capita energy consumption, financial development and urbanisation to per capita CO<sub>2</sub> emissions<sup>2</sup>. This finding is with the line with Liddle, (2014) findings, where there is positive relationship between urbanisation, energy consumption on CO<sub>2</sub> emission using cross-country time-variant data. Liddle and Lung, (2014) recent study using heterogeneous panel for 105

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<sup>2</sup> The EKC hypothesis indicates that initially economic growth increases CO<sub>2</sub> emissions but it declines CO<sub>2</sub> emissions after a threshold level of income per capita.

countries spanning 1971-2009 not able to detect long-run Granger causality for urbanisation and electricity consumption

Zou et al. (2014) used the EKC framework to identify the link between income, trade openness, energy intensity, industrial structure, population density and urbanisation on CO<sub>2</sub> emissions in China based on the ARDL estimates. The results show that, energy intensity and industrial structure is positively caused on CO<sub>2</sub> emissions, along with a little influence from trade openness. On other hand, the short-run environmental negative effect of urbanisation and long-run positive effect of population density are both significant, but energy intensity has positive relationship in the long-run and negatively significant in the short-run. Although, the federal government of China introduced energy-saving and emissions reduction policy, but the outcomes is still no improving much.

Ma and Du, (2012) explored the relationship between urbanisation, industrialization, energy prices and energy consumption for China. Their empirical results revealed that industrialization leads urbanisation and urbanisation is positively linked with energy consumption. This is a result of a rise in urban density. Moreover; impact of tertiary industrial value added has negative effect on energy use because of advanced technology used. The Chinese energy policies as well as environmental regulations have played a key role to reach this situation. Zhang and Lin, (2012) have also examined the impact of urbanisation on energy consumption by applying STIRPAT model for China. The results confirmed that urbanisation has a positive effect on energy demand; however it varies from region to another. Regional results showed that urbanisation lowers energy demand in West, Central and Eastern regions due to use of energy efficient technology. Empirical research also examines the issue using the model STIRPAT and reveals the nonlinear nature of the relationship. According to Zhao et al. (2014) and Sugar et al. (2014) China become the heaven for pollution because of fossil energy consumption and electricity production, heating

and industrial fuel use, urbanisation, agriculture activities, rural life demands, and trade openness are the main elements increases carbon flow in urban cities in China. Recently, Cao et al. (2015) reported that migration of population to Anhui province is main driver of environmental degradation. Wang and Zhao, (2015) also reported that urbanization deteriorates environment in less regions but energy intensity increases CO<sub>2</sub> emissions in developed regions of China.

Within the STIRPAT framework, Martinez-Zarzoso and Maruotti, (2011) show that the relationship is inverted-U shaped in nature in a panel of 88 developing countries over the period 1975-2003. Finally, Sadorsky (2014) uses the STIRPAT model to examine the case in 16 emerging countries over the period 1971-2009. He shows that estimated contemporaneous coefficients on energy intensity and affluence variables are positive and statistically significant. The result is fairly similar across different estimation techniques.

### **3. Model Building and Data Collection**

We follow the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model developed by Dietz and Rosa, (1994) and York et al. (2005). This model is rapidly investigated in existing literature to examine impact of socioeconomic changes on environmental degradation. Often, population is treated as independent variable to examine its impact on environmental quality. This model corrects the weakness of environmental Kuznets curves (EKC) where income per capita is used as independent variables and CO<sub>2</sub> emissions per capita as dependent variables but keeping the impact of population on environment unitary elastic. The point is that population elasticity of energy remains same in developed and developing economies. If the population elasticity of energy consumption varies in sample countries then the assumptions of EKC are also violated

(Poumanyong and Kaneko, 2010). The SIRPAT model, in its general form, can be expressed as follows:

$$E_t = \alpha EC^a P_t^b A_t^c T_t^d \mu_t \quad (1)$$

Where,  $E$  is energy pollutants,  $EC$  is energy consumption,  $P$  is population,  $A$  is affluence (economic growth),  $T$  is technology and  $\mu$  is error term. We extend this model by incorporating trade openness. Trade openness transfers advanced technology from the developed world towards emerging and developing economies which may be helpful in lowering energy pollutants. Trade openness promotes economic activity and hence economic growth. So, trade openness may affect energy consumption via income effect, technique effect and composite effect and hence CO<sub>2</sub> emissions. The augmented version of STIRPAT model is given below:

$$E_t = \alpha EC^a P_t^b A_t^c T_t^d O_t^e \mu_t \quad (2)$$

Where  $O_t$  is for trade openness (exports + imports). In line with Lean and Smyth (2010) and Shahbaz and Lean (2012), both sides of the equation are divided by population to obtain each series in per capita terms, leaving the impact of population constant. Taking logs, the linearized STIRPAT model is as follows:

$$\begin{aligned} \ln E_t = & \beta_1 + \beta_{EC} \ln EC + \beta_U \ln U + \beta_{U^2} \ln U^2 + \beta_Y \ln Y + \beta_K \ln K \\ & + \beta_{TR} \ln TR + \mu_t \end{aligned} \quad (3)$$

Where,  $\ln U_t$ ,  $\ln Y_t$ ,  $\ln K_t$  and  $\ln TR_t$  represent CO<sub>2</sub> emissions per capita, urbanisation per capita, real GDP per capita proxy for affluence, real capital use per capita and real trade openness per capita, respectively, in per capita terms each in natural logarithm; and  $\mu_t$  is a random error term. The data on all variables are gathered from the World Development Indicators (CD-ROM, 2012). The population series is used to convert all series into per capita. The data period of our study is 1971Q1-2011Q4. We use the *Interpolation Method* to convert the annual data of all the series into quarterly frequency<sup>3</sup>.

#### 4. Empirical Strategy

The standard procedure to test for cointegration between variables is to first test the stationary properties of each variables. The most frequently carried out tests for this purpose are the ADF (Dickey and Fuller, 1981); PP (Philip and Perron, 1988); DF-GLS (Elliot et al. 1996) and Ng-Perron (Ng and Perron, 2001). However, findings from these unit root tests could be biased under many circumstances. For instance, these test results suffer from small sample size bias and poor power properties as stated by Dejong et al. (1992). Thus unit root tests such as ADF, PP and DF-GLS may lead to over-rejection of the true null hypothesis or accepting the null when it is false. Although Ng-Perron, (2001) unit root test does not suffer from this particular problem, it provides biased results when structural breaks are present in the series. Under such circumstances, a more appropriate test is Clemente et al. (1998) test which takes care of the problems resulting from structural breaks and it has more power compared to the Perron and Volgelsang (1992), Zivot-Andrews (1992), ADF, PP and Ng-Perron unit root tests. The limitation of Perron and Volgelsang, (1992) and Zivot-Andrews, (1992) unit root tests is that they are appropriate if the series has one potential structural break. The Clemente et al. (1998) test is an improvement over these tests since it extends the

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<sup>3</sup> We used the interpolation method in EVIEWS-7 for converting the annual data of real GDP into quarterly data. This method was followed by Romero, (2005) and McDermott and McMenamin, (2008).

Perron and Volgelsang, (1992) method to allow for two structural breaks in the mean. In this case the null hypothesis  $H_0$  against alternate  $H_a$  is as follows:

$$H_0 : x_t = x_{t-1} + a_1DTB_{1t} + a_2DTB_{2t} + \mu_t \quad (4)$$

$$H_a : x_t = u + b_1DU_{1t} + b_2DTB_{2t} + \mu_t \quad (5)$$

In equation-5 and equation-6,  $DTB_{1t}$  is the pulse dummy variable which equals 1 if  $t = TB_1 + 1$  and zero otherwise. In addition,  $DU_{it} = 1$  if  $TB_i < t (i = 1,2)$  and zero otherwise. The modification the mean is captured by  $TB_1$  and  $TB_2$  time periods. To consider a simplistic version, we assume that  $TB_i = \delta_i T (i = 1,2)$  where  $1 > \delta_i > 0$  while  $\delta_1 < \delta_2$  (see Clemente et al. 1998). If innovative outliers cause the two structural breaks, unit root hypothesis can be examined with the help of equation-5 in the following form:

$$x_t = u + \rho x_{t-1} + d_1DTB_{1t} + a_2DTB_{2t} + d_3DU_{1t} + d_4DU_{2t} + \sum_{j=1}^k c_j \Delta x_{t-1} + \mu_t \quad (6)$$

The above equation estimates minimum value of t-ratio through simulations. The simulated value of the t-ratio then identifies all break points, provided that the value of autoregressive parameter is constrained to 1. We derive the asymptotic distribution of the estimate, by assuming that  $\delta_2 > \delta_1 > 0, 1 > \delta_2 - 1 > \delta_0$  where,  $\delta_1$  and  $\delta_2$  obtain the values in interval i.e.  $[(t+2)/T, (T-1)/T]$  by considering the largest window size. The assumption of  $\delta_1 < \delta_2 + 1$  ensures that cases where break points exist in repeated periods are purged (see Clemente et al. 1998). A two-step approach is used to test the unit root hypothesis, if shifts

are explained by the additive outliers. In the 1<sup>st</sup> step, the deterministic trend is removed and the following equation is estimated:

$$x_t = u + d_5 DU_{1t} + d_6 DU_{2t} + \hat{x} \quad (7)$$

The second step attempts to search for the minimum t-ratio to test the hypothesis that  $\rho = 1$ , using the following equation:

$$\hat{x}_t = \sum_{i=1}^k \phi_{1i} DTB_{1t-i} + \sum_{i=1}^k \phi_{2i} DTB_{2t-i} + \rho \hat{x}_{t-1} + \sum_{i=1}^k c_i \Delta \hat{x}_{t-1} + \mu_t \quad (8)$$

To ensure that the  $\min t_{\rho}^{IO}(\delta_1, \delta_2)$  congregates i.e. converges in distribution, a dummy variable

is included in the estimated equation in the following

form:  $\min t_{\rho}^{IO}(\delta_1, \delta_2) \rightarrow \inf_{\gamma} = \wedge \frac{H}{[\delta_1(\delta_2 - \delta_1)]^{1/2} K^{1/2}}$  with

$$\begin{aligned} H = & \frac{(\lambda_2 - \lambda_1)(1 - \lambda_2)}{2} [W(1)^2 - 1] - (1 - \lambda_2)(\lambda_2 - \lambda_1) W(\lambda_1) \int_0^1 W(r) dr \\ & + (1 - \lambda_2) [\lambda_2 W(\lambda_1) - \lambda_1 W(\lambda_2)] \int_{\lambda_1}^1 W(r) dr + \lambda_1 [(1 - \lambda_1) W(\lambda_2) - (1 - \lambda_2) W(\lambda_1)] \\ & - (\lambda_2 - \lambda_1) W(1) \int_{\lambda_2}^1 W(r) dr \end{aligned}$$

$$\begin{aligned} K = & \lambda_1 (\lambda_2 - \lambda_1) (1 - \lambda_2) \int_0^1 W(r^2) dr - (1 - \lambda_2) \lambda_2 \left[ \int_{\lambda_1}^1 W(r) dr \right]^2 - (1 - \lambda_1) \lambda_1 \left[ \int_{\lambda_2}^1 W(r) dr \right]^2 \\ & - (1 - \lambda_2) (\lambda_2 - \lambda_1) \left[ \int_0^1 W(r) dr \right]^2 + 2(1 - \lambda_2) \left[ \lambda_1 \int_{\lambda_2}^1 W(r) dr + (\lambda_2 - \lambda_1) \int_0^1 W(r) dr \right] \int_{\lambda_1}^1 W(r) dr \end{aligned}$$



where  $\Rightarrow$  shows weak convergence. The Wiener process on  $C[0, 1]$  is defined by  $W(r)$ . The estimates of  $\lambda_1$  and  $\lambda_2$  is denoted by  $\lambda \in \Lambda$  which is also belonged to closed  $[0, 1]$  subset interval.

#### 4.1 The ARDL Bounds Testing Approach

Due to the limitations of the traditional methods to investigate cointegration properties, to check the robustness of our results we rely on the structural break autoregressive distributed lag model or the ARDL bounds testing approach to cointegration which takes care of structural breaks present in the series. The ARDL bounds testing approach to cointegration has certain advantages such as its flexibility in relation to the integrating order of the variables whether variables are found to be stationary at  $I(1)$  or  $I(0)$  or  $I(1) / I(0)$ . Moreover, in the presence of small sample size this method is suitable as confirmed by the Monte Carlo investigation (Pesaran and Shin, 1999). Besides, a simple linear transformation helps us derive a dynamic unrestricted error correction model (UECM) from the ARDL bounds testing approach which integrates the short run dynamics with the long run equilibrium without losing any information for the long run. The empirical structure of the ARDL bounds testing approach to cointegration is as follows:

$$\begin{aligned} \Delta \ln E_t = & \alpha_1 + \alpha_{DUM} DUM + \alpha_{EC} \ln EC + \alpha_U \ln U_{t-1} + \alpha_{U^2} \ln U_{t-1}^2 + \alpha_Y \ln Y_{t-1} + \alpha_K \ln K_{t-1} + \alpha_O \ln O_{t-1} \\ & + \sum_{i=1}^p \alpha_i \Delta \ln EC_{t-i} + \sum_{j=0}^t \alpha_j \Delta \ln U_{t-n} + \sum_{k=0}^t \alpha_k \Delta \ln U_{t-1}^2 + \sum_{l=0}^q \alpha_l \Delta \ln Y_{t-j} + \sum_{m=0}^s \alpha_m \Delta \ln K_{t-1} \\ & + \sum_{n=0}^t \alpha_n \Delta \ln O_{t-m} + \mu_t \end{aligned} \quad (9)$$

Where,  $\ln E_t$ ,  $\ln EC_t$ ,  $\ln U_t$ ,  $(\ln U_t^2)$ ,  $\ln Y_t$ ,  $\ln K_t$  and  $\ln TR_t$  natural log of CO<sub>2</sub> emissions per capita, natural log of energy consumption per capita, natural log of urbanisation (natural log

of squared term of urbanisation), natural log of real GDP per, natural log of capitalization and natural log of trade openness per capita.  $\Delta$  is for difference operator and  $\mu_t$  denotes residual term. To determine the existence of cointegration we compute F-statistics to compare with upper and lower critical bounds generated by Pesaran et al. (2001). The null hypothesis to determine the existence of the long run relationship between the variables is  $H_0 : \alpha_E = \alpha_{EC} = \alpha_U = \alpha_{U^2} = \alpha_Y = \alpha_K = \alpha_{TR} = 0$  against alternate hypothesis ( $H_a : \alpha_E \neq \alpha_{EC} \neq \alpha_U \neq \alpha_{U^2} \neq \alpha_Y \neq \alpha_K \neq \alpha_{TR} = 0$ ) of cointegration for equation-6. According to Pesaran et al. (2001) critical bounds, if computed F-statistic is more than upper critical bound (UCB) there exists a cointegration between the variables. If computed F-statistic does not exceed lower critical bound (LCB) the variables are not cointegrated and does not show a long run relationship. The decision in respect of cointegration between the variables is uncertain if computed F-statistic is between lower and upper critical bounds. We use the critical bounds generated by Pesaran et al. (2001), instead of Narayan (2005), because the size of our sample is large with 160 observations and therefore using lower and upper critical bounds developed by Pesaran et al. (2001) is suitable.

#### **4.2 The VECM Granger Causality Approach**

As argued by Engle and Granger, (1987) that vector error correction model (VECM) is an appropriate method to examine the causality between the variables when series are integrated at I(1) and cointegration relationship exists between the series, we apply the VECM to investigate the causality. Empirically, the VECM Granger causality approach is modeled as follows:

$$\begin{aligned}
(1-L) \begin{bmatrix} \ln E_t \\ \ln U_t \\ \ln U_t^2 \\ \ln EC_t \\ \ln Y_t \\ \ln K_t \\ \ln O_t \end{bmatrix} &= \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ \alpha_5 \\ \alpha_6 \\ \alpha_7 \end{bmatrix} + \sum_{i=1}^p (1-L) \begin{bmatrix} b_{11i} & b_{12i} & b_{13i} & b_{14i} & b_{15i} & b_{16i} & b_{17i} \\ b_{21i} & b_{22i} & b_{23i} & b_{24i} & b_{25i} & b_{26i} & b_{27i} \\ b_{31i} & b_{32i} & b_{33i} & b_{43i} & b_{53i} & b_{36i} & b_{37i} \\ b_{41i} & b_{42i} & b_{43i} & b_{44i} & b_{45i} & b_{46i} & b_{47i} \\ b_{51i} & b_{52i} & b_{53i} & b_{54i} & b_{55i} & b_{56i} & b_{57i} \\ b_{61i} & b_{62i} & b_{63i} & b_{64i} & b_{65i} & b_{66i} & b_{67i} \\ b_{71i} & b_{72i} & b_{73i} & b_{74i} & b_{75i} & b_{67i} & b_{77i} \end{bmatrix} \times \begin{bmatrix} \ln E_{t-1} \\ \ln U_{t-1} \\ \ln U_{t-1}^2 \\ \ln EC_t \\ \ln Y_{t-1} \\ \ln K_{t-1} \\ \ln O_{t-1} \end{bmatrix} \\
&+ \begin{bmatrix} \alpha \\ \beta \\ \delta \\ \theta \\ \vartheta \\ \phi \\ \theta \end{bmatrix} ECT_{t-1} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \\ \varepsilon_{6t} \\ \varepsilon_{7t} \end{bmatrix}
\end{aligned} \tag{10}$$

Here  $(1-L)$  indicates difference operator and lagged residual term is  $ECT_{t-1}$  derived from the long run relationship, while  $\varepsilon_{1t}, \varepsilon_{2t}, \varepsilon_{3t}, \varepsilon_{4t}, \varepsilon_{5t}, \varepsilon_{6t}$  and  $\varepsilon_{7t}$  are error terms. These terms are supposed to show the property of homoscedasticity i.e. constant variance. The statistical significance of the coefficient of lagged error term i.e.  $ECT_{t-1}$  reveals the long run causal relationship between the variables while the short run causality is shown by statistical significance of F-statistic using Wald-test by incorporating differences and lagged differences of independent variables in the model. Moreover, the joint significance of the lagged error term with differences and lagged differences of independent variables provides joint long-and-short run causality. For example,  $b_{12,i} \neq 0 \forall_i$  implies that urbanisation Granger-causes CO<sub>2</sub> emissions. On the other hand,  $b_{21,i} \neq 0 \forall_i$  shows that CO<sub>2</sub> emissions Granger causes urbanization.

## 5. Results Interpretations

The descriptive statistics reveal that CO<sub>2</sub> emissions, urbanization, economic growth, energy consumption and trade openness are normally distributed (See, Table-1). The

correlation analysis indicates that urbanisation, economic growth, energy consumption and trade openness are positively correlated with CO<sub>2</sub> emissions. The positive correlation is found of economic growth, energy consumption and trade openness to urbanisation. Energy consumption and trade openness are positively correlated with economic growth. The positive correlation exists between energy consumption and trade openness.

**Table-1. Descriptive Statistics and Correlation Matrix**

Variables	$\ln E_t$	$\ln U_t$	$\ln Y_t$	$\ln EC_t$	$\ln O_t$
Mean	0.3197	0.9927	2.3172	1.7962	2.3851
Median	0.3330	0.9923	2.3221	1.8197	2.4156
Maximum	0.5443	1.0803	2.4825	1.9869	2.6347
Minimum	0.0903	0.8879	2.0961	1.5543	2.0209
Std. Dev.	0.1460	0.0573	0.1134	0.1335	0.2030
Skewness	-0.0430	-0.1157	-0.2031	-0.2983	-0.2872
Kurtosis	1.4957	1.7657	1.7779	1.8292	1.6563
$\ln E_t$	1.0000				
$\ln U_t$	0.0393	1.0000			
$\ln Y_t$	0.2536	0.2265	1.0000		
$\ln EC_t$	0.6366	0.1060	0.3633	1.0000	
$\ln O_t$	0.0018	0.2500	0.1130	0.0350	1.0000

Our next step is to test the unit root properties of the variables to proceed for the ARDL bounds testing approach to cointegration. The ARDL bounds testing approach is free from pre-unit root testing but we ensure that none of the variables is integrated at I(2). The bounds testing approach assumes that variables should be stationary at I(0) or I(1) or I(0)/I(1). So to overcome this issue, we have not worried about ADF test by Dickey and Fuller,

(1981); PP test by Philips and Perron, (1981) and DF-GLS test by Elliott et al. (1996) to apply for examining integrating properties of the variables. These unit root tests do not accommodate structural break arising in the series. The exact information about the structural break would help policy to consider these structural breaks while designing a comprehensive urbanisation and energy policies in the country. We have applied Zivot-Andrews unit root test (Zivot and Andrews, 1992) with single unknown structural breaks. The results are detailed in Table-2 show that variables are non-stationary at level in the presence of single structural breaks but integrated at I(1). This indicates that the null hypothesis of unit root is rejected with structural break points for the series. The estimated breakpoints are in the early and late 1990s.

The estimated break points coincide with 1970s urbanisation plan formulated from the New Economic Policy (NEP) and in 1980s, under the Malaysian Industrial Master Plan (IMP). Both of these dynamic plans have caused directly to the movement of people from rural to urban megacities at those particular breakpoints. This, indeed, makes a Malaysia's economic transition from agriculture towards industrializing economy starting from the breakpoints onward. In this particular period plenty of new policies and agreements has been introduced by the government such as National Development Policy, Industrial Policy, Privatization Policy, Look East Policy and Japan-Malaysia Economic Partnership Agreement. All these policy has contribute in term of urbanization process by establishing new industrial areas in the state of Selangor, Penang and Johor; increase volume of trade with Asian countries and United States; and increase foreign investment especially from Singapore, Japan and the United States. We find that all the variables are integrated at I(1) in the presence of structural break in the series.

**Table-2. Zivot-Andrews Structural Break Trended Unit Root Test**

Variable	At Level		At 1 <sup>st</sup> Difference	
	T-statistic	Time Break	T-statistic	Time Break
$\ln E_t$	-4.772 (1)	1989Q2	-12.913 (2)*	1995Q4
$\ln U_t$	-3.102 (2)	2000Q2	-9.723 (3)*	1989Q2
$\ln Y_t$	-4.311 (3)	1991Q2	-8.271 (1)*	1986Q3
$\ln EC_t$	-4.707 (2)	1993Q2	-12.317 (3)*	1978Q3
$\ln TO_t$	-3.231 (3)	1992Q2	-8.534 (2)*	1987Q3
Note: * and ** indicate the significance level at 1% and 5% respectively. () indicates the lag length of the variables.				

The unique order of the variables leads us to apply the ARDL bounds testing to examine cointegration between the variables. The ARDL bounds approach requires appropriate lag length for model specification. The results are reported in Table-3 by various lag length criteria. We followed Akaike information criteria to select an appropriate lag length since AIC has superior power properties for small sample data compared to other lag length criteria, as argued by Lütkepohl, (2006). Besides, AIC provides efficient and consistent results compared to final prediction error (FPE), Schwarz information criterion (SBC) and Hannan-Quinn information criterion (HQ). We find that according to AIC the optimum lag is 6 in the quarterly frequency data over the period 1970QI-2012QIV in the case of Malaysia.

**Table-3. Lag Order Selection Criteria**

VAR Lag Order Selection Criteria						
Lag	LogL	LR	FPE	AIC	SC	HQ
1	3732.632	3472.354	5.46e-27	-46.28290	-45.70630	-46.0487

2	3970.352	442.7531	3.83e-28	-48.9419	-47.8848*	-48.5126
3	3989.155	33.8463	4.15e-28	-48.8644	-47.3268	-48.2400
4	3995.621	11.2337	5.25e-28	-48.6327	-46.6146	-47.8132
5	4095.942	168.0381	2.06e-28	-49.5742	-47.0757	-48.5596
6	4159.265	102.1078*	1.29e-28*	-50.0533*	-47.0742	-48.8436*
7	4165.062	8.9852	1.66e-28	-49.8132	-46.3537	-48.4084
8	4170.038	7.4019	2.18e-28	-49.5629	-45.6229	-47.9630

Note: \* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

**Table-4. The Results of Bayer and Hanck Cointegration Analysis**

Estimated Models	EG-JOH	EG-JOH-BO-BDM	Cointegration
$E_t = f(U_t, U_t^2, Y_t, EC_t, TO_t)$	19.1949**	32.3441**	✓
$U_t = f(E_t, U_t^2, Y_t, EC_t, TO_t)$	5.4736	14.6372	None
$U_t^2 = f(E_t, U_t, Y_t, EC_t, TO_t)$	6.4536	13.4373	None
$Y_t = f(E_t, U_t, U_t^2, EC_t, TO_t)$	27.9797*	42.4363*	✓
$EC_t = f(E_t, U_t, U_t^2, Y_t, TO_t)$	23.5668*	48.4453*	✓
$TO_t = f(E_t, U_t, U_t^2, Y_t, EC_t)$	15.4007**	38.0285**	✓

Note: \*\* represents significant at 5 per cent level. Critical values at 5% level are 15.348 (EG-JOH) and 29.544 (EG-JOH-BO-BDM) respectively.

**Table-5. The Results of ARDL Cointegration Test**

Bounds Testing to Cointegration				Diagnostic tests		
Estimated Models	Optimal lag length	Break Year	F-statistics	$\chi^2_{NORMAL}$	$\chi^2_{ARCH}$	$\chi^2_{RESET}$
$E_t = f(U_t, U_t^2, Y_t, EC_t, TO_t)$	6, 6, 6, 6, 6	1989Q2	4.415*	0.1288	[1]: 0.2042	[2]: 1.6369
$U_t = f(E_t, U_t^2, Y_t, EC_t, TO_t)$	6, 5, 6, 5, 5	2000Q2	2.465	0.8438	[2]: 6.0988	[2]: 1.9194
$U_t^2 = f(E_t, U_t, Y_t, EC_t, TO_t)$	6, 5, 6, 6, 5	2000Q2	2.333	0.8807	[1]: 2.1681	[1]: 0.2631
$Y_t = f(E_t, U_t, U_t^2, EC_t, TO_t)$	6, 6, 6, 6, 6	1991Q2	4.187**	0.4428	[1]: 0.2837	[1]: 0.3734
$EC_t = f(E_t, U_t, U_t^2, Y_t, TO_t)$	6, 5, 6, 5, 6	1993Q2	4.654*	0.5202	[2]: 0.8983	[1]: 0.7414
$TO_t = f(E_t, U_t, U_t^2, Y_t, EC_t)$	6, 5, 6, 5, 5	1992Q2	3.246***	0.2509	[2]: 2.7208	[2]: 0.1206
Critical Values	Critical values					
	Lower bounds $I(0)$	Upper bounds $I(1)$				
1 per cent level	3.15	4.43				
5 per cent level	2.45	3.61				
10 per cent level	2.12	3.23				
<p>Note: The asterisks *, **, and *** represent the level of significance at 1, 5 and 10 per cent, respectively. The optimal lag length is determined by AIC. [ ] is the order of diagnostic tests. # Critical values are collected from Pesaran et al. (2001).</p>						

In such situation, the combined cointegration tests developed by Bayer and Hanck, (2013) are suitable to examine whether the cointegration exists. Table-4 illustrates the combined cointegration tests, including the EG-JOH, and EG-JOH-BO-BDM. We find that Fisher-statistics for EG-JOH and EG-JOH-BO-BDM tests exceed the critical values at 1 and 5 percent levels of significance as we used  $E_t$ ,  $Y_t$ ,  $\ln EC_t$  and  $TO_t$  as dependent variables. Thus it rejects the null hypothesis of no cointegration among the variables. In other words, it



shows existence of the cointegration among the variables. Therefore we may conclude that there exists a long run relationship between urbanisation, economic growth, trade openness and CO<sub>2</sub> emissions over the sample period of 1970Q1-2012Q4 in Malaysia.

However, as noted earlier that Bayer and Hanck, (2013) combined cointegration approach provides efficient empirical results but fails to incorporate structural breaks while investigating the long run relationship between the variables. We solve this problem by applying the ARDL bounds testing approach to cointegration in the presence of structural breaks following Shahbaz et al. (2013, 2014). Table-5 shows the empirical results of this bounds testing method and evidence reveals that the calculated F-statistic exceeds the upper critical bound at 1%, 5% and 10% levels of significance, respectively. This concludes that we may reject the null hypothesis of no cointegration. The results reported in Table-5 show that there is evidence of cointegration once we treated CO<sub>2</sub> emissions, economic growth, energy consumption and trade openness as regressand variables. This reveals the existence of four cointegrating vectors, thus providing evidence of the long run relationship between the variables in Malaysia.

The next turn is to find the impact of independent actors on dependent variable. The results show that urbanisation has a positive impact on CO<sub>2</sub> emissions. The linear and non-linear terms of urbanisation provide evidence in supporting U-shaped relationship between urbanisation and CO<sub>2</sub> emissions. The result indicates that a 1% rise in urbanisation will decline CO<sub>2</sub> emissions by 12.39% while positive sign of squared term seems to corroborate the delinking of CO<sub>2</sub> emissions and urbanisation at higher level of urbanisation. These evidences support that CO<sub>2</sub> emissions decline in the initial stage of urbanisation and increase it after a threshold point of urbanisation. This shows that Malaysia is more concern with environment issues when comes to developing urban areas and the government has launched National Green Technology Policy in 2009 and National Climate Change Policy in 2009.

Both policies aimed to protect urban areas from environment pollution from primary non-renewable energy consumption (Tenth Malaysia Plan, 2010).

The impact of economic growth on CO<sub>2</sub> emissions is positive but more elastic. This relation is statistically significant at the 1% level of significance. A 1% increase in economic growth is linked with 1.0802% CO<sub>2</sub> emissions. This is not a surprising result because the nation has developed well with 4-5% of economic growth continuously since 1990s (except in the Asian financial period) and mainly depending with manufacturing and industrial activities linked with agricultural sector (palm oil and rubber based industries). This has positively reflected Malaysia's economic performance and at the same moment has increased CO<sub>2</sub> emissions from the energy generation especially from fuel fossil and coal consumption, and environment hazards from the increased numbers of industrial estates in Penang (Seberang Prai and Butterworth), Kedah (Gurun and Kulim industrial park), Selangor (Shah Alam, Petaling Jaya and Klang); and Johor (Johor Bahru).

Energy consumption impacts CO<sub>2</sub> emissions positively and is significant at 1% significance level. All else is same, a 1% increase in energy consumption will increase CO<sub>2</sub> emissions by 0.4670%. The relationship between trade openness and CO<sub>2</sub> emissions is also positive and statistically significant at 1 % level of significance. A 1% increase in trade openness would increase CO<sub>2</sub> emissions by 0.1573%, holding other things constant. The increase in the level of CO<sub>2</sub> emissions is due to the increase in coal and fossil fuel consumptions which contributes almost 80% of energy generation projects in Salahudin Abdul Aziz (Selangor), Paka (Terengganu), Port Dickson (Negeri Sembilan), Pasir Gudang (Johor), Manjung (Perak) and Gelugor (Penang). All of these energy generation stations situated in urban areas and coal are imported from China and Australia, while fossil fuel sources are from domestic resources. This shows that, the current setup of Malaysia's environment friendly, electricity conservation and trade policies not able to reduce CO<sub>2</sub>

emissions. Indeed, manufacturing sector needs more energy sources in Malaysia in the past 2 decades, and the government has encourage local and foreign investors to participate in the industrialization activities, mostly in urban areas. This has boost industrialization activities along with high volume of CO<sub>2</sub> emissions and this scenario never be left from the process of nation Vision 2020 agenda. This finding can be a good lesson regarding policies related to primary energy consumption and trade policies for Malaysia. This implies that Malaysia should adopt new technologies and higher level of R&D to overcome the energy efficiency of power generation, especially renewable energy generation sources (hydro and biomass).

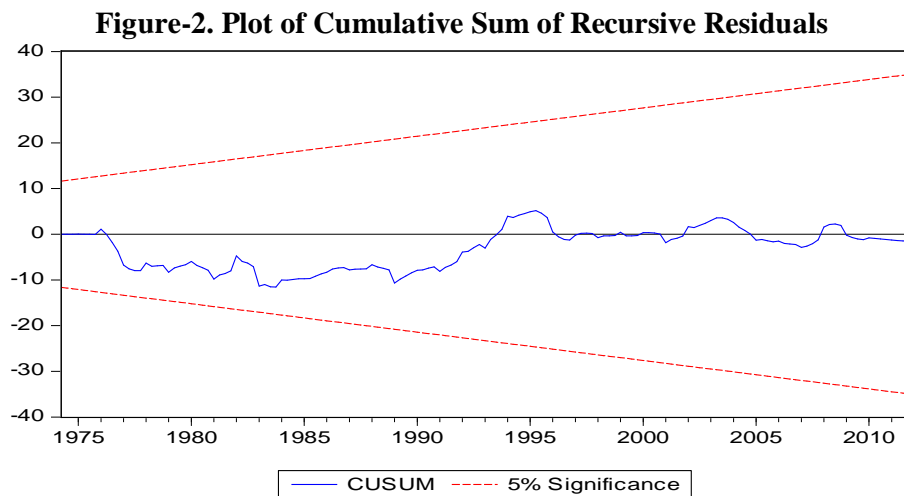
**Table-6. Long-and-Short Runs Analysis**

Dependent Variable = $\ln E_t$			
<b>Long-Run Results</b>			
Variable	Coefficient	Std. Error	T-Statistic
Constant	3.3355*	0.6045	5.5177
$\ln U_t$	-12.3907*	1.2474	-9.9326
$\ln U_t^2$	5.6305*	0.5702	9.8735
$\ln Y_t$	1.0802*	0.1472	7.3356
$\ln EC_t$	0.4670*	0.1055	4.4240
$\ln O_t$	0.1573*	0.0475	3.3106
$R^2$	0.9866		
F-statistic	23.8782*		
<b>Short-Run Results</b>			
Variable	Coefficient	Std. Error	T-Statistic
Constant	0.0040	0.0065	0.6240
$\Delta \ln E_{t-1}$	0.3506*	0.0635	5.5174

$\Delta \ln U_t$	-7.5671	12.8899	-0.5870
$\Delta \ln U_t^2$	03405	0.6096	0.5586
$\Delta \ln Y_t$	0.0402	0.2260	0.1780
$\Delta \ln EC_t$	0.6520*	0.1575	4.1402
$\Delta \ln O_t$	-0.0334	0.1133	-0.2942
$ECM_{t-1}$	-0.0500**	0.0263	-1.8978
$R^2$	0.5185		
F-statistic	10.096*		
<b>Diagnostic Tests</b>			
Test	F-statistic	Prob. Value	
$\chi^2_{NORMAL}$	0.6539	0.7211	
$\chi^2_{SERIAL}$	0.6447	0.4232	
$\chi^2_{ARCH}$	1.3588	0.2454	
$\chi^2_{WHITE}$	1.0538	0.4042	
$\chi^2_{REMSAY}$	0.7043	0.4026	
Note: *, ** and *** represent significance at 1%, 5% and 10% levels respectively.			

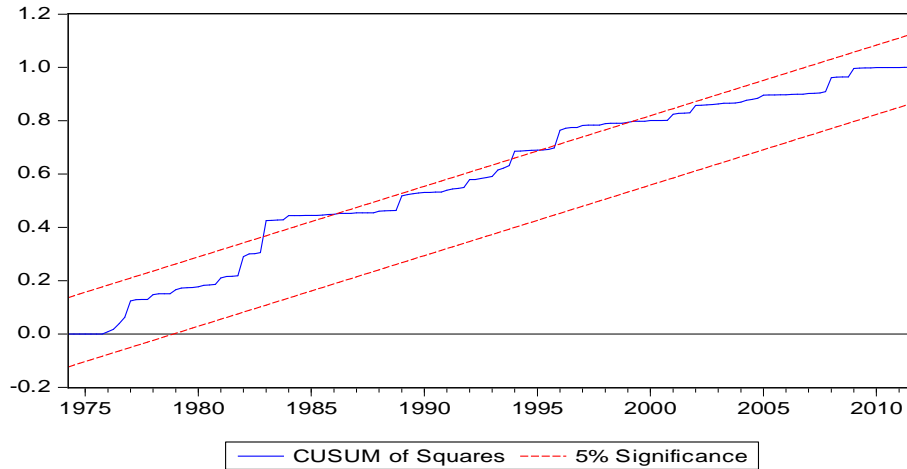
The short run results are also reported in lower segment of Table-6. The current CO<sub>2</sub> emissions are positively and significantly influenced by CO<sub>2</sub> emissions previous period. A 1% increase in CO<sub>2</sub> emissions in current period will increase CO<sub>2</sub> emissions in future by 0.3506 by keeping other things constant. The relationship between urbanisation and CO<sub>2</sub> emissions is U-shaped but statistically insignificant. Economic growth positively affects CO<sub>2</sub> emissions but this is also insignificant. However, capitalization has positive and statistically significant impact on energy demand and energy consumption raises CO<sub>2</sub> emissions. Trade

openness shows a negative link with CO<sub>2</sub> emissions however it is statistically insignificant. The negative and statistically significant estimate for  $ECM_{t-1}$ , -0.0865 provides strong evidence of long run relationship among the series in the case of Malaysia. The coefficient is statistically significant at 5 percent level and reveals that the short run deviations are corrected by 5 percent towards long run equilibrium path each quarter. The empirical model also passes the major diagnostic tests. The diagnostic tests reveal that error terms of short run models are normally distributed and free of serial correlation, heteroskedasticity, and ARCH problems. The functional form of the short run models are also well specified as revealed by the Ramsey reset test. We also provide the stability test of the ARDL bounds testing estimates using the CUSUM and CUSUMsq tests. The results illustrated in Figure-2 and 3 show that the plots of the CUSUM statistics are well within the critical bounds.



The straight lines represent critical bounds at 5% significance level

**Figure-3. Plot of Cumulative Sum of Squares of Recursive Residuals**



The straight lines represent critical bounds at 5% significance level

**Table-7. Chow Forecast Test**

Chow Forecast Test : Forecast from 1982Q1 to 2011Q4			
F-statistic	1.1320	Probability	0.3378
Log likelihood ratio	252.4127	Probability	0.0000
Chow Forecast Test: Forecast from 1994Q1 to 2011Q4			
F-statistic	0.9666	Probability	0.9425
Log likelihood ratio	76.2728	Probability	0.3429
Chow Forecast Test: Forecast from 1996Q1 to 2011Q4			
F-statistic	0.6351	Probability	0.9728
Log likelihood ratio	59.6584	Probability	0.6306

The plot of the CUSUMsq of squares statistics are not well within the critical bounds. Furthermore, we apply Chow forecast test to examine the significance structural breaks in an economy for the period 1982Q1-2011Q4 due to establishment of various economic policies in 1980s to archive positive economic growth in the region. Meanwhile, in late year 2000 the government has put more attention on environment sustainability to overcome the greenhouse problem by introducing several environment policies for the nation and supports the Kyoto protocol agenda proposed in 1997. In this study, F-statistics computed in Table-7 suggests

that there is no significant structural break in the economy during the sample period. The chow forecast test is more reliable and preferable than graphs (Leow, 2004). This confirms that the ARDL estimates are reliable and efficient.

### **5.1 The VECM Granger Causality Analysis**

The existence of long run (cointegration) relationship between the variables such as urbanisation, economic growth, energy consumption, trade openness and CO<sub>2</sub> emissions leads us to apply the VECM Granger causality approach which provides information about the causality between variables for both long and short runs. Therefore, the appropriate information on the direction of causality between the variables helps the policymakers to have a clear picture on the issue, enabling them to formulate urban, economic, energy, and trade policy with a view to improve environmental quality of the country and at the same time achieve sustainable economic growth to maintain high standard of living over a long period. Table-8 reports the results of Granger causality test. The long run causality is indicated by the significance of coefficient of the one period lagged error-correction term  $ECT_{t-1}$  in equation (7) using t-test. The short run causality can be detected by the joint significance of LR test of the lagged explanatory variables in the equation. Our empirical results suggest that the  $ECT_{t-1}$  has negative sign and it is statistically significant in all the VECM equations except in urbanisation VECM equation.

The results of long run causality reveal that the feedback effect is found between economic growth and CO<sub>2</sub> emissions. The relationship between energy consumption and CO<sub>2</sub> emissions is bidirectional. The unidirectional causality is found running from urbanisation to CO<sub>2</sub> emissions. Trade openness Granger causes CO<sub>2</sub> emissions but same is not true from opposite side.

**Table-8. The VECM Granger Causality Analysis**

Dependent Variable	Direction of Causality					
	Short Run					Long Run
	$\Delta \ln E_{t-1}$	$\Delta \ln U_{t-1}, \Delta \ln U_{t-1}^2$	$\Delta \ln Y_{t-1}$	$\Delta \ln EC_{t-1}$	$\Delta \ln O_{t-1}$	$ECT_{t-1}$
$\Delta \ln E_t$	....	1.0133 [0.3654]	2.6436*** [0.0743]	17.8972* [0.0000]	0.7041 [0.4959]	-0.0712* [-2.9150]
$\Delta \ln U_t, \Delta \ln U_t^2$	0.4948 [0.6106]	....	1.3248 [0.2688]	0.3405 [0.7119]	0.1351 [0.8737]	....
$\Delta \ln Y_t$	3.1246** [0.0467]	3.8830* [0.0049]	....	10.0056* [0.0001]	16.8491* [0.0000]	-0.0312* [-2.8881]
$\Delta \ln EC_t$	50.7782* [0.0000]	2.5403** [0.0421]	0.5494 [0.5484]	....	17.10007* [0.0001]	-0.1241* [-3.6543]
$\Delta \ln O_t$	0.9560 [0.3866]	0.9900 [0.4046]	7.3068* [0.0007]	0.5799 [0.5612]	....	....

Note: \*, \*\* and \*\*\* show significance at 1, 5 and 10 per cent levels respectively.

In short run, the bidirectional causality exists between economic growth and CO<sub>2</sub> emissions. The relationship between energy consumption and CO<sub>2</sub> emissions is bidirectional. Economic growth Granger causes trade openness and in resulting, trade openness leads economic growth. Trade openness Granger causes energy consumption. Energy consumption is Granger cause of energy consumption.

## 6. Conclusion, Policy Implications and Future Directions

This study provides new insights on how urbanisation affects CO<sub>2</sub> emission by using STIRPAT model in case of Malaysia. We examined the long run relationship among the variables using the ARDL bounds testing approach incorporating dummy variable to appropriately capture the structural breaks present in the series. Our results provide evidence



of cointegration between the variables in the presence of structural breaks. The empirical results also confirm the modernization theory for developing nation, predicting that environmental impacts may follow the basic Kuznets theory relative to urbanisation and energy use in Malaysia. This is not surprising, because Malaysia is moving forward with a high speed urbanisation process with huge numbers of industrial areas and well-planned housing settlements in the urban metropolitan cities since the 1990s. The government of Malaysia is trying to reduce energy use in urban cities, where transportation can be economized by putting more emphasis on urban transportation network.

This agenda is highlighted in the Tenth Malaysia Plan, (2010) and in the long term this program aims to reduce demand for energy in transportation sectors. Energy consumption in industrial production activities may be high in urban areas in Malaysia, especially in the newly open economic corridors. These economic corridors also bulk with urban population and various supporting economic activity concentrate with the corridors niche areas and decoupling demand for energy resources. Consequently, in the long-term this able to capture the urban environmental theory faced by developed countries. Since 1970s, Malaysia has formulated New Economic Policy (NEP), National Development Policy (NDP), Vision 2020 and Regional Corridors is formulated to ensure urbanisation process in Malaysia moves smoothly in the long-term period with sustainable environment protection. Under the Tenth Malaysia Plan (2010), the government has intensified efforts to reduce energy use and CO<sub>2</sub> emission by climate adaption and mitigation measures.

Unfortunately, as far we concern there is no comprehensive policies related on urbanization, trade, energy intensity on CO<sub>2</sub> emissions in Malaysia. We found that, there is only environment regulation which protecting environment which indirectly able to reduce energy consumption and CO<sub>2</sub> reduce in Malaysia. Although Malaysia already emphasis to major national environment policies, such as National Green Technology Policy and National

Climate Change Policy in 2009, we would like to suggest special needs of urbanization, trade and energy related policy to protect urban settlement from pollutant environment cause by energy consumption. On the other hand, transport and industrial sectors is the largest consumer of energy in urban areas in Malaysia, generally accounting 50-60%. To overcome this matter, efforts have been introduce by utilizing non-renewable energy resources. Therefore, Small Renewal Energy Power Program (SREP) and Malaysia Building Integrated Photovoltaic Technology Application Project (MBIPV) has been introduces in Iskandar Malaysia Development Corridor which is one of the rapid urbanize area located southern part of Peninsular Malaysia.

These types of innovative projects able to hamper out the energy consumption in urban areas and reduce CO<sub>2</sub> emissions in long cycle of urbanisation process in Malaysia. Hence, the low carbon cities policy package introduce in this urban corridor by energy efficiency improvement, lowering CO<sub>2</sub> emissions intensity and transport demand control also able to make to urbanize area be more sustained in term of environment in future decades. Recently, the government proposed Mass Rapid Transit (MRT) project which is a mega transportation project in the metropolitan city of Kuala Lumpur. This will able to reduce CO<sub>2</sub> emissions in this urban city in long-term period and serve 1.2 million people in urban areas around Kuala Lumpur when this project completed by 2017.

Some previous researchers pointed that comprehensive energy conservation is a right choice to overcome the conflict between urbanisation, income, trade and CO<sub>2</sub> emissions (Ren et al. 2014; Yazdi and Shakouri, 2014). In case of Malaysia, economic growth directly has increased energy demand and new economic agenda for Malaysia is to be a high income country by 2020 with high volume of economic growth. Therefore, an idea to reduce energy consumption in urban areas is not a good decision for policymakers because this will give negative impact on future economic performance, unemployment and social issues. For us,

technological innovation introduced in the recent urban corridors is the answer, to solve the puzzle which always surrounding developing countries such as Malaysia in the past three decades.

Toward this end, most of study related to CO<sub>2</sub> emissions is focusing on urbanization, energy consumption, trade openness, population, economic growth and, as a future direction; researchers should use micro-stage data according to the states or economic regions in Malaysia to compare empirically the effects of consumption, trade openness, population, economic growth on CO<sub>2</sub> emissions. This type of study may capture the effect of economic transformation plan introduced by the government with urbanisation and the demand side of energy use by states and regions in Malaysia. Other than that, it is generally evident that the movement of people from rural-urban migration, and reclassification of rural areas and agglomeration of built-up areas has created problems on productivity and unemployment level, mainly in the agriculture and industrial sectors. This problem may seriously effects on sustainable regional development of Malaysia in future. Therefore, these aspects should take into consideration in future direction of 'over-urbanisation' issues which might be faced in future by government. In order to face this issue, future studies should also put attention on urban population growth structure in urban and megacities in Malaysia while estimating the effects of urbanisation and energy use. Finally, and most importantly, the direction of future research is the nonlinear modeling procedures. Future researcher may use nonlinear approach to identify the robustness of the present linear cointegration and causality more efficiently. To conclude, future analysis should include more related variables with urbanisation and energy use with extended sample period to capture the effects of urbanisation policies introduced by the Malaysian government.

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