Econometric analysis of the impact of urbanization on CO_2 emissions and energy use of Turkey

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Abstract

This paper empirically investigates the the dynamic casual relationships between CO2 emissions, energy use, GDP growth, foreign trade and urbanization of Turkey. The long-run causal relationship among the variables are examined by employing ARDL approach. The long run Granger causality is tested by Todo-Yamamato approach and directions of the relationships are detected. Moreover, feedback relationships between the variables and their responses to unanticipated shocks are tested by generalized variance decompositions and impulse response functions. The empirical results suggests that long-run as well as short-run energy use and urbanization rate has positive and significant impact on CO2 emissions. Causality running from GDP growth to CO2 emissions and energy use, and from CO2 emissions to urbanization. These results imply any policy aiming to reduce CO2 emissions will be harmful for further increase of urbanization whereas policies implemented to reduce CO2 emissions will not be harmful for economic growth of Turkey.

Key Words: CO2 emissions, energy use, urbanization, dynamic causal relationship, ARDL approach, granger causality, generalized variance decomposition, generalized impulse response functions

1. Introduction

United Nations Convention on Climate Change declares that 75 percent of world population will be living in urban areas by the year 2030. In 2013, the Intergovernmental Panel on Climate Change (IPCC) report reveals that carbon dioxide concentrations have increased by 40 percent since pre-industrial times, primarily from fossil fuel emissions and secondarily from net land use change emissions. The report includes the global trends toward greater urbanization as one of the several

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important types of land use and land cover change. Moreover, it states that land use change has also contributed almost 30 percent of total anthropogenic CO2 emissions since 1850.

The theories of ecological modernization and urban environmental transition both recognize that urbanization can have positive and negative impacts on the environment despite the difficulty in determining the net effect a priori. There is a need for performing empirical analysis of the dynamic relationship between urban patterns and environmental quality as well as taking under consideration economic concerns. Acknowledging the links between land use and environmental problems will help to make green growth and sustainable development policies more explicit.

This research extends the final stream of research that examines dynamic relationship between carbon emissions, energy consumption and economic growth, which was introduced by Soytaş, Sari and Ewing (2007) by including the impacts of urbanization into the nexus. The objective of the study is to investigate empirically the dynamic casual relationships between CO2 emissions, energy use, GDP per capita, foreign trade and urbanization of Turkey through the cointegration and causality analysis. In case, urbanization has a statistically significant impact on CO2 emissions and energy use then this will have policy implications on sustainable development plans of Turkey.

The remainder of this paper is organized as follows: The next section outlines briefly the history of literature on the interrelationships between output, energy consumption and environmental pollutants and reviews the results of empirical studies including urbanization into the analysis. The third section discusses data and some descriptive statistics. The fourth section discusses the empirical model and results, and the last section concludes.

2. Literature Review

The literature on carbon emissions and economic growth is abundant. The first phase of research mainly has focused on testing the Environmental Kuznet's Curve (EKC) by analyzing for relationships between per capita income and CO2 emissions. However, these studies have provided mixed results and have criticized for their weak theoretical and conceptual frameworks as well as econometric issues (Soytaş et al., 2007). Then studies have attempted to analyze the link between energy consumption and output that examine the causal relationship between these variables. Furthermore, researchers have extended their analysis by incorporating financial development and foreign trade into the framework of CO_2 emission, output and energy consumption. The recent stream of research has emerged, which examines the long-run cointegrating relationship and short-run dynamics between CO_2 emission, output and energy consumption.

Urbanization is discussed both in the context of economic modernization and as a demographic indicator in the literature. According to Poumanyvong and Kaneko (2010), there are three relevant theories those can be used to explain possible impacts of urbanization on the natural environment. The theory of ecological modernization examines urbanization as a process of social transformation and focuses on social and institutional transformations as well as economic modernization to explain the effects of modernization on the environment (Crenshaw and Jenkins, 1996; Gouldson and Murphy, 1997; Mol and Spaargaren, 2000). This theory could be categorized as a supporter of EKC hypothesis since it determines an inverse relation between development stages and environmental degradation. The urban environmental transition theory is similar to ecological modernization theory but it mainly focuses on links between development and environmental issues at the city level. The compact city theory generally discusses the environmental benefits of high urban density as a result of economies of scale for urban public infrastructure (Burton, 2000; Capello and Camagni, 2000; Jenks et al., 1996; Newman and Kenworthy, 1989). However, there are also critics argue that the claimed benefits of these theories will be outweighted by the negative consequences of economic development and increased urban density (Breheny, 2001; Rudlin and Falk, 1999).

The empirical relationship between CO_2 emissions, energy consumption and urbanization have been extensively studied in the literature. However, the literature is inconclusive on how urbanization affect the environmental quality, which is widely proxied by CO_2 emissions. The magnitudes and signs of the effect are not comparable due to different data sets, assumptions and estimation methodologies (Sadorsky, 2014). In one of the earliest studies, Parikh and Shukla (1995) use a data set of 83 developed and developing countries for the year 1986 to examine the impact of urbanization on energy use and toxic emissions. They find that urbanization has a positive and significant impact on CO2 emissions, CH4 emissions, and CFC emissions. York et al. (2003) use a cross section of 137 countries to test for a relationship between urbanization and CO2 emissions and find evidence that increases in urbanization lead to increases in CO2 emissions. Fan et al. (2006) find a negative relationship between urbanization and carbon dioxide emissions for developing countries. Martinez-Zarzoso (2008) analyze the impact of urbanization on CO2 emissions in developing countries, taking into account the presence of heterogeneity in the different groups of countries and testing for the stability of the estimated elasticities over the period 1975 - 2003. Their results show that, whereas the impact of population growth on emissions is above unity and only slightly different for upper, middle, and low- income countries, urbanization demonstrate a very different impact on emissions for low and lower-middle-income countries and upper-middle income countries.

Poumanyvong and Kaneko (2010) investigate empirically the effects of urbanization on energy use and CO2 emissions with consideration of the different development stages. Using the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model and a balanced panel dataset of 99 countries over the period 1975 to 2005, they figure out that the impact of urbanization on energy use and emissions varies across the stages of development. The results of their study show that urbanization decreases energy use in the low-income group, while it increases energy use in the middle and high-income groups. Moreover, they find the impact of urbanization on emissions is positive for all the income groups, but it is more pronounced in the middle-income group than in the other income groups.

Martinez-Zarzoso and Maruotti (2011) also use a STIRPAT model in a panel of 88 developing countries to analyze the impact of urbanization on CO2 emissions over the period 1975 to 2003. The results show an inverted-U shaped relationship between urbanization and CO2 emissions. This paper contributed to the literature by using a semi-parametric mixture model that allows for unknown distributional shapes and endogenously classifies countries into homogeneous groups. The findings of the study show that urbanization's impact on CO_2 emissions differs considerably according to country groups. For two of the groups, a threshold level is identified beyond which the emission-urbanization elasticity is negative and further increases in the urbanization rate do not contribute to higher emissions. However, for the third group only population and affluence, but not urbanization, contribute to explain emissions. Sharma (2011) studies the determinants of carbon dioxide emissions for a global panel of 69 countries using a dynamic panel data (including high income, middle income, and low income countries) model over the period 1985–2005. The main findings are that trade openness, per capita GDP, and energy consumption have positive effects on CO_2 emissions. Urbanisation is found to have a negative impact on CO_2 emissions in high income, middle income, and low income panels. For the global panel, only GDP per capita and per capita total primary energy consumption are found to be statistically significant determinants of CO_2 emission, while urbanisation, trade openness, and per capita electric power consumption have negative effects on the CO_2 emissions. Hossain (2011) empirically examines the dynamic causal relationships between carbon dioxide emissions, energy consumption, economic growth, trade openness and urbanization for the panel of newly industrialized countries using the time series data for the period 1971–2007. The Granger causality test results support that there is no evidence of long-run causal relationship, but there is unidirectional short-run causal relationship from economic growth and trade openness to carbon dioxide emissions, from economic growth to energy consumption, from trade openness to economic growth, from urbanization to economic growth and from trade openness to urbanization.

Soheilakhoshnevis and Bahram (2014) investigate the long run cointegrating and short run dynamics relation among carbon emissions, energy consumption, economic growth, urbanization, financial development and openness to trade in Iran over the period 1975-2011 by using ARDL approach. The direction of causal relationship between the series is examined by VECM Granger causality approach. The estimated coefficient of openness, financial development, urbanization are negative and significant indicating that increasing level of urbanization and openness are responsible for CO_2 emission in Iran. The causality tests also indicate that there was a unidirectional Granger causality running from per capita real income, per capita energy consumption, financial development and urbanization to per capita carbon emissions. Sadorsky (2014) uses recently developed panel regression techniques that allow for heterogeneous slope coefficients and cross-section dependence to model the impact that urbanization has on CO2 emissions for a panel of emerging economies. The results of the study can be summarized as follows: the estimated contemporaneous coefficients on the energy intensity and affluence variables are positive, statistically significant and fairly similar across different estimation techniques; the estimated contemporaneous coefficient on the urbanization variable is positive but statistically insignificant in most specifications.

The empirical relationship between CO2 emissions, energy consumption and output have been studied extensively for Turkey. [2] Moreover, some of the recent studies that incorporate urbanization variable to energy-environment and economy nexus include Turkey in their panel data set. However, according to the knowledge of the author, no one of the studies has incorporated the variable urbanization in determining the carbon dioxide emissions in case of Turkey. Thus, this paper will contribute to literature by acknowledging the dynamic causal relationship between CO2 emissions, energy consumption, economic growth, openness to trade and urbanization of Turkey.

3. Data and time series properties

Annual time series data on Turkey that is provided by World Bank's Development Indicators for the period 1971–2007 is used in the analysis. The data consist of carbon dioxide emissions (CO2) (metric tons per capita), energy consumption (EN) (kg of oil equivalent per capita), foreign trade (TRADE) (% of exports and imports of GDP), per capita real GDP (PGDP) (constant 2000 US$) and urbanization (UR) (% urban population of total). All data are in natural logarithms.

The descriptive statistics, mean value, standard deviation and coefficient of variation of different variables are given in Table 1. The highest mean over the sample period is for GDP per capita, followed by energy use while the lowest mean is for CO2 emissions. This is not surprising since Turkey is a typical developing country in terms of its greenhouse gases emissions. In this regard,

[2] These studies include Halicioglu, 2009; Akbostanci et al., 2009; Soytas and Sari, 2009; Ozturk and Acaravci, 2013.; Altinay and Karagol, 2004

CO_2 emissions of Turkey is still low and per capita CO_2 emissions are below world average however emissions continue to increase. In terms of volatility, as defined by the standard deviation, foreign trade has the highest volatility, whereas urbanization rate has the lowest volatility. As discussed in the previous section, urbanization is a matter of social and economic transformation and a demographic indicator therefore any changes in urbanization can be observed in the long time of period. All the variables are skewed to left, indicating that these series have longer left tails than right tails.

[Table 1 is about here]

In order to get robust and reliable results, it is necessary to determine whether or not the data under investigation is stationary before employing the time series methods. For this purpose, six different unit root tests; namely augmented Dickey and Fuller (1979) (ADF), Dickey-Fuller GLS detrended (DFGLS) and Point Optimal (ERS-PO) (Elliot et al., 1996)), Phillips and Perron (1988) (PP), Kwiatkowski et al. (1992) (KPSS), and Ng and Perron's (2001) NPZa are used. The results of unit root tests are reported in Table 2 for levels and first differences under both constant and constant plus trend specifications, respectively. The results show that these variables exhibit different order of integration; some series are integrated of order one while others are stationary in levels. The null hypothesis is rejected for all variables in levels except for urbanization and CO_2 emissions. So, the variables urbanization and CO_2 emissions are I(1) while others are I(0).

[Table 2 is about here]

4. Empirical model and results

It is appropriate to proceed to test for long-run equilibrium relationship between these variables by using the autoregressive-distributed lag (ARDL) approach, which was developed by Pesaran and Pesaran (1997) and Pesaran et al. (2001). ARDL is the ideal approach since the results of the unit root tests imply mixed type of data. Because, this approach does not require the same order of integration for the series, as is the case in the Johansen and Engle-Granger cointegration methods. It is widely accepted in the literature that ARDL approach has certain econometric advantages over other cointegration methods, however they will not be discussed here to conserve space.[3]

The long-run causal relationship among the variables are examined in two-steps. As the first step, the bounds testing procedure is conducted to test for the cointegrating relationship among the variables. Then, the second step will test the casual relationship by using a specific ARDL model to estimate the long-run coefficients and the error-correction models with the presence of cointegrating relationships.

The bounds testing procedure is employed to identify the long-run relationship by posting a dependent variable determined by its forcing variables, however there is no information regarding the directions of the casual relationship at this stage (Sari et al., 2012). To implement the bounds test for cointegration, the following unrestricted regression equations have been formulated:

$$\begin{aligned} LCO2_t = a_c &+ \textstyle\sum_{i=0}^{r} b_{ic}\, \Delta LCO2_{t-l} + \sum_{i=0}^{r} c_{ic} \Delta LENG_{t-l} + \sum_{i=0}^{r} d_{ic} \Delta LGDP_{t-l} \\ &+ \textstyle\sum_{i=0}^{r} e_{ic} \Delta TRADE_{t-l} + \sum_{i=0}^{r} f_{ic} \Delta LURB_{t-l} \\ &+ \boldsymbol{\gamma}_{1c} LCO2_{t-1} + \boldsymbol{\gamma}_{2c} LENG_{t-1} + \boldsymbol{\gamma}_{3c} LGDP_{t-1} + \boldsymbol{\gamma}_{4c} LTRADE_{t-1} + \boldsymbol{\gamma}_{5c} LURB_{t-1} + \boldsymbol{\varepsilon}_{ct} \end{aligned}$$

$$\begin{aligned} LENG_t = a_e &+ \textstyle\sum_{i=0}^{r} b_{ie}\, \Delta LCO2_{t-l} + \sum_{i=0}^{r} c_{ie} \Delta LENG_{t-l} + \sum_{i=0}^{r} d_{ie} \Delta LGDP_{t-l} \\ &+ \textstyle\sum_{i=0}^{r} e_{ie} \Delta TRADE_{t-l} + \sum_{i=0}^{r} f_{ie} \Delta LURB_{t-l} \\ &+ \boldsymbol{\gamma}_{1e} LCO2_{t-1} + \boldsymbol{\gamma}_{2e} LENG_{t-1} + \boldsymbol{\gamma}_{3e} LGDP_{t-1} + \boldsymbol{\gamma}_{4e} LTRADE_{t-1} + \boldsymbol{\gamma}_{5e} LURB_{t-1} + \boldsymbol{\varepsilon}_{et} \end{aligned}$$

$$\begin{aligned} LGDP_t = a_g &+ \textstyle\sum_{i=0}^{r} b_{ig}\, \Delta LCO2_{t-l} + \sum_{i=0}^{r} c_{ig} \Delta LENG_{t-l} + \sum_{i=0}^{r} d_{ig} \Delta LGDP_{t-l} \\ &+ \textstyle\sum_{i=0}^{r} e_{ig} \Delta TRADE_{t-l} + \sum_{i=0}^{r} f_{ig} \Delta LURB_{t-l} \\ &+ \boldsymbol{\gamma}_{1g} LCO2_{t-1} + \boldsymbol{\gamma}_{2g} LENG_{t-1} + \boldsymbol{\gamma}_{3g} LGDP_{t-1} + \boldsymbol{\gamma}_{4g} LTRADE_{t-1} + \boldsymbol{\gamma}_{5g} LURB_{t-1} + \boldsymbol{\varepsilon}_{gt} \end{aligned}$$

$$\begin{aligned} LTRADE_t = a_x &+ \textstyle\sum_{i=0}^{r} b_{ix}\, \Delta LCO2_{t-l} + \sum_{i=0}^{r} c_{ix} \Delta LENG_{t-l} + \sum_{i=0}^{r} d_{ix} \Delta LGDP_{t-l} \\ &+ \textstyle\sum_{i=0}^{r} e_{ix} \Delta TRADE_{t-l} + \sum_{i=0}^{r} f_{ix} \Delta LURB_{t-l} \\ &+ \boldsymbol{\gamma}_{1x} LCO2_{t-1} + \boldsymbol{\gamma}_{2x} LENG_{t-1} + \boldsymbol{\gamma}_{3x} LGDP_{t-1} + \boldsymbol{\gamma}_{4x} LTRADE_{t-1} + \boldsymbol{\gamma}_{5x} LURB_{t-1} + \boldsymbol{\varepsilon}_{xt} \end{aligned}$$

$$\begin{aligned} LURB_t = a_u &+ \textstyle\sum_{i=0}^{r} b_{iu}\, \Delta LCO2_{t-l} + \sum_{i=0}^{r} c_{iu} \Delta LENG_{t-l} + \sum_{i=0}^{r} d_{iu} \Delta LGDP_{t-l} \\ &+ \textstyle\sum_{i=0}^{r} e_{iu} \Delta TRADE_{t-l} + \sum_{i=0}^{r} f_{iu} \Delta LURB_{t-l} \\ &+ \boldsymbol{\gamma}_{1u} LCO2_{t-1} + \boldsymbol{\gamma}_{2u} LENG_{t-1} + \boldsymbol{\gamma}_{3u} LGDP_{t-1} + \boldsymbol{\gamma}_{4u} LTRADE_{t-1} + \boldsymbol{\gamma}_{5u} LURB_{t-1} + \boldsymbol{\varepsilon}_{ut} \end{aligned}$$

In the equations, the parameters (b, c, d, e and f) represent the short-run coefficients and the parameters ($\boldsymbol{\gamma}_{1n}, \boldsymbol{\gamma}_{2n}, \boldsymbol{\gamma}_{3n}, \boldsymbol{\gamma}_{4n}, \boldsymbol{\gamma}_{5n}$), n=c, e, g, x, u denote the long-run multipliers of the underlying ARDL model. The general F-statistics are used to test the joint null hypothesis of “no cointegration” in

[3] See Pesaran et al., 2001; Ghatak and Siddiki, 2001; Pahlavani, 2001; Sari et al., 2012 for more

the *n*th equation is that $\gamma_{1n=}\gamma_{2n=}\gamma_{3n=}\gamma_{4n=}\gamma_{5n=}0$. The calculated F-statistics are compared with the critical values provided by Narayan (2005) because of small sample size. There are upper level and lower level critical values that are formulated for the assumption that all series are integrated of order one I(1) and order zero I(0), respectively. If the orders of the series are mixed, as in our case, then the calculated F-statistics are compared with the corresponding upper and lower level critical values. By following the Pesaran and Pesaran (1997); if the test statistic for the variables are below the lower level critical value we fail to reject the null of "no cointegration", but if the test statistic for the variables are above the upper level critical value we reject the null hypothesis. However, the test result is inconclusive in case the statistic falls between the lower and higher bounds.

4.1. Empirical results

Before applying the bounds testing procedure, it is necessary to determine the optimal lag length to ensure that the errors are white noise. All of the four out of five procedures; sequential modified LR test statistic, final prediction error (FPE), Schwarz information criterion (SC) and Hannan-Quinn information criterion (HQ) have selected 2 as the optimal leg order, while Akaike information criterion (AIC) has selected optimal lag length as 6. We proceed with the optimal lag length 2 since it is suggested by various lag length models and the LR test as reported in Table 3.

[Table 3 is about here]

The calculated F-statistics for the cointegration relationships obtained from bounds testing procedure are presented in Table 4. From the estimated results it can be concluded that there exist two cointegrating vectors at 5 percent significance level. The first long-run relationship refers the situation where CO_2 emissions is the dependent variable and the second one refers the situation where energy use is the dependent variable. The first vector indicates that energy use, GDP per capita, trade and urbanization are forcing variables of CO_2 emission. The second vector shows that CO_2 emission, GDP per capita, trade and urbanization are forcing variables of energy use. These findings are in line with our expectations. However, the results are inconclusive where GDP per capita, trade and urbanization are dependent variables.

[Table 4 is about here]

To examine the robustness of ARDL bounds test approach for long-run relationship, the Johansen and Juselius's (1990) test is also applied. Since the Johansen and Juselius's multivariate cointegration methodology is fairly well documented and widely employed in the literature, the method will not be described here. The optimal lag length of the unrestricted vector autoregressive (VAR) model is taken 2 as is the case in bounds testing procedure. The Johansen cointegration results, which are obtained using a VAR specification with no linear time trends model are reported in Table 5. The maximum eigen statistics and trace statistics, the 1% critical values in addition to corresponding eigenvalues are reported in Table 5. Both the trace statistics and max-eigen statistics indicate that there exist 2 cointegrating vectors at five percent level. This result is consistent with the bounds testing result.

[Table 5 is about here]

The long-run relationships are estimated using the following specified ARDL (k,l,m,n,p) models. Since the study has limited observations, the orders of the lags (k,l,m,n,p) in the model are selected based on Schwartz Bayesian Criterion (SBC). According to Pesaran and Pesaran (1997), the SBC selects the smallest possible lag length, so it tends to define more parsimonious specifications. The following equations are constructed regarding the presence of the cointegrating relationship to calculate the long-run coefficient estimates and the error correction models.

$$LCO2_t = a_c + \sum_{i=1}^{k} \alpha_{ic} \Delta LCO2_{t-l} + \sum_{i=0}^{l} \beta_{ic} \Delta LENG_{t-l} + \sum_{i=0}^{m} \mu_{ic} \Delta LGDP_{t-l} + \sum_{i=0}^{n} \delta_{ic} \Delta TRADE_{t-l} + \sum_{i=0}^{P} \phi_{ic} \Delta LURB_{t-l} + u_{tc}$$

$$LENG_t = a_e + \sum_{i=1}^{l} \beta_{ie} \Delta LENG_{t-l} + \sum_{i=0}^{k} \alpha_{ie} \Delta LCO2_{t-l} + \sum_{i=0}^{m} \mu_{ie} \Delta LGDP_{t-l} + \sum_{i=0}^{n} \delta_{ie} \Delta TRADE_{t-l} + \sum_{i=0}^{P} \phi_{ie} \Delta LURB_{t-l} + u_{te}$$

The estimated long-run coefficients for CO_2 emission equation are reported in Table 6. The results imply that energy use and urbanization have positive and significant relationship with CO_2 emissions in the long-run while GDP per capita and openness to trade have no significant impact on CO_2 emission in the long-run. According to estimated long-run coefficients, one percent increase in urbanization rate and energy use lead to 0.45 percent and 0.99 percent increase in CO_2 emissions, respectively.

[Table 6 is about here]

The error correction mechanism (ECM) is used to capture the short-run relationship among the variables. The speed of the adjustment in the short-run in case any deviation from the long-run equilibrium is represented by the error correction terms ECM (-1). A negative and significant term means that a certain variable is error-correcting in the sense that it adjusts after deviating from it (Sari et al., 2012).

The short-run dynamics when CO_2 emissions are the dependent variable are presented in Table 7. The estimated coefficient of ECM(-1) is statistically significant at 1% confidence level which indicates that there exists a stable long-run relationship. The estimated ECM (-1) is -0.378 with the expected sign, suggesting that when CO2 emissions are above or below its equilibrium level, it adjusts by almost 38% within the first year.

[Table 7 is about here]

The long run elasticity of CO_2 emissions with respect to energy use (0.9971) is smaller than short run elasticity of (1.074). This implies that the environmental quality is found to be good in respect of energy use in Turkey. Therefore, higher energy use in Turkey will not give rise to more CO2 emissions and the environment will be polluted less in the long run.

The long-run results for the energy use equation are reported in Table 8. These results show that CO_2 emission, GDP per capita and trade have positive and significant relationships with energy use in the long-run. On the other hand, the impact of the urbanization is negative and significant in the long-run. This implies that, one percent increase in urbanization rate leads to 0.3 percent decrease in energy use. This result is consistent with the “compact city theory” that focused on the benefits of the increased urbanization.

[Table 8 is about here]

The short-run dynamics for the dependent variable of energy use are shown in Table 9. The results show that the coefficient of estimated ECM (-1) is negative and statistically significant at 1% confidence level. This highly significant term could be a further proof of the existence of a stable long-run relationship between the variables (Bannerjee et al., 1998). The high coefficient estimation of -0.937 indicates a faster return to long-run equilibrium. This means that the full convergence process of energy use to its long-run equilibrium level will be realized almost within the first year.

[Table 9 is about here]

4.2. Diagnostics and granger causality test results

The cointegrating relationship indicates the existence of long-run relationship between variables, however it does not indicate the direction of the relationship. On the other hand, cointegration tests are potentially biased (Soytaş et al., 2007). The Todo Yamamato (1995) procedure is employed to test for long run Granger causality. This procedure has many advantageous over conventional procedures because it does not depend on the cointegration properties of the system (Zapata and Rambaldi, 1997; Soytaş et al., 2007). This procedure also can be applied to any level of integrated variables. Furthermore, it involves a vector autoregression (VAR) in levels which means there is no loss of information due to differencing.

By following Soytaş, Sarı and Ewing (2007), modified Wald test is employed to test for Granger causality. VAR (k+d) in levels of variables are estimated, where k denotes optimum lag length and d denotes maximum order of integration. So, standard Wald test on the first k parameters of other variable in VAR (k+d) is conducted. If they are found to be statistically significant, then we reject the null hypothesis of non-causality.

Unit root test results identified d as 1 and as discussed under the *empirical results* heading of the fourth section of the paper the optimum lag length is determined as 2. Hence, VAR (3) in levels is estimated and a variety of diagnostic results for all equations are reported in Table 10. The estimated VAR (3) system is as follows:

$$V_t=a_v + b_1 V_{t-1} + b_2 V_{t-2} + b_3 V_{t-3} + \boldsymbol{\varepsilon}_{vt}$$

where, V_t=($LCO2_t$, $LENG_t$, $LGDP_t$, $LTRADE_t$, $LURB_t$), a_v is a (5x1) vector of constants, b_1, b_2 and b_3 are (5x5) coefficient matrices, and $\boldsymbol{\varepsilon}_{vt}$ denotes white noise residuals.

The first column of Table 10 gives the adjusted R^2, which are quite high. Thus, this five predictor model has a strong explanatory power. Jarque-Bera (J-B) tests for normality do not tell any problems at 1 percent or 5 percent significance level. Lagrange multiplier test for autoregressive conditional heteroscedasticity (ARCH LM) appear to be significant at 5 percent level only for energy use equation. White tests do not imply heteroscedasticity at 1 percent or 5 percent significance level for any of the equations. Ramsey RESET tests, which is conducted for one fitted term using LR, imply parameter instability for the CO_2 emissions and energy use at 1 percent and 5 percent significance level, respectively. However, conducted CUSUM and CUSUM of squares tests do not verify a stability violation.[4]

[Table 10 is about here]

The Granger causality test results are presented in Table 11. The findings indicate trade Granger cause CO_2 emissions, energy use and urbanization in a unidirectional way. CO_2 emissions Granger cause urbanization. There is two-way directional causality between CO_2 emissions and energy use, and energy use and urbanization. The bidirectional causality between CO_2 emissions and energy use finding is inconsistent with Soytaş and Sari (2009) because their study concludes that carbon emissions seem to Granger cause energy consumption, but the reverse is not true. Furthermore, there is unidirectional causality running from GDP per capita to CO_2 emissions and energy use. This is a similar finding with Halicioglu (2009) that also finds long and short run bidirectional causality between CO2 emissions and income in Turkey.

[Table 11 is about here]

The results shows that the relationship between urbanization rate and GDP per capita is relatively weak, while the relationship between urbanization rate and foreign trade is relatively stronger. Both results support the previously reported causal relationship between these variables.

[4] Correlograms of residuals and squared residuals, CUSUM and CUSUM of squares are availavle from the author upon request.

On the other hand, neither of the variables leads economic output. The lack of a long run causal link between output and emissions is in line with the findings of the research that is conducted by Soytaş and Sari (2009) to investigate the long run Granger causality relationship between economic growth, carbon dioxide emissions and energy consumption in Turkey. This result may be implying that Turkey does not have to sacrifice economic growth to reduce carbon emissions.

4.3. Generalized variance decomposition and impulse response analysis

The generalized forecast error variance decompositions (GVD) and generalized impulse response (GIR) of Koop et al. (1996) and Pesaran and Shin (1998) are employed by following Sari et al. (2012). Both methods are based on the estimation of the moving average representation of the original VAR, and unlike the standard approach the GVD is not sensitive to the ordering of variables in the VAR system (Sari et al., 2012; Soytas et al., 2007). Forecast error variance decompositions capture what percentage of the variation, which is created as a response of unexpected shocks, in a variable can be explained by the changes in the variable itself and in another variable in the same VAR system. Impulse responses display the dynamic responses of a variable to shocks in its own and other variables in the same system of a VAR initially and whether the effect of the shock persists or dies out quickly.

The results of the generalized forecast error variance decompositions for all variables are summarized in Table 12. The overall results clearly suggests a strong feedback relationship between the variables. The most striking result indicates that after the 15th horizon the impact of urbanization on forecast error variance of all other variables is almost 50 percent or higher, which is higher than any other variable in the system. The results indicate that urbanization account for on average 5 percent (the lowest for GDP per capita (0.6 %) and highest for trade (12%)) of the variance in all other variables at the shorter horizons and more than 50 percent in the longer horizons. On the other hand, the results based on the urbanization equation indicate that most of the variations in urbanization rate is due to its own innovation. This findings are consistent with the characteristic of urbanization because it is a matter of social and economic transformation therefore any impacts of changes in urbanization can be observed in the long time of period.

[Table 12 is about here]

The generalized impulse responses of CO_2 emissions, GDP per capita, energy use and foreign trade to one standard deviation in urbanization rate are graphed in Figure 1. On the other hand, the responses of urbanization to changes in other variables are graphed in Figure 2. It is clear from Figure 1 that shocks to urbanization rate have not significant impacts on CO_2 emissions, GDP per capita, energy use and trade openness. However, the direction of relationship between variables can be captured from the graphs. In this regard, the initial impact of unanticipated changes in urbanization on CO2 emissions and openness to trade are positive and continue positively for CO2 emissions whereas it turns out negative for openness to trade. Instead, the initial impact of shocks to urbanization on GDP per capita and energy use are negative and turns out positive after 2^{nd} period.

[Figure 1 is about here]

Figure 2 shows that the initial impact of unanticipated changes in CO_2 emissions, GDP per capita and energy use on urbanization is also insignificant and negative as well as persist in a same manner by forming U-shape up to 10^{th} horizon. On the other hand, response of urbanization to shocks to trade is positive and significant between 2^{nd} and 3^{rd} period.

[Figure 2 is about here]

5. Conclusions and policy implications

This paper empirically investigates the the dynamic casual relationships between CO2 emissions, energy use, GDP growth, foreign trade and urbanization of Turkey. The long-run causal relationship among the variables are examined in two-steps; firstly the bounds testing procedure is conducted to test for the cointegrating relationship among the variables, secondly the casual relationship is tested by using a specific ARDL model to estimate the long-run coefficients and the error-correction models with the presence of cointegrating relationships. Then, by employing the Todo Yamamato (1995) procedure long run Granger causality is tested and directions of the relationships are detected. In order to capture feedback relationships between the variables and their responses to unanticipated shocks generalized variance decompositions and impulse responses are estimated.

The results suggest that long-run as well as short-run energy use and urbanization rate has positive and significant impact on CO2 emissions. This finding implies that consuming more energy and increasing urbanization rate create pressure on the environment. However, the long run elasticity of CO_2 emissions with respect to energy use is smaller than short run elasticity implies that the environmental quality is found to be good in respect of energy use in Turkey. Thus, in the long-run higher energy use, GDP growth, trade and urbanization rate will not give rise to more CO2 emissions. This result is also supported by the findings of the causality test that implies causality running from GDP growth to CO2 emissions and energy use. Thus, policies implemented to reduce CO2 emissions will not be harmful for economic growth.

The results suggest that any policy reducing energy use will lead urbanization rate to decrease while any policy increasing urbanization rate will lead energy use to increase. Causality running from CO2 emissions to urbanization means, any policy in respect of reduction of CO2 emissions will be harmful for further urbanization.

The overall results of generalized forecast error variance decompositions clearly suggests a strong feedback relationship between the variables. The most striking result indicates that in the long-run the impact of urbanization on forecast error variance of all other variables is almost 50 percent or higher, which is higher than any other variable in the system. This findings are consistent with the ecological modernization theory, which describes urbanization as a process of social transformation.

The empirical results of this research implies that Turkey need to embrace more energy conservation policies to reduce CO2 emissions. Although economic growth has priority, policies to boost growth should be integrated with environmental and energy policies to reduce the pressure of growth on environment. Economies of scale for public infrastructure should be optimized to limit the pressure of increasing urban density on energy use.

References

Akarca, A.T., Long, T.V., 1980. On the relationship between energy and GNP: a reexamination. Journal of Energy and Development 5, 326–331.

Akbostanci E, Turut-Asik S, Tunc GI., 2009. The relationship between income and environment in Turkey: is there an environmental Kuznets curve? Energy Policy 2009; 37: 861–7.

Altinay, G., Karagol, E., 2004. Structural break, unit root, and the causality between energy consumption and GDP in Turkey. Energy Economics 26, 985–994.

Banerjee, A., Cockerill, L., Russell, B., 2001. An I (2) analysis of inflation and the markup. Journal of Applied Econometrics 16, 221–240.

Breheny, M., 2001. Densities and sustainable cities: the UK experience. In: Echenique, M., Saint, A. (Eds.), Cities for the New Millennium. Spon Press, London, pp. 39–51.

Burton, E., 2000. The compact city: just or just compact? A preliminary analysis. Urban Studies 37 (11), 1969–2001.

Capello, R., Camagni, R., 2000. Beyond optimal city size: an evaluation of alternative urban growth patterns. Urban Studies 37 (9), 1479–1496.

Crenshaw, E.M., Jenkins, J.C., 1996. Social structure and global climate change: sociological propositions concerning the greenhouse effect. Sociological Focus 29 (4), 341–358.

Dickey, D.A., Fuller, W.A., 1979. Distribution of the estimators for autoregressive time series with a unit root. The Journal of American Statistical Association 74 (365), 427–431.

Elliott, G., Rothenberg, T.J., Stock, J.H., 1996. Efficient tests for an autoregressive unit root. Econometrica 64, 813–836.

Fan, Y., Lui, L.-C., Wu, G., Wie, Y.-M., 2006. Analyzing impact factors of CO2 emissions using the STIRPAT model. Environmental Impact Assessment Review 26 (4), 377–395.

Ghatak, S., Siddiki, J., 2001. The use of ARDL approach in estimating virtual exchange rates in India. J. Appl. Stat. 28, 573–583.

Gouldson, A.P., Murphy, J., 1997. Ecological modernization: economic restructuring and the environment. The Political Quarterly 68 (5), 74–86.

Halicioglu F., 2009. An econometric study of CO2 emissions, energy consumption, income and foreign trade in Turkey. Energy Policy 2009; 37: 699–702.

Hossain, S., 2012. An econometric Analysis for CO2 Emissions, Energy Consumption, Economic Growth, Foreign Trade and Urbanization of Japan. Low Carbon Economy, 3, 92-105

IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

Jenks, M., Burton, E., Williams, K. (Eds.), 1996. The Compact City: A Sustainable Urban Form? E & FN Spon, New York.

Johansen, S. and Juselius, K., 1990. Maximum likelihood estimation and inference on cointegration with applications to the demand for money, *Oxford Bulletin of Economics and Statistics,* 52, pp. 169–210.

Koop, G., Pesaran, M.H., Potter, S.M., 1996. Impulse response analysis in nonlinear multivariate models. Journal of Econometrics 74, 119–147.

Kwiatkowski, D., Phillips, P.C.B., Schmidt, P., Shin, Y., 1992. Testing the null hypothesis of stationary against the alternative of a unit root. Journal of Econometrics 54, 159–178.

Mol, A.P.J., Spaargaren, G., 2000. Ecological modernization theory in debate: a review. Environmental Politics 9 (1), 17–49.

Martínez-Zarzoso, I., 2008. The impact of urbanization on CO2 emissions: evidence from developing countries, CESifo working paper, No. 2377

Martinez-Zarzoso, I., Maruotti, A., 2011. The impact of urbanization on CO2 emissions: evidence from developing countries. Ecol. Econ. 70, 1344–1353.

Narayan, Paresh Kumar, 2005. The saving and investment nexus for China: evidence from cointegration tests', Applied Economics, 37: 17, 1979 — 1990

Newman, P.W.G., Kenworthy, J.R., 1989. Cities and Automobile Dependence: An International Sourcebook. Gower Technical, Aldershot.

Ozturk I, Acaravci A., 2010. The causal relationship between energy consumption and GDP in Albania, Bulgaria, Hungary and Romania: evidence from ARDL bound testing approach. Appl Energy 2010; 87:1938–43.

Parikh, J., Shukla, V., 1995. Urbanization, energy use and greenhouse effects in economic development: results from a cross-national study of developing countries. Global Environmental Change 5 (2), 87–103.

Pesaran, M.H., Pesaran, B., 1997. Working with Microfit 4.0 Camfit Data, Cambridge, England.

Pesaran, M.H., Shin, Y., 1998. Generalized impulse response analysis in linear multivariate models. Economics Letters 58, 17–29.

Pesaran, M.H., Shin, Y., Smith, R.J., 2001. Bounds testing approaches to the analysis of level relationships. J. Appl. Econ. 16, 289–326.

Phillips, P.C.B., Perron, P., 1988. Testing for a unit root in time series regressions. Biometrica 75, 335 346.

Poumanyvong, P., Kaneko, S., 2010. Does urbanization lead to less energy use and lower CO2 emissions? A cross-country analysis. Ecol. Econ. 70 (2), 434–444.

Rudlin, D., Falk, N., 1999. Building the 21st Century Home: The Sustainable Urban Neighborhood. Architectural Press, Oxford.

Sadorsky, P., 2014. The effect of urbanization on CO2 emissions in emerging economies. Energy Economics 41 (2014) 147-153

Sari, R., Hammoudeh, S., Chang, C-L., McAleer, M., 2012. Causality between market liquidity and depth for energy and grains. Energy Economics, 34 (2012) 1683-1692

Sharma, S.S., 2011. Determinants of carbon dioxide emissions: empirical evidence from 69 countries. Appl. Energy 88, 376–382.

Soheilakhoshnevis, Y. and and Bahram, S., 2014. The Econometric Model for CO2 Emissions, Energy Consumption, Economic Growth, Foreign Trade, Financial Development and Urbanization of Iran. Journal of Environmental Research and Development Vol. 8 No. 3A, January-March 2014

Soytas, U., Sarı, R., 2009. Energy consumption, economic growth, and carbon emissions: challenges faced by an EU candidate member. Ecological Economics.

Soytas, U., Sari, R., Ewing, B.T., 2007. Energy consumption, income, and carbon emissions in the United States. Ecological Economics 62, 482–489.

Toda, H.Y., Yamamoto, T., 1995. Statistical inference in vector autoregression with possibly integrated processes. Journal of Econometrics 66, 225–250.

York, R., Rosa, E.A., Dietz, T., 2003. STIRPAT, IPAT and ImPACT: analytic tools for unpacking the driving forces of environmental impacts. Ecological Economics 46 (3), 351–365.

Zapata, H.O., Rambaldi, A.N., 1997. Monte Carlo evidence on cointegration and causation. Oxford Bulletin of Economics and Statistics 59, 285–298.

World Development Indicators, www.worldbank.org

TABLES

Table 1: Descriptive statistics of data set

	LCO2	LENG	LGDP	LTRADE	LURB
Mean	0.699	6.685	8.381	3.171	3.909
Median	0.775	6.684	8.340	3.417	3.960
Maximum	1.419	7.284	8.966	4.007	4.259
Minimum	-0.494	5.952	7.748	1.745	3.450
Std. Dev.	0.529	0.387	0.347	0.657	0.263
Skewness	-0.633	-0.315	-0.060	-0.380	-0.253
Kurtosis	2.426	2.009	2.043	1.720	1.599
Observations	51	51	51	51	51

Data source: World Bank – World Development Indicators, 1960-2010 annual data

Notes: urb, co2, eng, trade, gdp refer to Urban population (% of total), CO2 emissions (metric tons per capita), Energy use (kg of oil equivalent per capita), Trade (% of GDP), and GDP per capita (constant 2005 US$) respectively. Natural logarithm of each series is used. L denotes natural logarithms

Table 2: Unit Root Test Results

		ADF		DFGLS		PP	KPSS	ERS-PO		NPZa	
Levels											
Intercept	lurb	-1.676046	2	-0.176381	2	-1.748174	0.941848 [a]	539.3010	2	-1.75407	2
	lco2	-2.812711 [c]	0	1.103035	0	-3.658240 [a]	0.927614 [a]	422.4536	0	1.25551	0
	leng	-2.149375	10	-0.237939 [b]	10	-1.189266	0.942913 [a]	1920.648	10	-7.51302 [c]	10
	ltrade	-1.967928	0	-0.016295	1	-1.968949	0.905321 [a]	51.27903	0	-0.04695	1
	lgdp	-0.633237	0	1.683421	0	-0.625451	0.951196 [a]	253.2863	0	1.764150	0
Intercept and Trend	lurb	-1.113958	2	-1.547791	2	-0.464056	0.178450 [b]	15.35823	2	-13.425	2
	lco2	-2.480281	0	-1.360981	0	-2.502573	0.206331 [b]	47.08657	0	-2.54689	0
	leng	-3.393534 [c]	10	-2.133021	0	-2.360810	0.165640 [b]	0.196912 [a]	10	-7.53759	0
	ltrade	-3.326579 [c]	1	-3.418001 [b]	1	-3.267308 [c]	0.119799 [c]	7.470837	1	-14.7466 [c]	1
	lgdp	-3.798144 [b]	3	-2.919712 [c]	0	-3.048181	0.077424	0.804867 [a]	3	-12.4281	0
First Difference											
Intercept	durb	-2.276350	1	-2.306152 [b]	1	-1.843831	0.322372	2.207462 [b]	1	-11.9841 [b]	1
	dco2	-7.002361 [a]	0	-6.712598 [a]	0	-7.003123 [a]	0.515676 [b]	1.150333 [a]	0	-34.9355 [a]	0
	deng	-6.942794 [a]	0	-1.056040	9	-6.943442 [a]	0.108650	1.532261 [a]	0	0.33789	9
	dtrade	-6.980066 [a]	0	-0.493892	6	-7.018168 [a]	0.144420	11.94402	0	-268.683 [a]	6
	dgdp	-7.274587 [a]	0	-6.506176 [a]	0	-7.274388 [a]	0.044256	1.756492 [a]	0	-22.3344 [a]	0
Intercept and Trend	durb	-2.735829	1	-2.697500	1	-2.198183	0.109886	6.375017 [c]	1	-14.8026 [c]	1
	dco2	-7.876807 [a]	0	-7.236383 [a]	0	-7.849077 [a]	0.082413	4.388378 [b]	0	-26.5944 [a]	0
	deng	-2.160558	9	-6.527479 [a]	0	-7.030148 [a]	0.040700	23.10195	9	-23.0119 [b]	0
	dtrade	-6.823377 [a]	0	-3.878598 [a]	0	-6.856554 [a]	0.047326	13.16349	0	-10.6018	0
	dgdp	-7.233764 [a]	0	-6.712232 [a]	0	-7.233858 [a]	0.038968	4.354170 [b]	0	-22.9265 [b]	0

Notes: Superscript: a,b,c represent significance at 1%, 5%, and 10%, respectively. Lag lengths are determined by Akaike Information Criterion (AIC).

Table 3: VAR Lag order specification

Lag	LogL	LR	FPE	AIC	SC	HQ
0	257.4544	NA	9.22e-12	-11.22019	-11.01945	-11.14536
1	510.6135	438.8091	3.67e-16	-21.36060	-20.15616	-20.91160
2	573.0800	94.39385*	7.24e-17*	-23.02578	-20.81764*	-22.20260*
3	589.3973	21.03111	1.19e-16	-22.63988	-19.42803	-21.44253
4	619.1773	31.76534	1.21e-16	-22.85232	-18.63678	-21.28081
5	648.5253	24.78282	1.52e-16	-23.04557	-17.82632	-21.09989
6	702.0125	33.28093	9.14e-17	-24.31167*	-18.08872	-21.99182

Notes: Sample: 1960-2010, included observations: 45; * indicates lag order selected by the criterion

Table 4: Bounds-testing procedure results

Cointegration Hypotheses	F-statistics
F(LCO2 l LENG, LGDP, LTRADE, LURB)	4.166203**
F(LENG l LCO2, LGDP, LTRADE, LURB)	4.832944**
F(LGDP l LCO2, LENG, LTRADE, LURB)	1.176172
F(LTRADE l LCO2, LGDP, LENG, LURB)	1.971631
F(LURB l LCO2, LGDP, LENG, LTRADE)	2.875474

Notes: Full sample covers the period 1963-2010. total number of observations= 48; Critical values for the bounds test: Case II: restricted intercept and no trend (Narayan,2005); The asterisks *, **, and *** denotes significance at the 1%, 5%, and 10% level, respectively.

Table 5: Johansen Cointegration Test Results (lag=2)

H_0	Eigenvalue	Trace Stat.	1%	Max-Eig Stat.	1%
None **	0.663863	106.3917	76.07	52.33136	38.77
At most 1 *	0.446778	54.06033	54.46	28.41580	32.24
At most 2	0.274379	25.64453	35.65	15.39491	25.52
At most 3	0.163074	10.24962	20.04	8.544936	18.63
At most 4	0.034891	1.704685	6.65	1.704685	6.65

Table 6: Estimated Long Run Coefficients using the ARDL Approach (ARDL(1,1,0,0,0)) based on SBC, dependent variable is LCO2

Regressor	Coefficient	T-ratio	Prob.
LENG	0.9971	3.809	0.000
LGDP	-0.1366	-0.618	0.540
LTRADE	0.0108	0.195	0.846
LURB	0.45655	1.857	0.071
C	-6604750	-13.972	0.000

Notes: 45 observations used for estimation from 1966 to 2010

Table 7: Error Correction Representation for the Selected ARDL Model (ARDL(1,1,0,0,0)) based on SBC, dependent variable is DLCO2

Regressor	Coefficient	T-ratio	Probability
DLENG	1.074	8.424	0.000
DLGDP	-0.052	-0.552	0.584
DLTRADE	0.004	0.198	0.844
DLURB	0.172	1.697	0.098
DC	-2495437	-2.956	0.005
ECM(-1)	-0.378	-3.0658	0.004

Notes: 45 observations used for estimation from 1966 to 2010

Table 8: Estimated Long Run Coefficients using the ARDL Approach (ARDL(1,0,2,2,2)) based on SBC, dependent variable is LENG

Regressor	Coefficient	T-ratio	Prob.
LCO2	0.588	14.639	0.000
LGDP	0.358	7.520	0.000
LTRADE	0.102	4.393	0.000
LURB	-0.373	-4.688	0.000
C	4428990	12.4619	0.000

Notes: 45 observations used for estimation from 1966 to 2010

Table 9: Error Correction Representation for the Selected ARDL Model (ARDL(1,0,2,2,2)) based on SBC, dependent variable is LENG

Regressor	Coefficient	T-ratio	Probability
DLCO2	0.552	11.543	0.000
DLGDP	0.224	4.144	0.000
DLGDP1	-0.113	-2.099	0.043
DLTRADE	0.044	2.539	0.016
DLTRADE1	-0.082	-3.782	0.001
DLURB	1.116	1.521	0.137
DLURB1	-2.187	-2.990	0.005
DC	4151725	10.834	0.000
ECM(-1)	-0.937	-13.6588	0.000

Notes: 45 observations used for estimation from 1966 to 2010

Table 10: Diagnostic test results

Equation	Adj R^2	J-B Test	ARCH LM	White Test	Ramsey Test
CO2	0.9912	1.0792	0.9517	34.3085	9.7316[a]
ENG	0.9911	4.1833	6.0260[b]	33.1977	5.1005[b]
GDP	0.9839	4.7795[c]	0.7367	32.6770	0.2741
TRADE	0.9505	5.1738[c]	3.4529	41.4784[c]	1.3473
URB	0.9999	2.7366	0.8280	32.0505	3.5819[c]

Table 21: Granger causality test results

Dependent variable	CO2	ENERGY	GDP	TRADE	URBAN
CO2	-	4.879408[b]	4.204321[b]	6.03319[a]	0.447633
ENERGY	2.50689[c]	-	5.559436[a]	8.321548[a]	2.811238[c]
GDP	0.232417	1.210086	-	1.823301	0.37528
TRADE	0.223967	0.001985	0.104603	-	1.690617
URBAN	3.294166[b]	3.462746[b]	0.837296	8.875314[a]	-

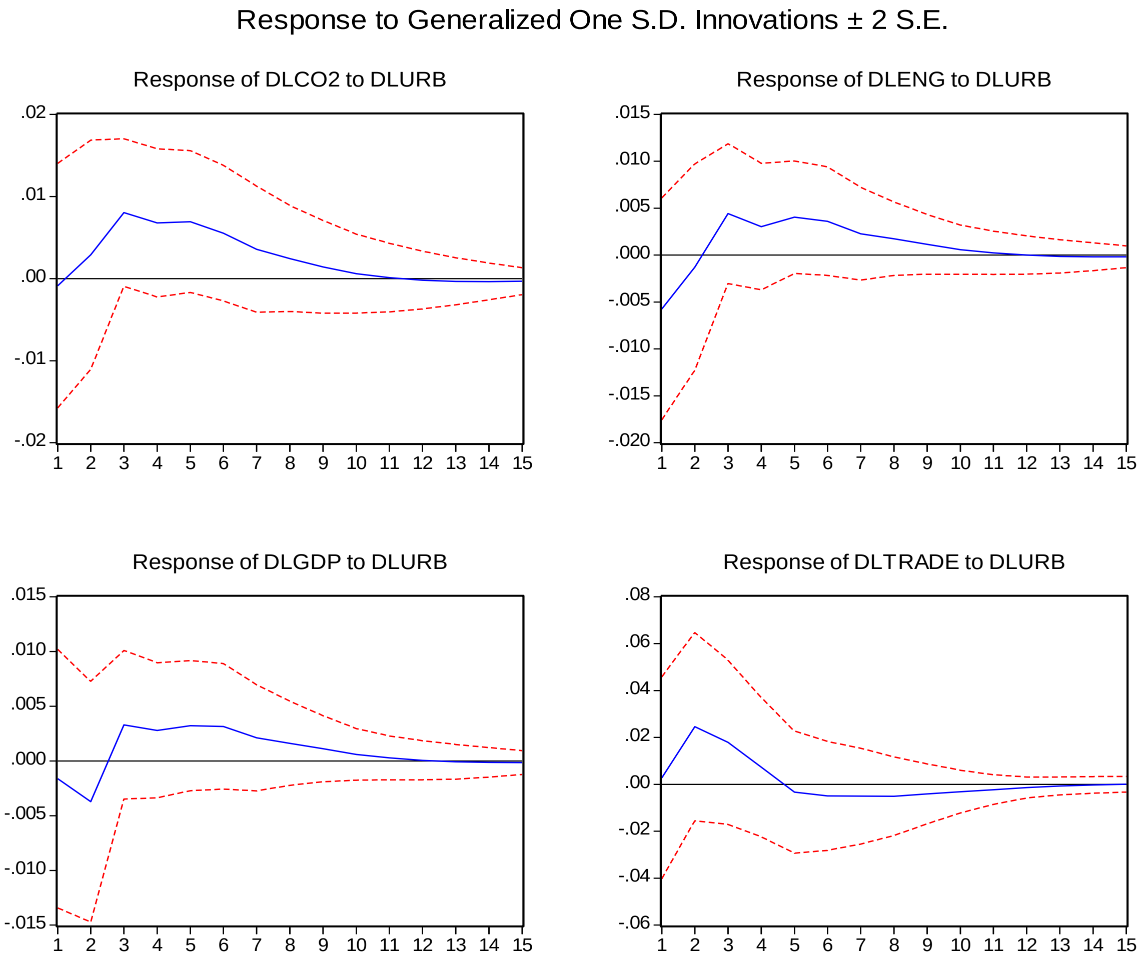
Notes: Superscripts a, b and c represent significance at the 1, 5, and 10% respectively.
Significance implies that the column variable Granger causes the row variable.

Table 12: Generalized forecast error variance decomposition

Dependent variable	Horizon	LCO2	LENG	LGDP	LTRADE	LURB
LCO2	0	1.00000	0.81493	0.31008	0.04007	0.02291
	1	0.87625	0.71926	0.34449	0.14043	0.01543
	5	0.61468	0.49181	0.39577	0.16099	0.12442
	10	0.37904	0.30980	0.29062	0.11152	0.41539
	15	0.26494	0.22671	0.24230	0.09150	0.55438
	20	0.21913	0.19631	0.23914	0.08201	0.59892
	25	0.19891	0.18423	0.24686	0.07694	0.61216
LENG	0	0.81493	1.00000	0.36901	0.07072	0.01150
	1	0.77507	0.88576	0.36662	0.17499	0.01725
	5	0.59789	0.64320	0.46798	0.21782	0.04409
	10	0.42352	0.46141	0.37619	0.16645	0.27989
	15	0.29390	0.32741	0.29012	0.13142	0.46968
	20	0.23268	0.26473	0.26346	0.11187	0.55064
	25	0.20505	0.23664	0.26216	0.10104	0.58031
LGDP	0	0.31008	0.36901	1.00000	0.00900	0.00012
	1	0.34700	0.40396	0.98569	0.00880	0.00099
	5	0.32112	0.37955	0.90409	0.04795	0.01859
	10	0.25520	0.31045	0.75370	0.05237	0.17794
	15	0.19062	0.23853	0.57527	0.05665	0.36666
	20	0.15507	0.19840	0.47468	0.05716	0.47447
	25	0.13944	0.18029	0.43043	0.05644	0.52301
LTRADE	0	0.04007	0.07072	0.00900	1.00000	0.02134
	1	0.04018	0.06880	0.01618	0.98000	0.05441
	5	0.05590	0.06232	0.04770	0.66955	0.30691
	10	0.04647	0.05492	0.04772	0.50684	0.46726
	15	0.05148	0.06239	0.07843	0.42336	0.51896
	20	0.05772	0.07037	0.10671	0.38068	0.53291
	25	0.06135	0.07525	0.12415	0.35773	0.53839
LURB	0	0.02291	0.01150	0.00012	0.02134	1.00000
	1	0.01836	0.00500	0.00143	0.08551	0.97156
	5	0.00446	0.00121	0.00139	0.07945	0.96627
	10	0.00861	0.01753	0.03282	0.06348	0.93768
	15	0.02586	0.04126	0.08702	0.05926	0.88359
	20	0.04044	0.05901	0.13225	0.05669	0.83881
	25	0.04940	0.06988	0.16144	0.05530	0.81005

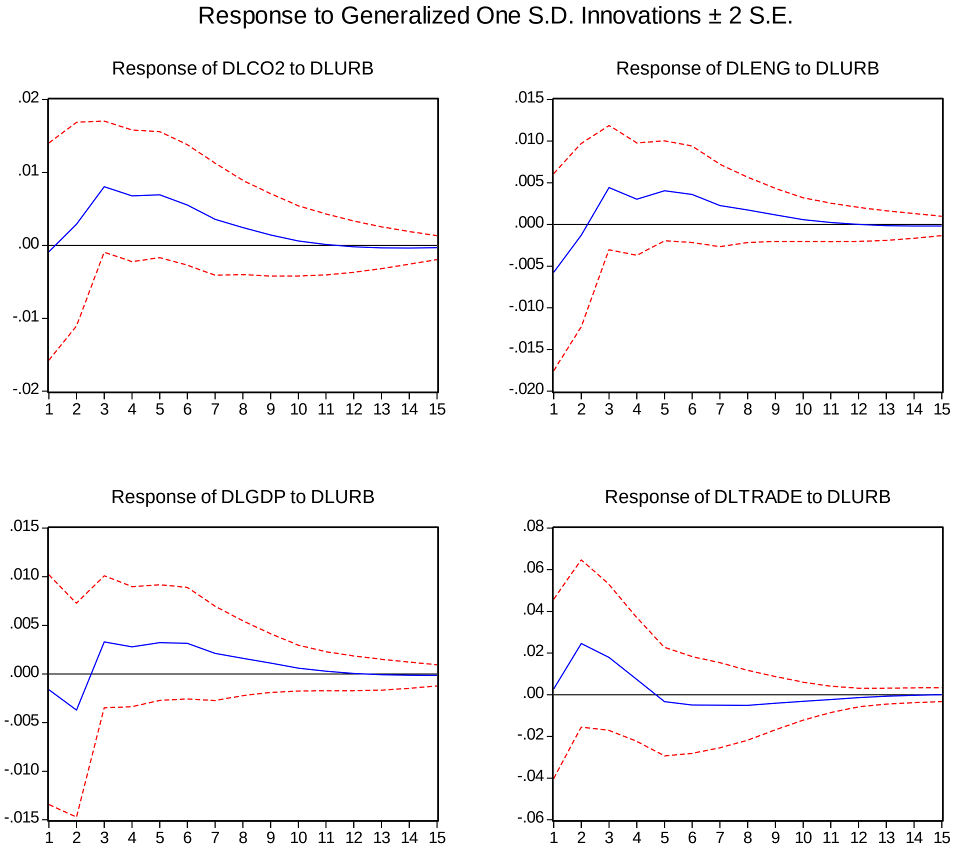
Notes: Based on 49 observations from 1962 to 2010.

Figure 1: Generalized impulse responses of CO_2 emissions, GDP per capita, energy use and foreign trade to one standard deviation in urbanization rate



Notes: D denotes the first difference operator

Figure 2: Generalized impulse responses of urbanization rate to one standard deviation in CO_2 emissions, GDP per capita, energy use and foreign trade



Notes: D denotes the first difference operator