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Structural Breaks, Urbanization and CO_2 Emissions: Evidence from Turkey

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Abstract
The aim of this study is to examine the relationship between urbanization and CO_2 emissions in the case of Turkey by adding economic growth and energy consumption to the CO_2 emissions specification. The study covers annual time series data over the period of 1960-2014. The autoregressive distributed lag bounds testing approach to cointegration was utilized to investigate the long-run relationship among under structural breaks. The causal relationship among the variables was explored through Toda-Yamamoto test. The empirical findings reveal that i) each variable (except for energy consumption) is integrated at I(1) under structural breaks, ii) the variables are cointegrated in the presence of structural break, iii) the validity of environmental Kuznets curve was confirmed both in the short-run and long-run, iv) CO_2 emissions are primarily affected by economic growth, energy consumption and urbanization in the long run and v) urbanization causes CO_2 emissions. The study provides important policy implications for Turkish economy.

Keywords: Urbanization, CO_2 emissions, Cointegration, Causality, Turkey

JEL Codes: C32; O47; Q43

1. Introduction

The climate change continues to be one of the most important problems in the world due to its impact on global warming, desertification and sea levels (Burck et al., 2017; Martinez-Zarzoso and Maruotti, 2011). According to the OECD report (2015), the number of premature deaths resulting from high local pollution levels is expected to rise from current levels of nearly 1.5 million to 3.5 million by 2050. Changes in the composition of plants and animals, alterations in the availability of fresh water and increases in the level of water and air pollution lead authorities to take measures to lessen the greenhouse gases (GHGs) emissions in developing countries.

The primary determinants of climate change and environmental pollution are carbon dioxide (CO_2), methane, and nitrous oxide currently accounting for 98% of the GHGs (OECD Environmental Outlook, 2011). It is expected that the global energy-related CO_2 emissions will

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rise from 32.3 billion metric tons in 2012 to 35.6 billion metric tons in 2020 (International Energy Outlook, 2016). The area of global energy consumption has shifted towards expeditiously urbanising, industrialising and growing India and China, as well as some of Latin American and African countries (World Energy Outlook, 2016). Today, almost half of the world's population reside in urban areas (3.5 billion urbans of the world's 7.1 billion people); by 2030 approximately 60% of total population of developing countries is estimated to live in urban cities (4.9 billion of the world's projected 8.3 billion) (Bekhet and Othman, 2017).

2. Literature Review

Urbanization, a long run continuing process, arises due to migration from rural to urban spaces, industrialization and economic development (Davis, 1965). According to Zi et al. (2016) and Behera and Dash (2017), urbanization is related to energy consumption and environmental pollution. They indicate that urban spaces account for approximately 75% of energy consumption and 60% of CO_2 emissions in the world. In addition, Sharma (2011), Farhani and Ozturk (2015) and Ali et al. (2016) argue that urbanization is a significant determinant of CO_2 emissions.

The existing literature indicates the presence of three theories which investigate the link between urbanization and natural environment. These are ecological modernization (Mol and Spaargaren, 2000), urban environmental transition (McGranahan et al., 2001) and compact city theories (Burton, 2000). According to these theories, the impact of urbanization on environment can be positive or negative depending on the net effect. It is suggested that economic activities intensify on urban and industrial spaces; therefore, urbanization can affect CO_2 emissions (Dodman, 2009; Glaeser and Kahn, 2010; Grimm et al., 2008; Martinez-Zarzoso and Maruotti, 2011), energy consumption (Dahl and Erdogan, 1994; Jones, 1991; Lenzen et al., 2006), and economic growth (Henderson, 2003; Quigley, 1998). The time series studies of Shahbaz et al. (2014a), Solarin and Lean (2016) and recent panel data studies of Saidi and Mbarek (2017), Xu and Lin (2016), Xu and Zhang (2016) and Wang et al. (2017) provide empirical evidences supporting that urbanization is linked with CO_2 emissions.

The present study investigates the link between urbanization and CO_2 emissions in Turkey by using economic growth and energy consumption as control variables parallel with the existing literature. Our study focuses on Turkish economy for several reasons. Firstly, Turkey is one of the fastest growing economies among developing countries because of successfully applied structural reforms and macroeconomic policies. Turkey was the 17th biggest economy in the world with a national income of around 863 billion dollars in 2016. Between 2005-2010, the average growth rate of Turkish economy reached 4.2% and between 2011-2016 it was 6.5% (Economic Outlook of Turkey, 2017). Secondly, Turkey is an energy-dependent country owing to its growing energy demand. It is estimated that Turkey's primary energy consumption will increase from 120 million tons in 2012 to 218 million tons in 2023 (World Energy Council, 2016). Thirdly, it is expected that Turkey's total population will rise from 79.8 million in 2016 to 84 million in 2023. Rapid population growth has led to rapid urbanization in Turkey. Urban population rate grew from 25% in 1950 to 75% in 2015 (World Bank, 2017). Turkey's rapid urbanization has changed demographic and economic structure.

Finally, in line with the increasing population, urbanization, economic growth and energy demand, Turkey's CO_2 emissions increased by 57% between 2000-2014. There exist 20 countries which are responsible for nearly 78% of global energy-related CO_2 emissions in the world. The top three CO_2 emitters -China, the United States and India, contribute more than half of total global emissions, while Turkey ranks 18th with a share of one percent (International Energy Agency, 2017). In terms of climate change performance index, Turkey is rated very low with a ranking of 47 out of 60 countries owing to its poor climate protection performance and

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its emissions have been growing at a very fast pace (Burck et al., 2017). However, according to the Paris pledge, Turkey is expected to decrease its 2020 emission level from 1.185 million tons to 940 million tons (World Energy Council, 2016).

Table 1 summarizes selected time series studies investigating the relationship between urbanization and CO_2 emissions. The literature review shows that: (i) Zi et al. (2016) for China, Ozturk and Al-Mulali (2015) for Cambodia did not investigate the presence of cointegration between the variables; (ii) Bekhet and Othman (2017) for Malaysia and Ouyang and Lin (2017) for China and Japan did not deal with the long run impact of urbanization on CO_2 emissions; (iii) the causal relationship between urbanization and CO_2 emissions were not examined by Ali et al. (2016) for Nigeria, Asumadu-Sarkodie and Owusu (2017) for Senegal, Azam and Khan (2016) for SAARC countries, Saboori et al. (2016) for Malaysia, Zi et al. (2016) for China, Ozturk and Al-Mulali (2015) for Cambodia, and Shahbaz et al. (2013) for South Africa; (iv) the positive link between urbanization and CO_2 emissions was found by Azam and Khan (2016) for Sri Lanka, Dogan and Turkekul (2016) for USA, Farhani and Ozturk (2015) for Tunisia, Ozturk and Al-Mulali (2015) for Cambodia, Saboori et al. (2016) for Malaysia, Shahbaz et al. (2014b) for United Arab Emirates (UAE) and Shahbaz et al. (2013) for South Africa, Solarin and Lean (2016) for China and India, Zi et al. (2016) for China; (v) the negative relationship between urbanization and CO_2 emissions was determined by Asumadu-Sarkodie and Owusu (2017) for Senegal, Azam and Khan (2016) for India and Bangladesh; (vi) the bidirectional causality between urbanization and CO_2 emissions was confirmed by Bekhet and Othman (2017) for Malaysia, Dogan and Turkekul (2016) for USA, Solarin and Lean (2016) for China and India; (vii) the unidirectional causality running from CO_2 emissions to urbanization was verified by Farhani and Ozturk (2015) for Tunisia, Ouyang and Lin (2017) for China and Japan, Shahbaz et al. (2016) for Malaysia and Shahbaz et al. (2014b) for UAE.

The literature review reveals that a handful studies investigated the causal linkage between urbanization and CO_2 emissions. The literature review also reveals that these studies are not related to Turkish economy. Besides, there exists limited empirical evidence for cointegration analysis with structural breaks. For these reasons, the aim of our study is to investigate the long-run and causal relationships between urbanization and CO_2 emissions by using a single framework for Turkey under structural breaks. Following the studies of Azam and Khan (2016), Bekhet and Othman (2017), Ouyang and Lin (2017) and Shahbaz et al. (2016), economic growth and energy consumption are incorporated into the CO_2 emissions specification. In addition, the series used in the study tend to move in the same direction over the period of 1960-2014 (Fig. 1). The empirical findings reveal that urbanization has a positive and statistically significant effect on CO_2 emissions in the long run. It is concluded that there is a unidirectional causation running from urbanization to CO_2 emissions. The novel empirical results not only expand the literature but also allow policy makers to derive some implications for Turkish economy.

Empirically, we apply Ng-Perron unit root test of Ng and Perron (2001) and Lee-Strazicich unit root test with two structural breaks of Lee and Strazicich (2003) to investigate the stationarity properties of the series. The autoregressive distributed lag (ARDL) bounds testing approach of Pesaran et al. (2001) is used to examine the existence of cointegration between the variables in the presence of structural break. Additionally, we use the Toda-Yamamoto causality approach of Toda and Yamamoto (1995) to examine the causality between the variables.

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Table 1: Selected time series studies on the relationship between urbanization and CO_2 emissions

Author	*Period/Country*	*Variables*	*Methodology*	*Cointegration*	*Long-run impact*	*Long-run causality*
Bekhet and Othman (2017)	1971-2015 Malaysia	CO_2, GDP, URB, EN, FD, INV	ARDL, VECM Granger causality	Yes	Not examined	URB↔CO_2
Ouyang and Lin (2017)	1989-2011 China and Japan	CO_2, GDP, GDP^2, URB, EN	Johansen cointegration, VECM Granger causality	Yes	Not examined	URB → CO_2
Asumadu-Sarkodie and Owusu (2017)	1980-2011 Senegal	CO_2, GDP, URB, FD, IND	Nonlinear iterative partial OLS	Yes	Negative	Not investigated
Saboori et al. (2016)	1980-2008 Malaysia	CO_2, GDP, GDP^2, URB, EN, TR	ARDL	Yes	Positive	Not investigated
Solarin and Lean (2016)	1965-2013 China and India	CO_2, GDP, GDP^2, URB, EN	Hatemi-J cointegration, Toda-Yamamoto causality	Yes	Positive	URB↔ CO_2
Ali et al. (2016)	1971-2011 Nigeria	CO_2, GDP, URB, TR, EN	ARDL	Yes	Insignificant	Not investigated
Azam and Khan (2016)	1982-2013 SAARC countries	CO_2, GDP, URB, EN, TP	Johansen cointegration, OLS	Yes	Negative for India and Bangladesh Positive for Sri Lanka	Not investigated
Shahbaz et al. (2016)	1970Q1-2011Q4 Malaysia	CO_2, GDP, URB, TR	Bayer-Hanck cointegration, ARDL, VECM Granger causality	Yes	Negative	URB → CO_2
Zi et al. (2016)	1979-2013 China	CO_2, GDP, URB	Threshold regression	Not examined	Positive	Not investigated
Dogan and Turkekul (2016)	1960-2010 USA	CO_2, GDP, GDP^2, URB, EN, TR, FD	ARDL, VECM Granger causality	Yes	Positive	URB↔ CO_2
Farhani and Ozturk (2015)	1971-2012 Tunisia	CO_2, GDP, URB, EN, TR	ARDL, VECM Granger causality	Yes	Positive	URB → CO_2
Ozturk and Al-Mulali (2015)	1996-2012 Cambodia	CO_2, GDP, GDP^2, URB, EN, GOV	Two-stage OLS, GMM	Not investigated	Positive	Not investigated
Shahbaz et al. (2014b)	1975-2011 UAE	CO_2, GDP, GDP^2, URB, EN, TR	Zivot-Andrews unit root, ARDL, VECM Granger causality	Yes	Positive	URB → CO_2
Shahbaz et al. (2013)	1965-2008 South Africa	CO_2, GDP, GDP^2, URB, FD, TR	Saikkonen-Lütkepohl unit root, ARDL, Granger causality	Yes	Positive	Not investigated

Notes: URB, GDP, GDP^2, CO_2, EN, TR, FD, GOV, TP, INV and IND denote urbanization, per capita real GDP, the square of per capita real GDP, carbon emissions, energy consumption, trade openness, financial development, government effectiveness, total population, domestic investments, and industrialization, respectively. → and ↔ indicate unidirectional causality and bidirectional causality, respectively.

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The study is constructed as follows. Section 2 presents the model and data. Section 3 deals with the econometric strategy. Section 4 describes the empirical results. Section 5 concludes the study and offers some policy implications.

3. Model and Data

Following Ali et al. (2016) for Nigeria, Farhani and Ozturk (2015) for Tunisia, Solarin and Lean (2016) for China and India, we examine the relation between urbanization, economic growth, energy consumption and CO_2 emissions in Turkish economy for the period 1960-2014. The long-run relationship is investigated using the log-linear model as follows:

$$lnCO_{2t} = \delta_0 + \delta_1 lnGDP_t + \delta_2 lnGDP_t^2 + \delta_3 lnURB_t + \delta_4 lnEN_t + \mu_t \quad (1)$$

where CO_{2t} is per capita CO_2 emissions (metric tons); GDP_t is per capita real GDP (constant prices in 2010 US$); GDPt2 is the square of per capita real GDP; URB_t is the urbanization rate (share of total population) and EN_t is per capita energy consumption (kt of oil equivalent). δ_0, t, μ denote the constant, the time index and the white noise error term, respectively. The annual data from 1960 to 2014 were compiled from World Bank's World Development Indicators database (WDI, 2017). Variables are used in natural logarithms.

δ_1, δ_2, δ_3 and δ_4 are estimated parameters and represent the long-run elasticity estimates of per capita CO_2 emissions with respect to per capita real GDP, the square of per capita real GDP, urbanization rate and per capita energy consumption, respectively. According to the environmental Kuznets curve (EKC) hypothesis, income level is linked with CO_2 emissions. There exists an inverted-U shaped relationship between income level and CO_2 emissions. Therefore, the signs of δ_1 and δ_2 are expected to be positive and negative, respectively (Behera and Dash, 2017; Omri, 2013). Based on the theories of compact city, the ecological modernization and the urban environmental transition, there exists a positive or negative link between urbanization and environmental pollution (Poumanyvong and Kaneko, 2010). Hence, the sign of δ_3 can be either positive or negative. Since energy is an important production factor, a rise in energy consumption will result in a rise in economic growth and carbon emissions (Ang, 2007; Ozturk and Acaravci, 2013). For this reason, we expect that the sign of δ_4 to be positive.

Descriptive statistics and pair-wise correlations between the series are presented in Table 2. The Jarque-Bera test results indicate that per capita real GDP, the square of per capita real GDP, per capita energy consumption, urbanization rate and per capita CO_2 emissions are normally distributed at 5% significance level. Correlation analysis reveals that per capita real GDP, the square of per capita real GDP, per capita energy consumption and urbanization rate are positively linked with per capita CO_2 emissions. The correlation analysis also reveals that urbanization rate and per capita energy consumption are positively correlated with per capita real GDP and the square of per capita real GDP. The positive correlation also exists between urbanization rate and per capita energy consumption. Fig. 1 shows that per capita CO_2 emissions have moved in the same direction as per capita real GDP, urbanization rate and per capita energy use in Turkey between 1960-2014.

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Table 2: Descriptive statistics and correlation matrix

Statistics/Variables	$lnCO_2$	*lnGDP*	$lnGDP^2$	*lnURB*	*lnEN*
Mean	0.754	8.736	76.470	3.935	6.733
Median	0.886	8.749	76.556	4.012	6.811
Std. dev.	0.548	0.388	6.812	0.270	0.411
Min.	-0.490	8.050	64.807	3.450	5.954
Max.	1.502	9.496	90.182	4.288	7.368
Skewness	-0.620	0.091	0.164	-0.325	-0.275
Kurtosis	2.433	2.116	2.136	1.643	2.019
Jarque-Bera	4.267(0.118)	1.865(0.393)	1.958(0.375)	5.191(0.074)	2.896 (0.234)
Observations	55	55		55	55
$lnCO_2$	1.000				
lnGDP	0.970	1.000			
$lnGDP^2$	0.965	0.999	1.000		
lnURB	0.978	0.965	0.961	1.000	
lnEN	0.991	0.989	0.986	0.982	1.000

Note: The values in parentheses denote the probabilities

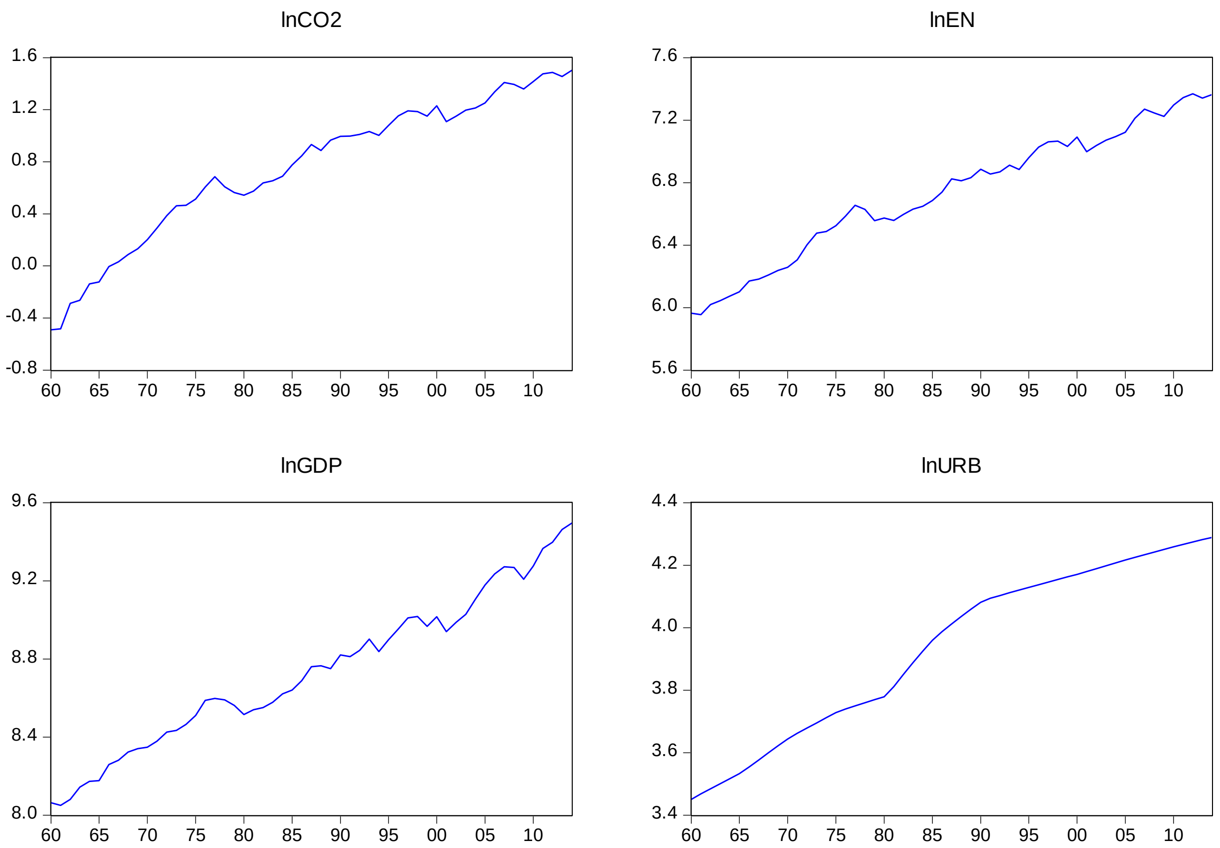

Figure 1: Trends in per capita CO_2 emissions, per capita real GDP, urbanization rate and per capita energy consumption for the case of Turkey, 1960-2014.

4. Econometric Strategy

The econometric strategy applied in the study consists of four steps. In the first step, the unit root properties of the series are investigated by the Ng-Perron and Lee-Strazicich unit root tests. In the second step, the presence of the long run relationship between the variables is examined by the ARDL bounds testing approaches to cointegration. In the third step, long-run and short-run elasticities of the variables are tested. Finally, the Toda-Yamamoto causality method is used to investigate the causal linkages between the variables.

4.1. Unit root analysis

We employ Ng and Perron unit root test to explore the stationarity properties of the variables. According to DeJong et al. (1992), Ng-Perron test provides more reliable and consistent results compared to other conventional unit root tests in addition to being more powerful for small sample sizes. Yet, the results of these tests might be inefficient and biased since they ignore possible structural breaks in the series (Perron, 1989). Therefore, we also employ the Lee-Strazicich unit root test with two structural breaks. This test, also known as two-break minimum LM unit root approach, has several advantages. Firstly, it endogenously determines the break points. Secondly, it does not suffer from the spurious rejection of the null hypothesis when there exists a unit root with breaks. Thirdly, when the alternative hypothesis is valid, the LM test is more power than the Lumsdaine-Papell test (Lee and Strazicich, 2003).

According to Lee and Strazicich (2003), the LM unit root test statistic can be estimated from the following specification:

$$\Delta x_t = \gamma' \Delta Z_t + \emptyset \tilde{S}_{t-1} + \mu_t \qquad (2)$$

where $\tilde{S}_{t-1} = x_t - \tilde{\psi}_x - Z_t\tilde{\gamma}, \quad t = 2, \ldots, T.$ $\tilde{\gamma}$ are the coefficients in the regression Δx_t on ΔZ_t and $\tilde{\psi}_x = x_1 - Z_1\tilde{\gamma}$, where x1 and Z1 are the first observations of xt and Zt. $\Delta\tilde{S}_{t-j}, j = 1, \ldots, k,$ terms are included to correct for serial correlation. The LM test statistic $\bar{\tau} = t$ is employed to test the null hypothesis $\emptyset = 0$. The present study uses Model A which allows two changes in level. This model is described by $Z_t = [1, t, D_{1t}, D_{2t}]'$, where $D_{jt} = 1$ for $t \geq T_{Bj} + 1$, j=1,2, and zero otherwise. Here D_{jt} and T_{Bj} denote a dummy indicator variable and the break date, respectively. Here, the null hypothesis $H_0: x_t = \mu_0 + d_1B_{1t} + d_2B_{2t} + x_{t-1} + v_{1t}$ of a unit root is set against the alternative hypothesis $H_A: x_t = \mu_1 + \sigma_t + d_1D_{1t} + d_2BD_{2t} + v_{2t}$ of trend stationarity. In order to endogenously determine the relative break points (i.e., $\lambda_1 = TB_1/T, \lambda_2 = TB_2/T$), the minimum LM unit root test uses a grid search as follows:

$$LM_\rho = Inf_\lambda \tilde{\rho}(\lambda); LM_\tau = Inf_\lambda \tilde{\tau}(\lambda) \qquad (3)$$

Lee and Strazicich (2003) tabulated critical values for two-break case.

4.2. Cointegration analysis

The study applies auto regressive distributed lags approach to determine the presence of cointegration amongst the variables under structural breaks. The ARDL bounds test is a more suitable method than the standard cointegration approaches since it can be applied irrespective of whether the explanatory variables are *I(0)*, *I(1)* or mutually cointegrated. In addition, ARDL approach is more efficient in small sample sizes (Pesaran and Shin, 1999). The short and long run parameters are simultaneously investigated by an unrestricted error correction model (UECM) obtained from the ARDL model. The UECM can be specified as below:

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$\Delta lnCO_{2t} = \theta_0 + \sum_{i=1}^{m} \theta_{1i} \Delta lnCO_{2t-i} + \sum_{i=0}^{m} \theta_{2i} \Delta lnGDP_{t-i} + \sum_{i=0}^{m} \theta_{3i} \Delta lnGDP_{t-i}^2 + \sum_{i=0}^{m} \theta_{4i} \Delta lnURB_{t-i} + \sum_{i=0}^{m} \theta_{5i} \Delta lnEN_{t-i} + \delta_0 DUM_{1971} + \delta_1 DUM_{1993} + \delta_2 lnCO_{2t-1} + \delta_3 lnGDP_{t-1} + \delta_4 lnGDP_{t-1}^2 + \delta_5 lnURB_{t-1} + \delta_6 LEN_{t-1} + \varepsilon_t$ (4)

where, θ_0, Δ and ε_t denote the constant parameter, difference operator and the error term, respectively. DUM denotes dummy variable for structural break point. In line with Shahbaz et al. (2014), we use dummy variable which considers the structural break stemming in the data.

In the ARDL bounds testing approach, the calculated F-statistic is compared with the critical bounds computed by Pesaran et al. (2001) or Narayan (2005). The null hypothesis of bounds F test is $H_0: \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = 0$ against the alternative hypothesis of $H_A: \delta_2 \neq \delta_3 \neq \delta_4 \neq \delta_5 \neq \delta_6 \neq 0$. If the calculated F-statistic is greater than the upper critical bound (UCB), the null hypothesis is rejected indicating that there exists a long run relationship among the variables. If the computed F-statistic is less than the lower critical bound (LCB), the null hypothesis cannot be rejected, meaning that there is not an existence of a long run relationship among the variables. The inference would be inconclusive if the calculated F-statistic falls between the UCB and LCB.

The robustness of the ARDL model was assessed using functional form, autocorrelation, normality of error term and heteroskedasticity tests. Also, the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squares of recursive residuals (CUSUMsq) tests presented by Brown et al. (1975) can be used to examine the stability of the parameters of ARDL model.

The ordinary least square (OLS) method was employed to estimate the long run parameters in the ARDL bounds testing approach to cointegration. In the ARDL process, the short run dynamics are examined applying error correction model (ECM) based on ARDL model. The specification of ECM is expressed as follows:

$$\Delta lnCO_{2t} = \beta_0 + \sum_{i=1}^{m} \beta_{1i} \Delta lnCO_{2t-i} + \sum_{i=0}^{n} \beta_{2i} \Delta lnGDP_{t-i} + \sum_{i=0}^{p} \beta_{3i} \Delta lnGDP_{t-i}^2 + \sum_{i=0}^{r} \beta_{4i} lnURB_{t-i} + \sum_{i=0}^{s} \beta_{5i} \Delta lnEN_{t-i} + \gamma ECT_{t-1} + \mu_t \quad (5)$$

In the ECM approach, the error correction term (ECT_{t-1}) shows how quickly the model returns to the long-run equilibrium at any disturbance or shock. Negative and statistically significant error correction term indicates the presence of a long run relationship between the variables.

4.3. Causality analysis

We apply the Toda-Yamamoto causality method known as the Granger non-causality test to investigate the causality among the variables. Toda and Yamamoto (1995) indicate that this test is applicable whether the VAR's are stationary, integrated of an arbitrary order, cointegrated of an arbitrary order. This method offers an augmented VAR ($k+d_{max}$) model where k and $k+d_{max}$ indicate the optimal lag length in the original VAR system and the maximal order of integration of the variables in the VAR system, respectively. In this procedure, a modified Wald (MWald) test is used for restrictions on the parameters of a VAR (k). The MWald statistic has an asymptotic chi-squared distribution. The causal linkages between the variables can be examined by the following VAR ($k+d_{max}$) model:

$$lnCO_{2t} = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} lnCO_{2t-i} + \sum_{j=k+1}^{d_{max}} \alpha_{2j} lnCO_{2t-j} + \sum_{i=1}^{k} \alpha_{3i} lnGDP_{t-i} + \sum_{j=k+1}^{d_{max}} \alpha_{4j} lnGDP_{t-j} + \sum_{i=1}^{k} \alpha_{5i} lnGDP^2_{t-i} + \sum_{j=k+1}^{d_{max}} \alpha_{6i} lnGDP^2_{t-j} + \sum_{i=1}^{k} \alpha_{7i} lnURB_{t-i} + \sum_{j=k+1}^{d_{max}} \alpha_{8i} lnURB_{t-j} + \sum_{i=1}^{k} \alpha_{9i} lnEN_{t-i} + \sum_{j=k+1}^{d_{max}} \alpha_{10i} lnEN_{t-j} + \varepsilon_t \quad (6)$$

5. Empirical Results

Table 3 indicates the findings of Ng-Perron unit root test. The constant model results imply that all the variables are non-stationary at their levels. The results also imply that all the variables are stationary at their first differences. So, they are *I(1)* variables. However, Ng-Perron test does not incorporate structural breaks. In order to further investigate the stationary properties of the variables, we also employed the Lee-Strazicich unit root test with two structural breaks. The results given in Table 4 show that all variables are integrated at order one. The unit root findings validate the use of ARDL bounds testing approach to investigate the existence of long-run relationship among per capita CO_2 emissions, per capita real GDP, the square of per capita real GDP, urbanization rate and per capita energy consumption.

Table 3: Ng-Perron unit root test results

Regressor	MZ_a	MZ_t	*MSB*	*MPT*
$lnCO_2$	1.264	2.008	1.588	174.334
lnGDP	2.321	3.236^{***}	1.393	164.050
$lnGDP^2$	2.453	3.348^{***}	1.364	160.962
lnURB	-1.372	-0.581	0.423	12.286
lnEN	1.533	2.312	1.507	166.126
$\Delta lnCO_2$	-26.405^{***}	-3.627^{***}	0.137^{***}	1.780^{***}
ΔlnGDP	-25.554^{***}	-	0.139^{***}	0.998^{***}
$\Delta lnGDP^2$	-25.633^{***}	-	0.139^{***}	1.001^{***}
ΔlnURB	-11.675^{**}	-2.366^{**}	0.202^{**}	2.292^{**}
ΔlnEN	-25.738^{***}	-3.584^{***}	0.139^{***}	0.962^{***}

Notes: The optimal lag length is selected using SBC. *** and ** denote significance at 1% and 5% levels, respectively.

The first structural break stems in the series of per capita CO_2 emissions, per capita real GDP, the square of per capita real GDP, urbanization rate and per capita energy consumption in 1971, 1979, 1979, 1992 and 1987, respectively. The second structural break stems in the series of per capita CO_2 emissions, per capita real GDP, the square of per capita real GDP, urbanization rate and per capita energy consumption in 1993, 2009, 2009, 1994 and 2000, respectively. It should be noted that all these years correspond to various economic crises and instabilities in Turkish economy.

We use the bounds F-test for cointegration to examine the long-run relationship among the variables. The results shown in Table 5 reveal that the computed F statistic is larger than UCB at 1 percent level of significance. This finding implies that per capita CO_2 emissions, per capita real GDP, the square of per capita real GDP, urbanization rate and per capita energy consumption are cointegrated. This also implies the presence of a long-run relationship among the variables when structural changes are accommodated. This finding is in line with Solarin and Lean (2016) for China and India. The diagnostic tests reported in the lower part of Table 5 reveal that the ARDL model passes all the relevant tests. This indicates that error terms are normally distributed, homoscedastic and not serially correlated. In addition, the model's functional form is well specified.

Table 4: Lee-Strazicich LM test results

Panel A: Level	*lnCO_2*	*lnGDP*	*lnGDP^2*	*lnURB*	*lnEN*
Test statistics	-1.591	-2.888	-2.891	-3.204	-3.850**
Lag	0	0	0	1	5
TB1	1971	1979	1979	1992	1987
TB2	1993	2009	2009	1994	2000
Panel B: First difference	*dlnCO_2*	*dlnGDP*	*dlnGDP^2*	*dlnURB*	*dlnEN*
Test statistics	-7010***	-7.404***	-7.952***	-3.743*	-
Lag	0	0	0	3	-
TB1	1973	1976	1978	1986	-
TB2	1989	1998	1997	1990	-

Notes: TB1 and TB2 indicate the break dates. Critical values at 1, 5 and 10% levels for Model A are -4.545, -3.842 and -3.504, respectively (Lee and Strazicich, 2003). ***, ** and * denote significance at 1%, 5% and 10% levels, respectively

After determining the presence of long run relationship between the variables, the impact of per capita real GDP, the square of per capita real GDP, urbanization rate and per capita energy consumption on per capita CO_2 emissions are analyzed. The long-run results are presented in Table 6. The findings indicate that urbanization rate has a positive and statistically significant impact on per capita CO_2 emissions at 1 percent level of significance. This implies that 1 percent increase in urbanization rate raises per capita CO2 emissions by 0.35 per cent. This empirical finding is consistent with Azam and Khan (2016) for Sri Lanka, Bekhet and Othman (2017) for Malaysia, Dogan and Turkekul (2016) for USA, Farhani and Ozturk (2015) for Tunisia, Liddle (2014) for OECD countries, Saboori et al. (2016) for Malaysia, Solarin and Lean (2016) for China and Japan, Ozturk and Al-Mulali (2015) for Cambodia, Shahbaz et al. (2014b) for UAE, and Shahbaz et al. (2013) for South Africa. However, this empirical result is not consistent with Ali et al. (2016) for Nigeria, Asumadu-Sarkodie and Owusu (2017) for Nigeria and Shahbaz et al. (2016) for Malaysia.

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Table 5: Bounds *F*-test results

Bounds F-test	*F(lnCO$_2$/ lnGDP, lnGDP^2, lnURB, lnEN)*	
Structural breaks	1971, 1993	Calculated *F*-statistics
ARDL model	[2,1,0,0,2]	10.012***
Pesaran et al. (2001) critical value bounds of the F-statistic: Unrestricted intercept and no trend		
Significance level	*Lower bounds, I(0)*	*Upper bounds, I(1)*
1%	3.74	5.06
5%	2.86	4.01
10%	2.45	3.52
Narayan (2005) critical value bounds of the F-statistic: Unrestricted intercept and no trend (T = 55)		
Significance level	*Lower bounds, I(0)*	*Upper bounds, I(1)*
1%	4.24	5.72
5%	3.06	4.33
10%	2.57	3.71
	Diagnostic tests	
R^2		0.928
Adjusted-R^2		0.897
F-statistic		29.316***
Breusch-Godfrey LM test		0.014 (0.906)
ARCH LM test		0.152 (0.698)
J-B normality test		1.753 (0.416)
Ramsey RESET test		0.215 (0.645)

Notes: The optimal lag length is selected using SBC. The values in parentheses denote the probabilities. *** denotes significance at 1% level.

The long run estimates also indicate that the effect of per capita real GDP and the square of per capita real GDP on per capita CO2 emissions are positive and negative as expected. This demonstrates the presence of EKC hypothesis in Turkish economy. This result is consistent with Ertugrul et al. (2016), Saboori et al. (2016), Seker et al. (2015), Shahbaz et al. (2013), Shahbaz et al. (2014b) and Asumadu-Sarkodie and Owusu (2017). However, this result is not proved by Dogan and Turkekul (2016), Farhani and Ozturk (2015), Solarin and Lean (2016), Ozturk and Al-Mulali (2015).

The impact of per capita energy consumption on per capita CO_2 emissions was found to be positive and statistically significant at 1 percent level of significance. This implies that 1 percent raise in per capita energy consumption increases per capita CO_2 emissions by 0.42 per cent. This finding is consistent with by Ali et al. (2016) for Nigeria, Asumadu-Sarkodie and Owusu (2017) for Nigeria, Dogan and Turkekul (2016) for USA, Farhani and Ozturk (2015) for Tunisia, Solarin and Lean (2016) for China and Japan, Shahbaz et al. (2016) for Malaysia, Saboori et al. (2016) for Malaysia, Ozturk and Al-Mulali (2015) for Cambodia, and Shahbaz et al. (2013) for South Africa. However, this result is inconsistent with Shahbaz et al. (2014b) for UAE.

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The diagnostic tests summarised in the latter part of Table 6 reveal that the underlying model passes all the tests successfully. The error terms are normally distributed. The problems of heteroscedasticity and serial correlation do not exist. In addition, graphical representations of cumulative sum and cumulative sum of squares are plotted in Figure 2 and 3. The results show that both test statistics stay within critical bounds at 5% significance level and therefore confirm the ARDL parameters are stable.

Table 6: Long-run results

Dependent variable: $lnCO_2$		
Regressor	*Coefficient*	*t-statistic*
Constant	-34.173	-6.977***
lnGDP	6.365	5.610***
$lnGDP^2$	-0.326	-5.406***
lnURB	0.356	3.610***
lnEN	0.423	2.993***
Diagnostic test statistics		
R^2	0.999	
Adjusted-R^2	0.998	
F-statistic	4322.948***	
Breusch-Godfrey LM test	0.027 (0.868)	
ARCH LM test	0.502 (0.481)	
J-B normality test	1.084 (0.581)	
Ramsey RESET test	1.756 (0.192)	

Notes: The optimal lag length is selected using SBC. The values in parentheses indicate the probabilities. *** denotes significance at 1% level.

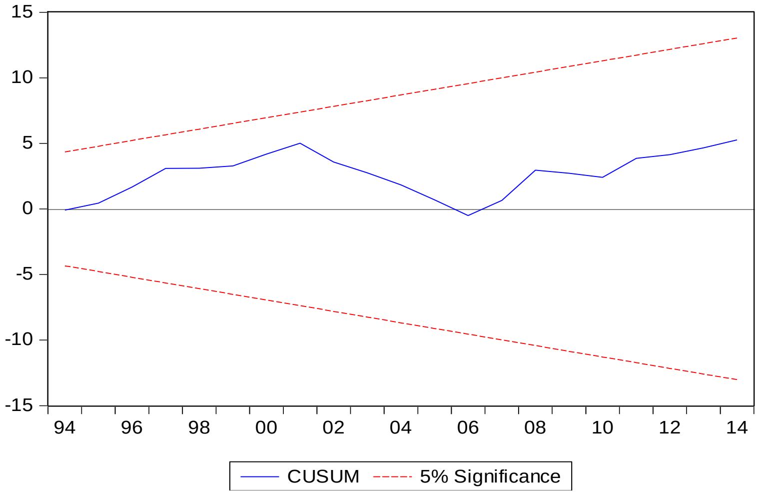

Figure 2: Plot of cumulative sum of recursive residuals.

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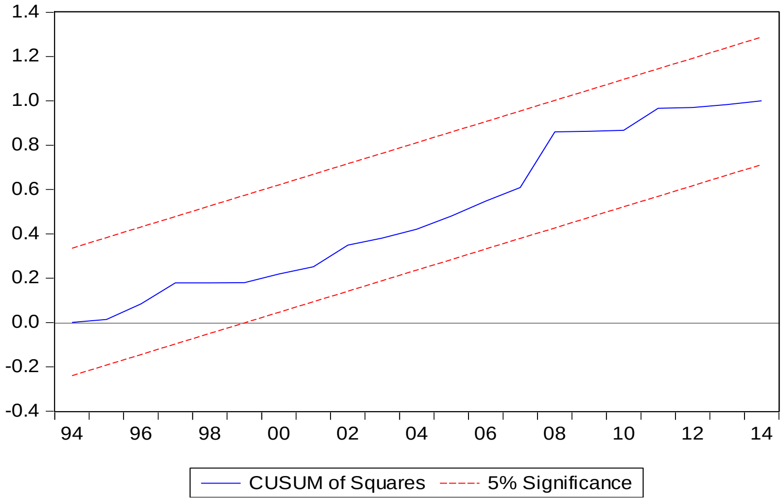

Figure 3: Plot of cumulative sum of squares of recursive residuals.

The short run results are displayed in Table 7. The empirical findings are consistent with the long-run results except for urbanization rate. The results confirm that the EKC hypothesis is valid for Turkey. This result is in accordance with Shahbaz et al. (2014b) and Tiwari et al. (2013). This finding is not in accordance with Dogan and Turkekul (2016) and Farhani and Ozturk (2015). The results also reveal that per capita energy consumption positively affects per capita CO_2 emissions. This finding is proved by Ali et al. (2016), Dogan and Turkekul (2016) and Shahbaz et al. (2016). The result with urbanization rate is consistent with Ali et al. (2016), Shahbaz et al. (2014b), Shahbaz et al. (2016), Shahbaz and Lean (2012). This finding is not consistent with Dogan and Turkekul (2016) and Farhani and Ozturk (2015).

The coefficient of ECT_{t-1} is found to be statistically significant with a negative sign indicating the existence of long run relationship between per capita real GDP, the square of per capita real GDP, urbanization rate, per capita energy consumption and per capita CO_2 emissions. This also indicates that deviation of per capita CO_2 emissions from short-run to long-run is corrected by 69.10 percent each year.

Finally, the results of Toda-Yamamoto test are given in Table 8. The causality results show that the null hypothesis of non-causality running from urbanization rate to per capita CO_2 emissions is rejected at 10 percent level of significance. This proves that there exists causality running from urbanization rate to per capita CO_2 emissions. This result is in line with Farhani and Ozturk (2015) for Tunisia, Ouyang and Lin (2017) for China and Japan, Shahbaz et al. (2016) for Malaysia, and Shahbaz et al. (2014b) for UAE. The causality results also show that there exists causality running from per capita energy consumption to urbanization rate. This implies that energy consumption causes urbanization over the period. This finding is confirmed by Farhani and Ozturk (2015) for Tunisia. However, this finding is not confirmed by Bekhet and Othman (2017) for Malaysia, Ghosh and Kanjilal (2014) for India, Hossain (2011) for NIC, Shahbaz et al. (2016) for Malaysia and Siddique et al. (2016) for South Asia.

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Table 7: Short run results

Dependent variable: $\Delta lnCO_2$		
Regressor	*Coefficient*	*t-statistic*
Constant	-0.001	-0.321
ΔlnGDP	4.059	2.991***
$lnGDP^2$	-0.223	-2.953***
ΔlnURB	0.366	1.337
ΔlnEN	1.015	12.715***
ECT(-1)	-0.691	-9.689***
Diagnostic test statistics		
R^2	0.931	
Adjusted-R^2	0.917	
F-statistic	65.044***	
RSS	0.010	
SE of regression	0.015	

Notes: The optimal lag length is selected using SBC. The values in parentheses indicate the probabilities. *** denotes significance at 1% level.

Table 8: Toda-Yamamoto causality analysis

Dependent variable	*Independent variable (χ^2)*				
	$lnCO_2$	lnGDP	$lnGDP^2$	lnURB	lnEN
$lnCO_2$	-	0.004	0.003	2.863*	0.191
lnGDP	0.283	-	1.079	0.158	0.014
$lnGDP^2$	0.229	1.090	-	0.166	0.018
lnURB	0.614	0.896	0.772	-	2.800*
lnEN	0.667	0.014	0.014	0.278	-

Notes: The optimal lag length is selected using SBC. * denotes significance at 10% level.

6. Conclusion

As an upper middle-income country, Turkey has been one of the rapidly growing countries in the world since the 2000s. Turkey has witnessed a rapid economic and structural change, high-speed industrialization and urbanization process, and substantial increase in energy use. These developments have caused a steady increase in the level of CO_2 emissions, especially in urban spaces. This study investigates the cointegration and causal relationships among economic growth, urbanization, energy consumption and CO_2 emissions in Turkey over the period of 1960-2014. We use the Ng-Perron and Lee-Strazicich unit root tests to examine the stationarity properties of the variables. We also use the ARDL bounds testing approach with structural break to investigate the presence of cointegration between the variables. Finally, causality amongst the variables are tested by the Toda-Yamamoto causality analysis.

The ARDL bounds testing approach reveals that per capita CO_2 emissions, per capita real GDP, the square of per capita real GDP, urbanization rate and per capita energy consumption are cointegrated in the presence of structural breaks. The empirical results reveal that there exists an inverted-U shaped relationship between per capita real GDP and per capita CO_2 emissions validating the presence of EKC hypothesis in both the short run and the long run. The empirical results also reveal that per capita energy consumption and urbanization rate are positively linked with per capita CO_2 emissions in the long run. The Toda-Yamamoto causality analysis shows that there exists unidirectional causality running from urbanization rate to per capita CO_2 emissions. This implies that urbanization rate causes per capita CO_2 emissions over the period.

Based on this study's findings, the government should pay more attention to energy and urbanization policies in order to reduce CO_2 emissions and overcome environmental pollution problem. In this respect, the policy makers should intensify on the several energy policies which will increase energy efficiency/diversity and support the utilization of cleaner and renewable energy sources such as solar, hydropower, geothermal sources and biofuels. It is a fact that rapid urbanization affects energy use and environmental pollution in developing countries. Moreover, the empirical results reveal that urbanization rate is a crucial factor in increasing Turkey's CO_2 emissions. Therefore, urbanization process and related environmental consequences should be integrated into the main energy policies. The energy use should be differentiated between urban and rural areas. Turkish government should pay special attention to effective urban planning. For this purpose, the speed of urbanization and rural-to-urban migration should be controlled. Finally, Turkish government should facilitate the import of cleaner technologies and financial sector should effectively support environmentally-sensitive production, technology and investments to decrease CO_2 emissions.

The present study does not provide comparative findings since it includes a single-country time series analysis. Therefore, future research could be conducted by using time series data for several developing countries. Besides, future studies may incorporate several control variables such as financial development, trade openness and population into the CO_2 emissions specification in order to derive comprehensive policy implications from their empirical findings.

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