An econometric study of CO2 emissions, energy consumption, income and foreign trade in Turkey

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Abstract

This study attempts to examine empirically dynamic causal relationships between carbon emissions, energy consumption, income, and foreign trade in the case of Turkey using the time series data for the period 1960-2005.
This research tests the interrelationship between the variables using the bounds testing to cointegration procedure. The bounds test results indicate that there exist two forms of long-run relationships between the variables. In the case of first form of long-relationship, carbon emissions are determined by energy consumption, income and foreign trade. In the case of second long-run relationship, income is determined by carbon emissions, energy consumption and foreign trade. An augmented form of Granger causality analysis is conducted amongst the variables. The long-run relationship of CO_2 emissions, energy consumption, income and foreign trade equation is also checked for the parameter stability.
The empirical results suggest that income is the most significant variable in explaining the carbon emissions in Turkey which is followed by energy consumption and foreign trade. Moreover, there exists a stable carbon emissions function. The results also provide important policy recommendations.

Keywords: CO_2 emissions; energy consumption; income; EKC hypothesis; foreign trade.
JEL Classifications: Q43, Q53, Q56, C22.

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1. Introduction

The increasing threat of global warming and climate change have been the major on-going concerns of humans in the last two decades. The impacts of global warming on the world economy have been assessed intensively by the researchers since 1990s. The world wide organizations such as the United Nations have been attempting to reduce the adverse impacts of global warming through intergovernmental and binding agreements. The Kyoto protocol is such an agreement that was signed in 1997 after hefty discussions. It is a protocol to the United Nations Framework Convention on Climate Change (UFCCC) with the objective of reducing greenhouse gases (GHG) that cause climate change. The Kyoto protocol identifies constraints to environmental pollutants and requires a timetable for realizations of the emission reductions for the developed countries. It demands reduction of the GHG emissions to 5.2 % lower than the 1990 level during 2008-2012 periods. It came into force in 2005: as of April 2008, 178 states have signed and ratified the protocol. Turkey is one of 17 countries, which has refused to sign it so far. However, the Turkish government recently declared its intention to sign it. Turkish refusals to sign the protocol are mainly related to its excess implementation costs and consequently fear of degrading her competitiveness unfairly in international trade. As a candidate country to the European Union (EU), nevertheless Turkey has strict environmental obligations to fulfill for the full membership. According to the Commission of the European Communities, CEC (2007), the EU aims at reducing the environmental pollutants 30% below the 1990 levels by 2020. Consequently, it is expected that Turkey will be under strong pressure from the EU to comply with the Union's regulations on environmental policy, even though pollutant emission reduction is not currently a membership criterion.

Amongst several environmental pollutants causing climate change, Carbon dioxide (CO_2) is held responsible for 58.8% of the GHG in a report of World Bank (2007a). According to World Development Indicators of the World Bank (2007b), Turkey's share of CO_2 emissions in the world has 31st place in 1960 and it moved to 21st place in 2005. The share of Turkey in the total world CO_2 emissions was 0.81% in 2005. 71% of Turkish energy production in 2005 was generated from the combustion of fossil fuels. The combustion of fossil fuels is the largest single contributor to CO_2 emissions and total GHG emissions and, of all major sources, has grown the most rapidly over the period 1970 to the present. The international panel on Climate Change (IPCC) fourth assessment report of the World Bank (2007a) shows that a long observed trend in declining global CO_2 emissions intensity per unit of Gross Domestic Product (GDP) reversed around the year 2000. This means that global CO_2 emissions are growing faster than at any time since 1970.

The relationships between economic growth and environmental pollution, as well as economic growth and energy consumption, have been intensively analyzed empirically over the past two decades. The first nexus is closely related to testing the validity of the so-called environmental Kuznets curve (EKC) hypothesis. A recent and emerging line of literature seems to incorporate both nexuses into multivariate framework. This approach facilitates the examination of the dynamic relationships between economic growth, energy consumption and environmental pollutants altogether, see for example, Ang (2007), Ang (2008), Soytas *et al.* (2007), Soytas and Sari (in press).

This research adopts the same approach but extends the above mentioned multivariate framework further by including the impacts of foreign trade into the nexus. This attempt may also reduce the problems of omitted variable bias in econometric estimation.

The Hecksher-Ohlin trade theory suggests that, under free trade, developing countries would specialize in the production of goods that are intensive in the factors that they are endowed with in relative abundance: labor and natural resources. The developed countries would specialize in human capital and manufactured capital intensive activities. Trade entails the movement of goods produced in one country for either consumption or further processing. This implies that pollution is generated in the production of these goods is related to consumption in another country. Wyckoff and Roop (1994) estimates that 13% of the total carbon emissions of the six largest OECD countries are embodied in their imports of manufactured goods. A similar line of argument also exists in Mongelli *et al.* (2006). Therefore, this research argues that there are strong dynamic inter-relationships between output, energy consumption, environmental pollutants and foreign trade, which should be investigated in the same multivariate framework. This research seeks to fill the gap in the literature. The dynamic interrelationships amongst the four variables are analyzed using a recent cointegration technique and the Granger causality link both in the short run and the long run.

The remainder of this paper is organized as follows: the next section outlines briefly the literature on the inter-relationships between output, energy consumption and environmental pollutants. The third section describes the study's model and methodology. The fourth section discusses the empirical results, and the last section concludes.

2. A Brief Literature Review

It appears that there are basically two well established research strands in the literature on economic growth, energy consumption and environmental pollutants. The first strand mainly concentrates on the environmental pollutants and output nexus, which is mainly devoted to test the validity of the EKC hypothesis. Kuznets (1955) predicted that the changing relationship between per capita income and income inequality is an inverted U-shaped curve. As per capita income increases, income inequality also increases at first and then starts declining after a turning point. This relationship between income per capita and income inequality can be represented by a bell-shaped curve. This observed phenomenon is described as the Kuznet Curve (KC). In the 1990s and onwards, the KC took on a new existence. There is evidence that the level of environmental degradation and income per capita follows the same inverted U-shaped relationship as does income inequality and income per capita in the original KC. As a result, Kuznets Curve has become a tool for describing the relationship between the measured levels of environmental quality indicators such as CO_2, SO_2, etc. and income per capita. This inverted U-shaped relationship between economic growth and measured pollution indicators is known as the EKC. The EKC hypothesis states that pollution levels increase as a country develops, but begin to decrease as rising incomes pass beyond a turning point. This hypothesis was first proposed and tested by Grossman and Krueger in 1991. A large number of studies tested the economic growth and environmental pollution nexus. Stern (2004) and Dinda (2004) provide extensive review surveys of these studies. Further examples consist of Shafik (1994), Heil and Selden (1999), Friedl and Getzner (2003), Dinda and Coondoo

(2006), Coondoo and Dinda (2008), and Managi and Jena (2008). Samples of studies incorporating trade as a variable in testing the EKC hypothesis include Grossman and Krueger (1991), Lucas *et al.* (1992), Wyckoff and Roop (1994), Suri and Chapman (1998), and Nohman and Antrobus (2005). The empirical results, however, appear to be inconclusive.

The second strand of the research is related to energy consumption and output nexus. This nexus suggests that economic development and output may be jointly determined because economic growth is closely related to energy consumption as higher economic development requires more energy consumption. Likewise, more efficient energy use needs a higher level of economic development. Therefore, the direction of causality may not be determined *a priori*. Starting with the seminal study of Kraft and Kraft (1978), the literature has been populated quickly with an extensive number of empirical works, which present inconclusive evidence. Examples of this line of research include Masih and Masih (1996), Yang (2000), Wolde-Rufael (2006), Narayan and Singh (2007), and Narayan *et al*. (2008).

Finally, a combined approach of these two approaches has emerged in the recent literature which enables the researchers to conduct the validity of both nexuses in the same framework. Ang (2007) and Soytas *et al*. (2007) initiated this combined line of research.

A wide range of econometric techniques and procedures have been utilized to test the validity of nexus between output-energy and output-environmental pollutants. The results and implications of these studies clearly depend on the underlying variables, data frequency and the development stages of a country.

3. Model and econometric methodology

3. 1 Model

Following the empirical literature in energy economics, it is plausible to form the long-run relationship between CO_2 emissions, energy consumption, economic growth and foreign trade in linear logarithmic quadratic form with a view of testing the validity of the EKC hypothesis as follows:

$$c_t = a_0 + a_1 e_t + a_2 y_t + a_3 y_t^2 + a_4 f_t + \varepsilon_t \qquad (1)$$

where c_t is CO_2 emissions per capita, e_t is commercial energy use per capita, y_t is per capita real income, y_t^2 is square of per capita real income, f_t is openness ratio which is used as a proxy for foreign trade, and ε_t is the regression error term . The lower case letters in equation (1) demonstrates that all variables are in their natural logarithms.

As for the expected signs in equation (1), one expects that $a_1 > 0$ because higher level of energy consumption should result in greater economic activity and stimulate CO_2 emissions. Under the EKC hypothesis, the sign of a_2 is expected to be positive whereas a negative sign is expected for a_3. If one finds that a_3 is statistically insignificant it indicates a monotonic increase in the relationship between per capita CO_2 emissions and per capita income. The expected sign of a_4 is mixed depending on the level of economic development stage of a country. In the case of developed countries, it is expected to be negative as countries develop; they cease to produce certain pollution intensive goods and begin to import these from other countries with less restrictive environmental protection laws. This sign expectation is reversed in the case of developing countries as they tend to have dirty industries with heavy share of pollutants, as discussed in Grossman and Krueger (1995).

3.2 Cointegration methodology

In the last two decades, several econometric procedures were employed to investigate the environmental pollution functions. With regards to univariate cointegration approaches, there are several examples including Engle and Granger (1987) and the fully modified OLS procedures of Phillips and Hansen (1990). There are also many examples of multivariate cointegration procedures of Johansen (1988), Johansen and Juselius (1990), and Johansen's (1996) full information maximum likelihood technique. A recent single cointegration approach, known as autoregressive-distributed lag (ARDL) of Pesaran *et al.* (2001), has become popular amongst researchers. Pesaran *et al.* cointegration approach, also known as bounds testing, has certain econometric advantages in comparison to other single cointegration procedures. They are as follows: i) endogeneity problems and inability to test hypotheses on the estimated coefficients in the long-run associated with the Engle-Granger method are avoided; ii) the long and short-run parameters of the model in question are estimated simultaneously; iii) the ARDL approach to testing for the existence of a long-run relationship between the variables in levels is applicable irrespective of whether the underlying regressors are purely $I(0)$, purely $I(1)$, or fractionally integrated; iv) the small sample properties of the bounds testing approach are far superior to that of multivariate cointegration, as argued in Narayan (2005).
An ARDL representation of equation (1) is formulated as follows:

$$\begin{aligned}\Delta c_t &= b_0 + \sum_{i=1}^{m} b_{1i}\Delta c_{t-i} + \sum_{i=0}^{m} b_{2i}\Delta e_{t-i} + \sum_{i=0}^{m} b_{3i}\Delta y_{t-i} + \sum_{i=0}^{m} b_4\Delta y_{t-i}^2 + \sum_{i=0}^{m} b_5 f_t + \\ &\quad b_6 c_{t-1} + b_7 e_{t-1} + b_8 y_{t-1} + b_9 y_{t-1}^2 + b_{10} f_{t-1} + v_t \end{aligned} \qquad (2)$$

Given that Pesaran *et al.* cointegration approach is a relatively recent development in the econometric time series literature, a brief outline of this procedure is presented as follows. The bounds testing procedure is based on the F or Wald-statistics and is the first stage of the ARDL cointegration method. Accordingly, a joint significance test that implies no cointegration hypothesis, (H_0: $b_6 = b_7 = b_8 = b_9 = b_{10} = 0$), against the alternative hypothesis, (H_1: $b_6 \neq b_7 \neq b_8 \neq b_9 \neq b_{10} \neq 0$) should be performed for equation (2). The F test used for this procedure has a non-standard distribution. Thus, Pesaran *et al.* compute two sets of critical values for a given significance level with and without a time trend. One set assumes that all variables are $I(0)$ and the other set assumes they are all $I(1)$. If the computed F-statistic exceeds the upper critical bounds value, then the H_0 is rejected. If the F-statistic falls into the bounds then the test becomes inconclusive. Lastly, if the F-statistic is below the lower critical bounds value, it implies no cointegration. This study, however, adopts the critical values of Narayan (2005) for the bounds F-test rather than Pesaran *et al.* (2001). As discussed in Narayan (2005) given relatively a small sample size in this study (46 observations), the critical values produced by Narayan (2005) are more appropriate than that of Pesaran *et al.* (2001).

Once a long-run relationship has been established, equation (2) is estimated using an appropriate lag selection criterion. At the second stage of the ARDL cointegration procedure, it is also possible to perform a parameter stability test for the selected ARDL representation of the error correction model.

A general error correction model (ECM) of equation (2) is formulated as follows:

$$\Delta c_t = c_0 + \sum_{i=1}^{m} c_{1i}\Delta c_{t-i} + \sum_{i=0}^{m} c_{2i}\Delta e_{t-i} + \sum_{i=0}^{m} c_{3i}\Delta y_{t-i} + \sum_{i=0}^{m} c_{4i}\Delta y_{t-i}^2 + \sum_{i=0}^{m} c_{5i}\Delta f_{t-i} + \lambda EC_{t-1} + \mu_t \tag{3}$$

where λ is the speed of adjustment parameter and EC_{t-1} is the residuals that are obtained from the estimated cointegration model of equation (1).

3. 3 Granger causality

The Granger representation theorem suggests that there will be Granger causality in at least one direction if there exists a cointegration relationship among the variables in equation (1), providing that they are integrated order of one. Engle and Granger (1987) cautions that the Granger causality test, which is conducted in the first-differences variables by means of a vector autoregression (VAR), will be misleading in the presence of cointegration. Therefore, an inclusion of an additional variable to the VAR system, such as the error correction term would help us to capture the long-run relationship. To this end, an augmented form of the Granger causality test involving the error correction term is formulated in a multivariate *p*th order vector error correction model.

$$(1-L)\begin{bmatrix} c_t \\ e_t \\ y_t \\ y_t^2 \\ f_t \end{bmatrix} = \begin{bmatrix} c_1 \\ c_2 \\ c_3 \\ c_4 \\ c_5 \end{bmatrix} + \sum_{i=1}^{p}(1-L)\begin{bmatrix} d_{11i}d_{12i}d_{13i}d_{14i}d_{15i}d_{16i} \\ d_{21i}d_{22i}d_{23i}d_{24i}d_{25i}d_{26i} \\ d_{31i}d_{32i}d_{33i}d_{34i}d_{35i}d_{36i} \\ d_{41i}d_{42i}d_{43i}d_{44i}d_{45'}d_{46i} \\ d_{51i}d_{52i}d_{53i}d_{54i}d_{55i}d_{56i} \end{bmatrix}\begin{bmatrix} c_{t-i} \\ e_{t-i} \\ y_{t-i} \\ y_{t-i}^2 \\ f_{t-i} \end{bmatrix} + \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \lambda_4 \\ \lambda_5 \end{bmatrix}\left[EC_{t-1}\right] + \begin{bmatrix} \omega_{1t} \\ \omega_{2t} \\ \omega_{3t} \\ \omega_{4t} \\ \omega_{5t} \end{bmatrix} \tag{4}$$

$(1-L)$ is the lag operator. EC_{t-1} is the error correction term, which is obtained from the long-run relationship described in equation (1), and it is not included in equation (4) if one finds no cointegration amongst the vector in question. The Granger causality test may be applied to equation (4) as follows: i) by checking statistical significance of the lagged differences of the variables for each vector; this is a measure of short-run causality; and ii) by examining statistical significance of the error-correction term for the vector that there exists a long-run relationship. As a passing note, one should reveal that equation (3) and (4) do not represent competing error-correction models because equation (3) may result in different lag structures on each regressors at the actual estimation stage; see Pesaran *et al.* (2001) for details and its mathematical derivation. All error-correction vectors in equation (4) are estimated with the same lag structure that is determined in unrestricted VAR framework; see for example, Narayan and Smyth (2006). This study utilizes the latter procedure.

3.4 Model stability

The existence of a cointegration derived from equation (2) does not necessarily imply that the estimated coefficients are stable, as argued in Bahmani-Oskooee and Chomsisengphet (2002). The stability of coefficients of regression equations are, by and large, tested by means of Chow (1960), Brown *et al.* (1975), Hansen (1992), and Hansen and Johansen (1993). The Chow stability test requires *a priori* knowledge of structural breaks in the estimation period and its shortcomings are well documented, see for example Gujarati (2003). In Hansen (1992) and Hansen and Johansen (1993) procedures, stability tests require $I(1)$ variables and they check the long-run parameter constancy without incorporating the short-run dynamics of a model into the testing - as discussed in Bahmani-Oskooee and Chomsisengphet (2002). Hence, stability tests of Brown *et al.* (1975), which are also known as cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests based on the recursive regression residuals, may be employed to that end. These tests also incorporate the short-run dynamics to the long-run through residuals. The CUSUM and CUSUMSQ statistics are updated recursively and plotted against the break points of the model. Provided that the plots of these statistics fall inside the critical bounds of 5% significance, one assumes that the coefficients of a given regression are stable. These tests are usually implemented by means of graphical representation.

4. Empirical results

Annual data over the period 1960-2005 were used to estimate equation (2) by the Pesaran *et al.* (2001) procedure. Data definition and sources of data are cited in Appendix.

All the series in equation (1) appear to contain a unit root in their levels but stationary in their first differences, indicating that they are integrated at order one i.e., $I(1)$ and visual inspections show no structural breaks in the time series. For brevity of presentation, they are not reported here.

4.1 Bounds test for cointegration

Equation (2) was estimated in two stages. In the first stage of the ARDL procedure, the long-run relationship of equation (1) was established in two steps. Firstly, the order of lags on the first–differenced variables for equation (2) was obtained from unrestricted VAR by means of Akaike Information Criterion (AIC) and Schwarz Bayesian Criterion (SBC). The results of this stage are not displayed here to conserve space. Secondly, a bounds F test was applied to equation (2) in order to establish a long-run relationship between the variables.

In order to avoid a possible selection problem at this stage, one may follow the procedure of Bahmani-Oskooee and Goswami (2003) which sequentially test the long-run cointegration relationship in equation (2) on the basis of different lag lengths. This study adopts the second approach which implicitly assumes that equation (2) is free from a trend due to the differenced variables. In summary, the F tests indicate that there exist two cointegrating relationships. The first long-run relationship is based on the situation that c is the dependent variable. The second long-run relationship refers a situation that y is the dependent variable. Evidence of cointegration among variables also rules out the possibility of estimated relationship being “spurious”. The results of the bounds F testing are displayed in Table 1.

Table 1. The Results of F-test for Cointegration

	Calculated F-statistics for different lag lengths		
	1 lags	3 lags	5 lags
$F_C(c \mid e, y, y^2, f)$	4.60	2.33	2.67
$F_C(e \mid c, y, y^2, f)$	2.40	0.66	3.50
$F_C(y \mid c, e, y^2, f)$	4.83	2.16	3.19
$F_C(y^2 \mid c, e, y, f)$	3.76	2.83	3.05
$F_C(f \mid c, e, y, y^2)$	1.92	3.34	1.49

The critical value ranges of F-statistics with four explanatory variables are 4.39– 5.91, 3.17 – 4.45 and 2.63 – 3.77 at 1%, 5% and 10% level of significances, respectively. See Narayan (2005), p.1988, Case III.

4.2 ARDL model selection

Given the existence of a long-run relationship, in the next step the ARDL cointegration procedure was implemented to estimate the parameters of equation (2) with maximum order of lag set to 2 to minimize the loss of degrees of freedom. This stage involves estimating the long-run and short-run coefficients of equations (1) and (2). In search of finding the optimal length of the level variables of the short-run coefficients, several lag selection criteria such as $\overline{R}^2$, AIC, SBC and Hannan-Quinn Criterion (HQC) were utilized at this stage. The long-run results of equation (2) based on several lag criteria are reported in Panel A of Table 2 along with their appropriate ARDL models. The results from model selection criteria of $\overline{R}^2$, AIC and HQC are identical. As can be seen from Table 2, the models of $\overline{R}^2$, AIC and HQC models provide exactly the same results with regard to coefficient magnitudes and statistical significance. The short and long-run elasticities of SBC model are also exactly the same indicating that there is no dynamics in the ARDL model of SBC criterion. Therefore, SBC model selection is disregarded. On the basis of estimated models, short-run elasticities are computed, and the results are reported in Panel B of Table 2. The short-run elasticities, as expected, are smaller than the long-run values. However, the magnitudes of elasticities are very close in all the models.

The diagnostic test results of equation (2) for short-run estimations are also displayed in the respective columns of each selection criterion in Panel C of Table 2. All the estimated models display the expected signs for the regressors and they are statistically significant. All short-run models pass a series of standard diagnostic tests such as serial correlation, functional form, and heteroscedasticity, except normality.

Table 2. ARDL results for the 1960-2005 time span

Panel A: the long-run elasticities
Dependent variable c

	Model Selection Criterion			
Regressors	$\bar{R}^2$ ARDL (1,1,0,0,0)	AIC ARDL (1,1,0,0.0)	SBC ARDL (0,0,0,0,0)	HQC ARDL (1,1,0,0,0)
e	0.78	0.78	0.76	0.78
	(3.07)*	(3.07)*	(3.97)*	(3.07)*
y	12.31	12.31	12.73	12.31
	(5.83)*	(5.83)*	(8.04)*	(5.83)*
y^2	-0.83	-0.83	-0.83	-0.83
	(6.04)*	(6.04)*	(8.30)	(6.04)*
f	0.07	0.07	0.07	0.07
	(1.97)*	(1.97)*	(2.56)	(1.97)*
Constant	-49.98	-49.98	-51.47	-49.98
	(7.31)*	(7.31)*	(10.06)*	(7.31)*
Panel B: the short-run computed elasticities				
e	0.57	0.57	0.76	0.57
y	$12.31-1.66y$	$12.31-1.66y$	$12.73-1.66y$	$12.31-1.66y$
f	0.05	0.05	0.07	0.05
Panel C: the short-run diagnostic test statistics				
	$\chi^2_{SC}(1)=1.32$	$\chi^2_{SC}(1)=1.32$	$\chi^2_{SC}(1)=0.36$	$\chi^2_{SC}(1)=1.32$
	$\chi^2_{FC}(1)=0.82$	$\chi^2_{FC}(1)=0.82$	$\chi^2_{FC}(1)=1.46$	$\chi^2_{FC}(1)=0.82$
	$\chi^2_{N}(2)=7.29$	$\chi^2_{N}(2)=7.29$	$\chi^2_{N}(2)=6.53$	$\chi^2_{N}(2)=7.29$
	$\chi^2_{H}(1)=0.40$	$\chi^2_{H}(1)=0.40$	$\chi^2_{H}(1)=0.34$	$\chi^2_{H}(2)=0.40$

Notes for Panel B: Own calculations from above models.

Notes for Panel C: The absolute value of t-ratios is in parentheses. χ^2_{SC} , χ^2_{FC}, χ^2_{N} , and χ^2_{H} are Lagrange multiplier statistics for tests of residual correlation, functional form mis-specification, non-normal errors and heteroskedasticity, respectively. These statistics are distributed as Chi-squared variates with degrees of freedom in parentheses. * and ** indicate 5 % and 10 % significance levels, respectively

The error-correction model was only estimated in the case of AIC since the other model selection criteria displayed the identical results. The results are summarized in Table 3. The error-correction term is statistically significant and its magnitude is quite high indicating a fast return to equilibrium in the case of disequilibrium.

The long run elasticity of CO_2 emissions with respect to energy consumption is 0.78, indicating that for each 1% increases in per capita commercial energy consumption will rise per capita CO_2 emissions by 0.78%. The elasticity of CO_2 emissions with respect to income in the long-run is$12.31-1.66y$. The statistical significance of the square of per capita real income rules out the suggestion in which output raises monotonically with the level of CO_2 emissions. The results also provide some support for the EKC hypothesis that the level of environmental pollution initially increases with income, until it reaches its stabilization point, then declines. However, this hypothesis could not be confirmed with a graphical representation. Therefore, it is concluded that the EKC does not hold for Turkey. The elasticity of CO_2 emissions with respect to openness ratio in the long run is 0.07, suggesting the contribution of the foreign trade to CO_2 emissions is rather minimal during the estimation period.

The error-correction term is –0.72 with the expected sign, suggesting that when per capita CO_2 is above or below its equilibrium level, it adjusts by almost 72% within the first year. The full convergence process to its equilibrium level takes about one and half years. Thus, the speed of adjustment is significantly fast in the case of any shock to CO_2 emissions equation. The results support the notion that there is little control on the growth of the CO_2 emissions.

Table 3. ECM results for the 1960-2005 time span

Dependent variable Δc_t

Regressors	Model Selection Criterion AIC ARDL (1,1,0,0,0)
Δe_t	1.05 $(4.34)^{*}$
Δy_t	8.93 $(3.36)^{*}$
Δy_t^2	-0.60 $(3.40)^{*}$
Δf_t	0.05 $(1.85)^{**}$
Constant	-36.25 $(3.59)^{*}$
EC_{t-1}	-0.72 $(4.48)^{*}$
$\overline{R}^2$	0.70
F-statistic	22.33^{*}
DW-statistic	2.08
RSS	0.03

Notes: The absolute values of t-ratios are in parentheses. RSS stands for residual sum of squares. * and ** indicate 5 % and 10 % significance levels, respectively.

4.3 Results of Granger causality

According to the bounds test results revealed in Table 1, there exist two cointegrating relationships in the forms of [c, e, y, y^2, f] and [y, e, c, y^2, f]. Therefore, the Granger causality test was conducted to equation (4) as such that only two long run relationships were estimated with an error correction term. However, the Granger causality tests were applied to other models without the error correction terms, since one could not ascertain any long-run relationship for the other vectors. The statistical significance of the coefficients associated with the error correction term provides evidence of an error correction mechanism that drives the variables back to their long-run relationship. Table 4 summarizes the results of the long run and short-run Granger causality. According to the coefficient on the lagged error-correction term, there exists a long run relationship among the variables in the form of equation (1) as the error-correction term is statistically significant, which also confirms the results of the bounds test. In the long run, energy consumption, income, squared income and foreign trade Granger cause the CO_2 emissions and the direction of causality runs interactively through the error-correction term from energy consumption, income, squared income and foreign trade to the CO_2 emissions. There exists another long-run Granger causality which runs interactively through the error-correction terms from energy consumption, CO_2 emissions, squared income and foreign trade to the income. In the case of short run causality tests, Table 4 reveals there are four bilateral Granger causality relationships. Out of these, two of them have meaningful economic implications. The first causality relationship indicates that there exists bi-directional Granger causality between CO_2 emissions and commercial energy consumption. This result reveals contradiction to the study of Soytas and Sari (in press), which suggests that there exists Granger causality and it only runs from CO_2 emissions to energy consumption The second Granger causality relationship revealed in this study is based on bi-directional Granger causality between CO_2 emissions and income.

Table 4. Results of Granger causality

	F-statistics (probability)					
Dependent Variable	Δc_t	Δe_t	Δy_t	Δy_t^2	Δf_t	EC_{t-1} (*t*-statistics)
Δc_t	-	11.49^*	3.78^*	3.80^*	0.21	-0.81
		(0.00)	(0.03)	(0.03)	(0.80)	$(3.79)^*$
Δe_t	10.89^*	-	1.47	1.78	1.44	-
	(0.00)		(0.24)	(0.18)	(0.25)	
Δy_t	5.00^*	1.06	-	5.27^*	0.12	-0.50
	(0.01)	(0.35)		(0.00)	(0.88)	$(2.99)^*$
Δy_t^2	4.97^*	1.41	5.31^*	-	0.08	-
	(0.01)	(0.25)	(0.00)		(0.91)	
Δf_t	1.22	1.49	2.11	1.99	-	-
	(0.30)	(0.24)	(0.13)	(0.15)		

Causality inference : $c \leftrightarrow e$, $c \leftrightarrow y$, $c \leftrightarrow y^2$, $y \leftrightarrow y^2$.

Notes: * indicates 5 % significance level. The probability values are in brackets. The optimal lag length is 1 and is based on SBC.

4.4 CUSUM and CUSUMSQ test results

The AIC based error-correction model of equation (2) is selected to implement the CUSUM and CUSUMSQ stability tests. The related graphs of these tests are presented in Figures 1 and 2. As can be seen from Figures 1 and 2, the plots of CUSUM and CUSUMSQ statistics are well within the critical bounds, implying that all coefficients in the error-correction model are stable. Therefore, the preferred CO_2 emissions model can be used for policy decision-making purposes such that the impact of policy changes considering the explanatory variables of CO_2 emissions equation will not cause major distortion in the level of CO_2 emissions, since the parameters in this equation seems to follow a stable pattern during the estimation period.

Figure 1. Plot of CUSUM

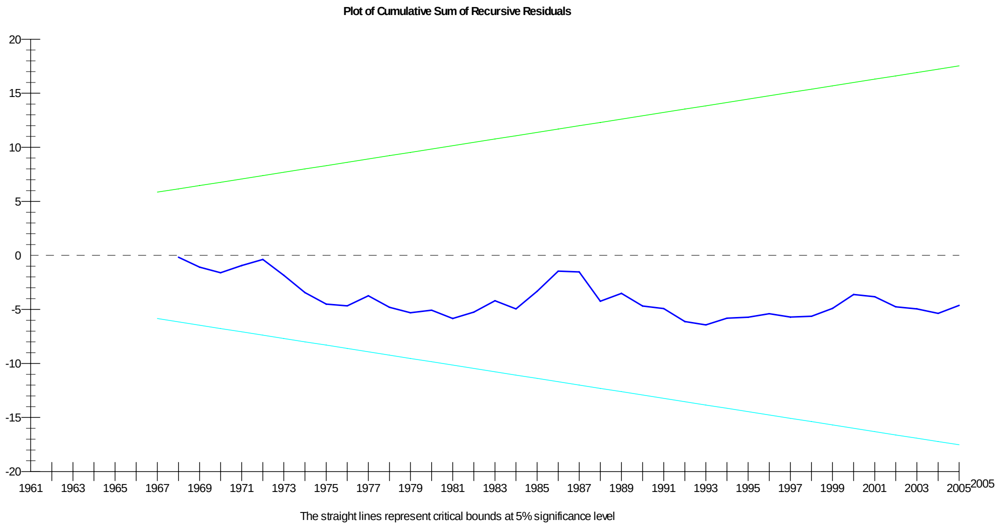
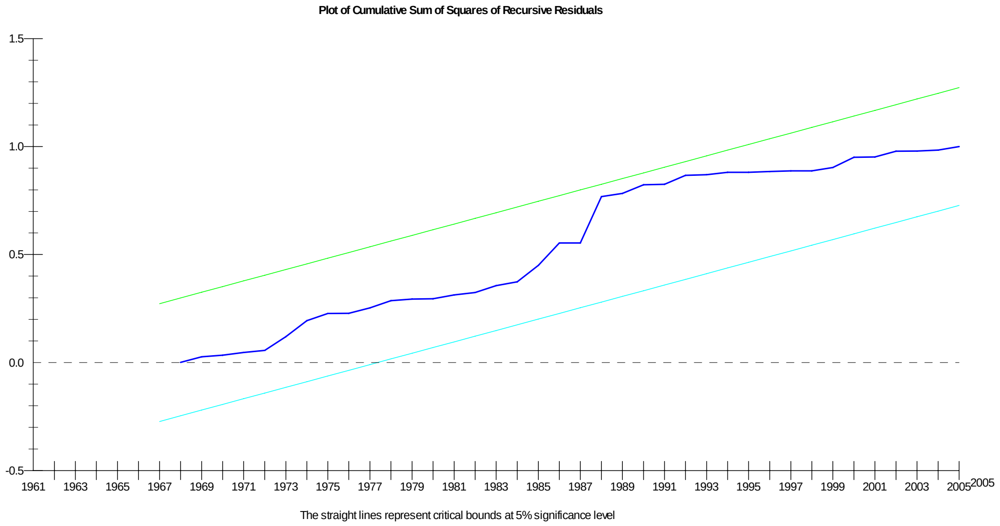


Figure 2. Plot of CUSUMSQ



5. Conclusions

This paper has attempted to analyze empirically the dynamic relationships between CO_2 emissions, commercial energy consumption, income and foreign trade for Turkey. The long-run relationship in which CO_2 emissions is the dependent variable is used to test the short run and long run elasticities of CO_2 emissions with respect to explanatory variables. The long run elasticity of CO_2 emissions with respect to energy consumption is computed as 0.78. Similarly, the elasticity of CO_2 emissions with respect to income in the long-run found to be $12.31 - 1.66y$. The impact of foreign trade on CO_2 emissions seems to be noticeable. Granger causality tests indicate that Granger causality runs in both directions between CO_2 emissions and income both in the short run and long run. Therefore, it is possible to forecast the future levels of these variables from the past levels of each other. The stability of the CO_2 emissions equation suggests that policy changes considering the explanatory variables of CO_2 emissions equation will not cause major distortion in the level of CO_2 emissions.

The results show that Turkey should design new environmental policies to reduce environmental degrading. Currently, the high economic growth gives rise to environmental degrading but the reduction in economic growth will increase unemployment further which is already running at around 10% annually. The policies to tackle environmental pollutants require the identification of some priorities to reduce the initial costs and efficiency of investments. Turkey should measure the exact scale of environmental pollutants that it generates and imports by industries. To this extent, the recent study of Tunc *et al.* (2007) presents a detailed analysis of CO_2 emissions by sectors and industries.

Tunc *et al* (2007) argue that the World bank under estimates the level of Turkish CO_2 emissions by 14% less than the actual level. Using the input-output approach, they compute that 75% of the estimated CO_2 emissions is due to production to satisfy domestic final amount, 11% is due to production to satisfy export demand and 13% is due to direct private consumption and public consumption. Moreover, Turkey is a net importer of CO_2 and it accounts for 5% of the total CO_2 emissions in 1996. The same study also decomposes the CO_2 emissions by industry which is reported as manufacturing (32%), energy and mining (30%), transportation and other services (16%), and agriculture (6%).

Apart from rules and regulations to reduce pollutant emissions, the market based solutions in the form of pollutant taxes would ease the extent of this problem. Telli *et al.* (2008) presents useful policy alternatives in which carbon tax is used as a main policy tool. Telli *et al.* (2008) outlines several scenarios for policy makers to reduce the share of Turkish CO_2 and comply with the EU's environmental pollution targets for 2020. It is suggested that Turkey should impose a carbon tax of 15-20% over 2006-2020. Their results from Computable General Equilibrium (CGE) model reveals that the GDP loss incurred is above 30% as of 2020. Their best environmental policy aims at reducing energy intensities in production which leads to a 1.5% decrease in GDP annually and requires 23% tax rate on energy inputs usage.

The results of this study along with the studies of Tunc *et al.* (2007) and Telli *et al.* (2008) indicate that Turkey should incorporate environmental concerns into her macroeconomic policies more intensely to reduce the pollutant emissions and to sustain economic growth.

Appendix

Data definition and sources

All data are collected from International Financial Statistics of (IMF), World Development Indicators of World Bank (WB) and Annual Statistics of Turkish Statistical Institute (TSI).

c is CO_2 emission measured in metric tons per capita, in logarithm. Source: WB.
e is commercial energy use measured in kg of oil equivalent per capita, in logarithm. Source: WB.
y is per capita real gross national income in Turkish lira, in logarithm. Base year is 2000=100. Sources: IMF and TSI.
y^2 is square of per capita real gross national income: Source: Own calculation.
f is openness ratio measured as summation of real exports and imports over real gross national product in USA dollars, in logarithm. Base year is 2000=100. Source: IMF.

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