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The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey

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ABSTRACT

The aim of this paper is to examine the causal relationship between financial development, trade, economic growth, energy consumption and carbon emissions in Turkey for the 1960–2007 period. The bounds *F*-test for cointegration test yields evidence of a long-run relationship between per capita carbon emissions, per capita energy consumption, per capita real income, the square of per capita real income, openness and financial development. The results show that an increase in foreign trade to GDP ratio results an increase in per capita carbon emissions and financial development variable has no significant effect on per capita carbon emissions in the long- run. These results also support the validity of EKC hypothesis in the Turkish economy. It means that the level of CO_2 emissions initially increases with income, until it reaches its stabilization point, then it declines in Turkey. In addition, the paper explores causal relationship between the variables by using error-correction based Granger causality models.

1. Introduction

The carbon emissions in a country do not necessarily depend on its income level alone; energy consumption, foreign trade (or trade openness) and financial development may be another sources. Thus, researchers have attempted to incorporate not only output/income or economic development *per se* but also extended their analysis for financial development or for variables capturing openness or trade intensity of a country (Zhang, 2011).

The branch of literature which emphasizes the relationship between carbon emission and foreign trade considers the fact that pollution is generated in the production of goods and is related to consumption in another country and therefore the intensity of foreign trade of an economy might have important implication to the level of pollution of that country.

On the other hand, the effects of financial development on the carbon emissions have been investigated by many authors, such as Frankel and Romer (1999), Dasgupta et al. (2001), Sadorsky (2010) and Zhang (2011), who argue that financial development increases carbon emissions. According to these studies, financial development leads to increase in carbon emissions for the following reasons: First, stock market development helps listed enterprises to lower financing costs, increase financing channels, disperse operating risk and optimize asset/liability structure, so as to buy new installations and invest in new projects and then increase energy consumption and carbon emissions. Second, financial development may attract foreign direct investment so as to boost economic growth and increase carbon emissions. Third, prosperous and efficient financial intermediation seems conducive to consumers' loan activities, which makes it easier for consumers to buy big ticket items like automobiles, houses, refrigerators, air conditioners, washing machines, etc. and then emit more carbon dioxide (Zhang, 2011:2197). However, Tamazian et al. (2009) and Claessens and Feijen (2007) argue that financial development may increase energy efficiency and enterprises' performance and then reduce energy consumption and carbon emissions.

Recent studies which examine the effects of financial development on carbon emissions are as follows: Tamazian et al. (2009) investigate the relationship among economic growth, financial development and environmental quality in the BRIC countries, and find that financial development proves a key factor to cut carbon emissions. Sadorsky (2010) explores the influence of financial development in 22 emerging countries on energy consumption using a panel data model, and argues that, as a whole, financial development in these countries significantly

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promote the increase of energy consumption. Tamazian and Bhaskara Rao (2010) point out that financial development in transition countries may exert evident influence on carbon emissions. Zhang (2011) investigates the influence of financial development on carbon emissions in China. Following results obtained: China's financial development acts as an important driver for carbon emissions increase, the influence of financial intermediation scale on carbon emissions outweighs that of other financial development indicators but its efficiency's influence appears by far weaker although it may cause the change of carbon emissions statistically and finally China's stock market scale has relatively larger influence on carbon emissions but the influence of its efficiency is very limited. Jalil and Feridun (2011) investigate the impact of financial development, economic growth and energy consumption on environmental pollution in China. The results of the analysis reveal a negative sign for the coefficient of financial development, suggesting that financial development in China has not taken place at the expense of environmental pollution. On the contrary, it is found that financial development has led to a decrease in environmental pollution. In addition, the findings confirm the existence of an EKC in China. According to the mentioned studies, we can conclude that financial development and trade variables play an important role in the environmental issues.

Turkish economy had witnessed impressive growth rates and a high level of financial development between 2002–2010. Also the annual growth rate of CO_2 emissions in Turkey was 4% between 2000–2008. CO_2 emissions increased from 0.5 in 1960 to 4 in 2008. In fact, this kind of work is of great importance for Turkey to design the path for carbon emissions intensity reduction. During 1960–2010 period, the electricity use per capita rose from 379.6 to 1,440.6. Since there are only a limited number of empirical evidences on the linkages between financial sector development and environmental performance, this paper proposes to make a contribution to the existing literature through examining the relationship between financial development and carbon emissions in Turkey.

The rest of the paper is organized as follows. Section 2 presents the methodology and data. Empirical results are given in Section 3, and Section 4 concludes the paper.

2. Methodology and data

Following the empirical literature, the standard log-linear functional specification of long-run relationship between per capita carbon emissions, per capita energy consumption, per capita real income, the square of per capita real income, openness and financial development in Turkey may be expressed as:

$$co_t = \beta_1 + \beta_2 ec_t + \beta_3 y_t + \beta_4 y^2{}_t + \beta_5 op + \beta_6 fd + \varepsilon_t \quad (1)$$

where, co is the carbon dioxide emissions (measured in metric kilograms per capita), ec is the energy use (measured in kg of oil equivalent per capita), y is per capita real GDP (constant 2000 US$), y^2 is the square of per capita real GDP, *op* is the openness indicator (foreign trade, % of GDP), fd is the financial development indicator (domestic credit to private sector, % of GDP) and ε_t is the error term. The annual time series data are taken from the World Development Indicators (WDI) online database for the 1960–2007 period. All variables are employed with their natural logarithms form to reduce heteroskedasticity and to obtain the growth rate of the relevant variables by their differenced logarithms. The parameters, β_i, i = 2, 3 …, 6, indicate the long-run elasticity estimates of per capita carbon emissions, per capita energy consumption, per capita real income, the square of per capita real income, openness and financial development, respectively. The positive long-run elasticity estimates of per capita carbon emissions with respect to per capita energy consumption, $\beta_2 \rangle 0$, indicate that increase in per capita energy consumption results in an increase in per capita carbon emissions. Under the EKC hypothesis the long-run elasticity estimates of per capita carbon emissions with respect to per capita real income and the square of per capita real income expected to be $\beta_3 \rangle 0$ and $\beta_4 \langle 0$. This means there exists an inverted U-shape pattern that as per capita real income increases, per capita carbon emissions increase as well until some threshold level of per capita real income is reached after which per capita carbon emissions begin to decline. We also expect $\beta_5 \rangle 0$ and $\beta_6 \rangle 0$. Table 1 provides the descriptive statistics of these series for Turkish Economy.

The long-run and causal relationships between per capita carbon emissions, per capita energy consumption, per capita real income, the square of per capita real income, openness and financial development in Turkey will be performed in two steps. Firstly, we will test the long run relationships among the variables by using the ARDL bounds testing approach of cointegration. Secondly, we will test the causal relationships by using the error-correction based causality models.

2.1. Autoregressive distributed lag (ARDL) cointegration analysis

The ARDL bounds testing approach of cointegration is developed by Pesaran and Shin (1999) and Pesaran et al. (2001). The ARDL cointegration approach has numerous advantages in comparison with other cointegration methods such as Engle and Granger (1987), Johansen (1988), and Johansen and Juselius (1990) procedures: (i) no need for all the variables in the system be of equal order of integration, (ii) it is efficient estimator even if samples are small and some of the regressors are endogenous, (iii) it allows that the variables may have different optimal lags, and (iv) it employs a single reduced form equation.

Table 1
Descriptive statistics of variables.

	Mean	Max.	Min.	St. dev.
Log levels				
Carbon dioxide emissions (metric kg per capita)	7.52	8.28	6.39	0.51
Energy use (kg of oil equivalent per capita)	6.61	7.22	5.93	0.37
Real GDP (2000 US dollars per capita)	7.93	8.54	7.35	0.32
Square of real GDP (2000 US dollars per capita)	63.01	72.89	54.02	5.10
Foreign trade (% of GDP)	3.13	4.01	1.74	0.65
Domestic credit to private sector (% of GDP)	2.88	3.38	2.54	0.17
Growth rates (%)				
Carbon dioxide emissions (metric kg per capita)	4.03	19.45	−12.00	5.66
Energy use (kg of oil equivalent per capita)	2.74	9.53	−9.58	3.97
Real GDP (2000 US dollars per capita)	2.50	8.18	−7.34	3.71
Square of real GDP (2000 US dollars per capita)	39.71	127.36	−121.21	59.86
Foreign trade (% of GDP)	1.09	25.28	−42.54	13.37
Domestic credit to private sector (% of GDP)	4.60	73.45	−28.07	18.67

However, if the order of integration of any of the variables is greater than one, for example an I(2) variable, then the critical bounds provided by Pesaran et al. (2001) and Narayan (2005) are not valid. They are computed on the basis that the variables are I(0) or I(1). For this purpose, it is necessary to test for unit root to ensure that all the variables satisfy the underlying assumptions of the ARDL bounds testing approach of cointegration methodology before proceeding to the estimation stage. In order to overcome the low power problems associated with conventional unit root tests, especially in small samples, we therefore prefer the weighted symmetric ADF test (ADF-WS) of Park and Fuller (1995). It requires much shorter sample sizes than conventional unit root tests to attain the same statistical power. Leybourne et al. (2005) have recently noted that ADF-WS has good size and power properties compared to other tests.

Basically, the ARDL bounds testing approach of cointegration involves two steps for estimating long-run relationship. The first step is to investigate the existence of long run relationship among all variables in the equation. The ARDL model for Eq. (1) may follow as:

$$\Delta co_t = \alpha_1 + \sum_{g=1}^{a1}\alpha_{2g}\Delta co_{t-g} + \sum_{h=0}^{b1}\alpha_{3h}\Delta ec_{t-h} + \sum_{i=0}^{c1}\alpha_{4i}\Delta y_{t-i} + \sum_{j=0}^{d1}\alpha_{5j}\Delta y^2{}_{t-j} + \sum_{m=0}^{e1}\alpha_{6m}\Delta op_{t-m} + \sum_{n=0}^{f1}\alpha_{7n}\Delta fd_{t-n} + \delta_1 co_{t-1} + \delta_2 ec_{t-1} + \delta_3 y_{t-1} + \delta_4 y^2{}_{t-1} + \delta_5 op_{t-1} + \delta_6 fd_{t-1} + \varepsilon_{1t} \quad (2)$$

where ε_{1t} and Δ are the white noise term and the first difference operator, respectively. An appropriate lag selection based on a criterion such as Akaike information criterion (AIC) and Schwarz Bayesian Criterion (SBC). The bounds testing procedure is based on the joint F-statistic or Wald statistic that is tested the null of no cointegration, H_0:$\delta_r = 0$, against the alternative of H_1:$\delta_r \neq 0$, $r = 1, 2, \ldots, 6$. Two sets of critical values that are reported in Pesaran et al. (2001) provide critical value bounds for all classifications of the regressors into purely $I(1)$, purely $I(0)$ or mutually cointegrated. If the calculated F-statistics lies above the upper level of the band, the null is rejected, indicating cointegration. If the calculated F-statistics is below the upper critical value, we cannot reject the null hypothesis of no cointegration. Finally, if it lies between the bounds, a conclusive inference cannot be made without knowing the order of integration of the underlying regressors. Recently, Narayan (2005) argues that existing critical values which are based on large sample sizes cannot be used for small sample sizes. Thus, Narayan (2005) regenerated the set of critical values for the limited data ranging from 30–80 observations by using the Pesaran et al.'s (2001) GAUSS code. With the limited annual time series data this study employs the critical values of Narayan (2005) for the bounds F-test rather than Pesaran et al. (2001).

2.2. Causality analysis

ARDL cointegration method tests the existence or absence of long-run relationships between variables. It doesn't indicate the direction of causality. Thus, we use the two-steps procedure from the Granger (1988) model to examine the causal relationship between variables. Granger (1988) emphasizes that a vector error correction (hereafter VEC) modeling should be estimated rather than a VAR as in a standard Granger causality test, if variables in model are cointegrated. Following Granger (1988), to test for Granger causality in the long-run relationship, we employed a two step process: The first step is the estimation of the long-run model for Eq. (1) in order to obtain the long-run relationship as error-correction term (ECT) in the system. The next step is to estimate the Granger causality model with the variables in first differences and including the ECT in the systems. In our case, the VEC multivariate systems take the following forms:

$$\begin{bmatrix}\Delta co_t\\ \Delta ec_t\\ \Delta y_t\\ \Delta y_t^2\\ \Delta op_t\\ \Delta fd_t\end{bmatrix} = \begin{bmatrix}\mu_1\\ \mu_2\\ \mu_3\\ \mu_4\\ \mu_5\\ \mu_6\end{bmatrix} + \begin{bmatrix}\pi_{11,1} & \pi_{12,1} & \pi_{13,1} & \pi_{14,1} & \pi_{15,1} & \pi_{16,1}\\ \pi_{21,1} & \pi_{22,1} & \pi_{23,1} & \pi_{24,1} & \pi_{25,1} & \pi_{26,1}\\ \pi_{31,1} & \pi_{32,1} & \pi_{33,1} & \pi_{34,1} & \pi_{35,1} & \pi_{36,1}\\ \pi_{41,1} & \pi_{42,1} & \pi_{43,1} & \pi_{44,1} & \pi_{45,1} & \pi_{46,1}\\ \pi_{51,1} & \pi_{52,1} & \pi_{53,1} & \pi_{54,1} & \pi_{55,1} & \pi_{56,1}\\ \pi_{61,1} & \pi_{62,1} & \pi_{63,1} & \pi_{64,1} & \pi_{65,1} & \pi_{66,1}\end{bmatrix} \begin{bmatrix}\Delta co_{t-1}\\ \Delta ec_{t-1}\\ \Delta y_{t-1}\\ \Delta y_{t-1}^2\\ \Delta op_{t-1}\\ \Delta fd_{t-1}\end{bmatrix} + \ldots + \begin{bmatrix}\pi_{11,k} & \pi_{12,k} & \pi_{13,k} & \pi_{14,k} & \pi_{15,k} & \pi_{16,k}\\ \pi_{21,k} & \pi_{22,k} & \pi_{23,k} & \pi_{24,k} & \pi_{25,k} & \pi_{26,k}\\ \pi_{31,k} & \pi_{32,k} & \pi_{33,k} & \pi_{34,k} & \pi_{35,k} & \pi_{36,k}\\ \pi_{41,k} & \pi_{42,k} & \pi_{43,k} & \pi_{44,k} & \pi_{45,k} & \pi_{46,k}\\ \pi_{51,k} & \pi_{52,k} & \pi_{53,k} & \pi_{54,k} & \pi_{55,k} & \pi_{56,k}\\ \pi_{61,k} & \pi_{62,k} & \pi_{63,k} & \pi_{64,k} & \pi_{65,k} & \pi_{66,k}\end{bmatrix} \begin{bmatrix}\Delta co_{t-k}\\ \Delta ec_{t-k}\\ \Delta y_{t-k}\\ \Delta y_{t-k}^2\\ \Delta op_{t-k}\\ \Delta fd_{t-k}\end{bmatrix} + \begin{bmatrix}\psi_1\\ \psi_2\\ \psi_3\\ \psi_4\\ \psi_5\\ \psi_6\end{bmatrix} ECT_{t-1} + \begin{bmatrix}\varepsilon_{2t}\\ \varepsilon_{3t}\\ \varepsilon_{4t}\\ \varepsilon_{5t}\\ \varepsilon_{6t}\\ \varepsilon_{7t}\end{bmatrix}. \quad (3)$$

Residual terms, ε_{2t},ε_{3t}, ε_{4t},ε_{5t},ε_{6t} and ε_{7t}, independently and normally distributed with zero mean and constant variance.

The VEC modeling approach allows us to distinguish between “short-run” and “long-run” Granger causality. The Wald-tests of the “differenced” explanatory variables give us an indication of the “short-term” causal effects, whereas the “long-run” causal relationship is implied through the significance or other wise of the t test(s) of the lagged error-correction term that contains the long-term information since it is derived from the long-run cointegrating relationship. Nonsignificance or elimination of any of the “lagged error-correction terms” affects the implied long-run relationship and may be a violation of theory. The nonsignificance of any of the “differenced” variables that reflects only short-run relationship, however, does not involve such violations because; theory typically has little to say about short-term relationships (see Masih and Masih, 1996).

Using Eq. (3), causal relationships can be examined in two ways: i) Short-run or weak Granger causalities are detected through the F-statistics or Wald test for the significance of the relavant π coefficients on the first differenced series. Masih and Masih (1996) and Asafu-Adjaye (2000) interpreted the weak Granger causality as ‘short run’ causality in the sense that the dependent variable responds only to short-term shocks to the stochastic environment. ii) Masih and Masih (1996) point out that another possible source of causation is the ECT in equations. The coefficients of the ECTs represent how fast deviations from the long run equilibrium are eliminated following changes in each variable. The long-run causalities are examined through the t-test or Wald test for the significance of the relavant ψ coefficients on the lagged error-correction term. For example if ψ_1 is zero, per capita carbon emissions does not respond to the deviations from the long-run equilibrium in the previous period. $\psi_i = 0$, $i = 1, 2, \ldots, 6$ for all i is equivalent to both Granger non-causality in the long-run and the weak exogeneity (Hatanaka, 1996).

3. Empirical results

Results of the weighted symmetric ADF test (ADF-WS) are presented in Table 2. The null hypothesis is unit root and the alternative hypothesis is level stationary. The Dickey–Fuller regressions include an intercept and a linear trend in the levels, and include an intercept in the first differences. The numbers of optimal lags are based on SBC. 95% simulated critical values for several observations are computed by stochastic simulations. The results indicate that openness and finanacial development variables are stationary in their levels, and other variables are stationary in their first differences. Thus, we can confidently apply the ARDL methodology to Eqs. (1, 2).

Table 2
Unit root test results.

Levels			1st differences		
	ADF-GLS	ADF-WS		ADF-GLS	ADF-WS
co	−1.0412 (0) c+t	−0.8857 (0) c+t	co	−5.9332 (0) c	−7.0530 (0) c
ec	−2.1148 (0) c+t	−2.3021 (0) c+t	ec	−5.6320 (0) c	−6.8104 (0) c
y	−2.9913 (0) c+t	−2.7343 (0) c+t	y	−5.7176 (0) c	−7.1144 (0) c
y^2	−2.7414 (4) c+t	−3.2388 (4) c+t	y^2	−3.1065 (4) c	−3.9559 (4) c
op	−3.0785 (1) c+t	−3.8580 (1) c+t	op		
fd	−3.9076 (1) c+t	−4.1361 (1) c+t	fd		
CV	−3.3314 (0)	−3.4628 (0)	CV	−2.3148 (0)	−2.5587 (0)
5%	−3.2632 (1)	−3.4264 (1)	5%	−2.2845 (1)	−2.6556 (1)
	−3.1153 (2)	−3.3405 (2)		−2.2659 (2)	−2.5934 (2)
	−3.1164 (3)	−3.4130 (3)		−2.2227 (3)	−2.6403 (3)
	−3.0816 (4)	−3.4623(4)		−2.2243 (4)	−2.7084 (4)

Notes: Model c+t has the Dickey–Fuller regressions include an intercept and a linear trend, model c has the Dickey–Fuller regressions include an intercept but not a trend. Numbers of lags are in ( ). CV is the 95% simulated critical value, computed by stochastic simulations for relevant numbers of lags are in ( ) using 43 observations and 1000 replications.

Table 3
Estimated ARDL models and bounds *F*-test for cointegration.

ARDL model		F-statistics	CV 1% I(0) I(1)	CV 5% I(0) I(1)
(co|ec, y, y^2, op, fd)	(1,1,1,0,1,0)	6.644	3.674 5.019	2.694 3.829

Notes: The critical values (CV) for the lower *I*(0) and upper *I*(1) bounds are taken from Narayan (2005, Appendix: Case II).

According to Pesaran and Shin (1999), the SBC is generally used in preference to other criteria because it tends to define more parsimonious specifications. With the limited observations, this study used the SBC to select an appropriate lag for the ARDL model. Table 3 presents the estimated ARDL model that has passed several diagnostic tests that indicate no evidence of serial correlation and heteroskedasticity.

The bounds *F*-test for cointegration test yields evidence of a long-run relationship between per capita carbon emissions, per capita energy consumption, per capita real income, the square of per capita real income, openness and financial development at 1% significance level in Turkey (See Table 3).

In addition, due to the structural changes in Turkish economies it is likely that macroeconomic series may be subject to one or multiple structural breaks. For this purpose, the stability of the short-run and long-run coefficients are checked through the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests proposed by Brown et al. (1975). Unlike Chow test, requires break point(s) to be specified, the CUSUM and CUSUMSQ tests are quite general tests for structural change in that they do not require a prior determination of where the structural break takes place. Fig. 1 presents the plot of CUSUM and CUSUMSQ tests statistics that fall inside the critical bounds of 5% significance. This implies that the estimated parameters are stable over the periods.

The long-run elasticity estimates of per capita carbon emissions with respect to per capita energy consumption expected to be $\beta_2\rangle 0$. This means as an increase in per capita energy consumption results in an increase in per capita carbon emissions. We found β_2 is about 0.5 at 5% significance level. Under the EKC hypothesis, the long-run elasticity estimates of per capita carbon emissions with respect to per capita real income and the square of per capita real income expected to be $\beta_3\rangle 0$ and $\beta_4\langle 0$. This means as per capita real income increases, per capita carbon emissions increase as well until some threshold level of per capita real income is reached after which per capita carbon emissions begin to decline. In long-run analysis we found $\beta_3\rangle 0$ and $\beta_4\langle 0$ at 1% significance level. These results support the validity of EKC hypothesis in Turkish economy. Therefore, beyond a threshold level of per capita real income, any increase in per capita real income likely reduces the per capita carbon emissions in Turkey. In addition, the coefficient of openness variable is also positive at 5% significance level. It shows that an increase in foreign trade to GDP ratio results in an increase in per capita carbon emissions. Finally, financial development variable has no significant effect on per capita carbon emissions in the long- run. The coefficients of estimated *ECT*s are also negative and statistically significant at 1% confidence level. These values indicate that any deviation from the long-run equilibrium between variables is corrected for each period to return the long-run equilibrium level (See Table 4).

This study also explores causal relationship between the variables by using error-correction based Granger causality models which are weak (short-run) Granger causality and long-run Granger causality. The results of both Granger causality models (see Table 5) can be summarized as follows:

i) There is an evidence of a long-run causal relationship from per capita energy consumption, per capita real income, the square of per capita real income, openness and financial development to per capita carbon emissions. This long-run causality results also

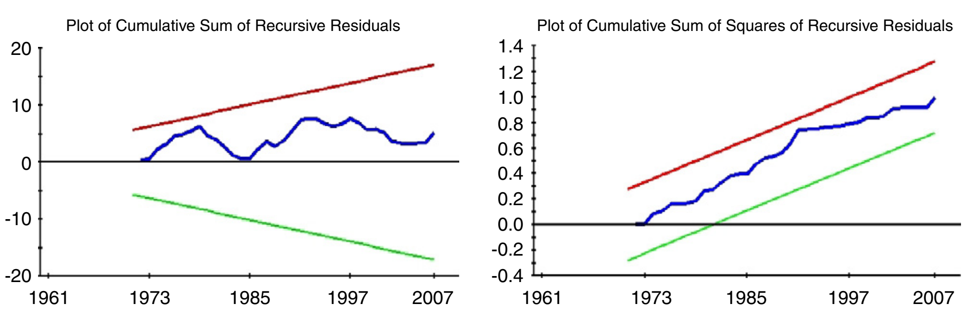

Fig. 1. Plot of CUSUM and CUSUMSQ tests for the parameter stability.

Table 4
Estimated coefficients from ARDL model.

Regressors	Short-run elasticities		Long-run elasticities
co(−1)	0.2721 (1.8352)*		
ec	1.1075 (6.9582)***		0.4796 (2.3820)**
ec(−1)	−0.7584 (−4.1488)***		
y	8.3468 (4.1851)***		12.0689 (8.9576)***
y(−1)	0.4385 (4.1851)***		
y^2	−0.5135 (−4.2193)***		−0.7054 (−9.4255)***
op	−0.0012 (−0.0547)		0.0559 (2.2190)**
op(−1)	0.0419 (1.8716)*		
fd	0.0227 (0.7822)		0.0312 (0.8056)
Constant	−34.3428 (−4.2061)***		−47.1786 (−9.4751)***
ect(−1)			−0.7279 (−4.9101)***
R^2	0.9983	RSS	0.0195
$\chi^2_{LM}(1)$	1.554 [0.213]	$\chi^2_{HET}(1)$	4.009 [0.135]
$\chi^2_{NORM}(1)$	1.868 [0.393]	$\chi^2_{RESET}(2)$	0.571 [0.450]

Notes: (−1) refers one lag of relevant variables. t-statistics for coefficients are in ( ). RSS is the residual sum of squares. χ^2_{LM} is the Lagrange multiplier test of residual serial correlation; χ^2_{HET} is the heteroskedasticity test based on the regression of squared residuals on squared fitted values; χ^2_{NORM} is the normality test based on a test of skewness and kurtosis of residuals and χ^2_{RESET} is the test for functional form based Ramsey's RESET test using the square of the fitted values. Their degrees of freedom and p-values are in ( ) and in [ ], respectively. *, ** and *** are 1%, 5% and 10% significance levels, respectively.

present that a reduction on the level of energy consumption or real income or openness have decrease the level of carbon emissions. As an energy policy implication to reach the lower environmental pollution, policymakers have to explore the alternative energy policies for example decreasing energy intensity, increasing energy efficiency and increasing the utilization of cleaner energy sources.

ii) There is an evidence of a short-run unidirectional causal relationship from financial development to per capita energy consumption, per capita real income and the square of per capita real income. Also an improvement on financial sector will cause the rising of energy consumption and income in the short run. This result implies that financial development has an important role on the higher energy consumption and income in Turkey as an emerging market country. Therefore, the policymakers have to include the financial development indicators to estimate of the level of energy demand or income.

4. Concluding remarks

This paper investigates the causal relationship between financial development, openness, economic growth, energy consumption and carbon emissions in Turkey for 1960–2007 period. The bounds *F*-test for cointegration test yields evidence of a long-run relationship between per capita carbon emissions, per capita energy consumption, per capita real income, the square of per capita real income, openness and financial development. The results also support the validity of EKC hypothesis in Turkish economy. It means that the level of CO_2 emissions initially increases with income, until it reaches its stabilization point, then it declines in Turkey. In addition, the coefficient of openness variable is also positive at 5% significance level which shows that an increase in foreign trade to GDP ratio (openness) results in an increase in per capita carbon emissions. Finally, financial development variable has no significant effect on per capita carbon emissions in the long- run. The coefficients of estimated *ECT*s are also negative and statistically significant at 1% confidence level. These values indicate that any deviation from the long-run equilibrium between variables is corrected for each period to return the long-run equilibrium level.

This paper also explores causal relationship between the variables by using error-correction based Granger causality models. The results of both Granger causality models can be summarized as follows: i) there is an evidence of a long-run causal relationship from per capita energy consumption, per capita real income, the square of per capita real income, openness and financial development to per capita carbon emissions. ii) There is an evidence of a short-run unidirectional causal relationship from financial development to per capita energy consumption, per capita real income and the square of per capita real income.

Finally, due to limited data availability, the results in this paper can be much enriched in the future, but hopefully the research is conducive to not only Turkey's financial reforms but also carbon emissions intensity reduction efforts. We hope that other researchers will use our results and methodology to get improved insights into the economic–finance and environment nexus in other developing countries.

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Table 5
Granger causality test results.

Variables	Short-run (or weak) Granger causalities						Long-run Granger causalities
	Δco	Δec	Δy	Δy^2	Δop	Δfd	ψ_i
Δco	–	0.2273 (0.6336)	1.0967 (0.2950)	1.2617 (0.2613)	2.2509 (0.1335)	1.6813 (0.948)	5.4393 (0.0197)**
Δec	1.2879 (0.2564)	–	0.2864 (0.5925)	0.3707 (0.5426)	0.5056 (0.4770)	3.9771 (0.0461)**	0.6611 (0.4162)
Δy	0.3840 (0.5355)	0.0118 (0.9135)	–	0.2303 (0.6313)	0.2000 (0.6547)	10.2797 (0.0013)***	0.8433 (0.3585)
Δy^2	0.3317 (0.5647)	0.0138 (0.9065)	0.0489 (0.8251)	–	0.1452 (0.7032)	10.5641 (0.0012)***	0.8792 (0.3484)
Δop	0.0142 (0.9053)	1.5467 (0.2136)	0.3586 (0.5493)	0.4277 (0.5131)	–	0.4638 (0.4958)	1.4241 (0.2327)
Δfd	0.3372 (0.5615)	0.3788 (0.5382)	0.0460 (0.8301)	0.0445 (0.8329)	1.0351 (0.3090)	–	0.0179 (0.8936)

Notes: The null hypothesis is that there is no causal relationship between variables. Values in parentheses are p-values for Wald tests with a χ^2 distribution. Δ is the first difference operator. *, ** and *** are 1%, 5% and 10% significance levels, respectively. The number of appropriate lag is one according to Akaike information criterion, Schwarz information criterion and Hannan–Quinn information criterion.

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