# Financial Development, $CO_2$ Emissions, Fossil Fuel Consumption and Economic Growth: The Case of Turkey

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## ABSTRACT

Many past studies have explored the relationships between income and $CO_2$ emissions; however, most have not covered the possible effects of financial indicators on their frameworks. This study investigates the relationships between financial development and environmental degradation in Turkey from 1960 to 2011 using a multivariate framework that focuses on economic growth and fuel consumption as additional determinants of environmental degradation. Because a unit root test indicated that data were not stationary, the Johansen co-integration test was applied, revealing that the variables under investigation are co-integrated in the long run. After establishing the long-run relationship between variables, error correction modeling identified the long-run and short-run coefficients of the variables. The findings show that in the long-run, economic growth has negative and significant effect on carbon emissions (-0.069) while fuel consumption has positive and elastic impact on carbon emissions (2.82). Therefore, the error correction term implies that $CO_2$ moves to its long-run equilibrium level at a speed of adjustment of 16.97% by the contributions of gross domestic product (GDP), fossil fuel consumption and financial development.

## INTRODUCTION

The industrial revolution, which can be characterized by more efficient use of resources, large-scale production of manufactured goods, lower production cost, rapid economic growth, and less costly and faster transportation and communication, led to higher quality living conditions according to conventional measures of human well-being. However, the industrial revolution exacted its costs, environmental degradation being among the largest. Economic growth required high levels of energy consumption, mostly satisfied by fossil fuels which were accompanied by pollutants including carbon dioxide ($CO_2$) emissions, resulting in environmental degradation and increased global warming [1]. For the last few decades, intense competition among countries, growth in developing countries, market liberalization and globalization accelerated these developments [2].

Mitigation of global warming is one of the world's important challenges. Over the past three decades, greenhouse gas (GHG) and $CO_2$ emissions have increased almost 1.6% annually due to greater use fossil fuels, which have increased 1.9% annually. The Intergovernmental Panel on Climate Change (IPCC) has predicted that global atmospheric temperatures will rise between 1.1°C and 6.4°C over the next century [3]. This projection led the United Nations to approve the Kyoto protocol in 1997, a major milestone in combating global warming [4]. These developments make it crucial to identify the sources of carbon emissions [5].

The interaction between economic growth, energy consumption and environmental degradation has been widely debated and is a mainstream research area of energy economics since the work of Kraft and Kraft [6,7]. Many studies have since investigated the co-integration and causality relationships between economic growth and energy consumption in different countries [8-14]. To prevent omitted variable bias (OVB) and improve our understanding, past studies examined the economic growth-environmental pollution nexus degradation in multivariate frameworks with researchers expanding their models by including variables such as foreign trade, trade openness, urbanization and foreign direct investment [15-18].

Our study further expands the standard energy consumption-economic growth model by employing a financial development variable. The effect of financial development on carbon emissions is a controversial topic. On the one hand, there are many reasons why financial development could cause air pollution to increase. First, with improved market conditions, companies can lower their project financing costs, so they tend to increase investments in new projects creating greater demand for energy and more $CO_2$ emissions. Second, developing financial sectors may pave the way for expanding direct foreign investment to prompt economic growth, subsequently causing increases in $CO_2$ emissions. Third, efficient and successful financial interventions allow consumers to purchase costly items by providing loans, but buying larger air-conditioned homes and automobiles and other consumer items can lead to increases in $CO_2$ emissions [19,20]. A counter argument suggests that financial development has a vital role in helping firms expand by raising capital, thus providing opportunities for improved environmental protection and helping to reduce $CO_2$ emissions. Companies expanding through financial development may often exhibit more efficient use of resources and energy, contributing to decreases in the levels of air pollution [21,22].

The economy of Turkey was transformed toward liberalization as a result of reforms deployed since 1980, aiming to integrate with the world economy, increase economic growth, and improve living conditions. The country's 2000-2001 economic crisis triggered new structural reforms, leading to higher levels of financial development and growth after 2002. As a rapidly developing economy, Turkey has supported industrialization which is greatly reliant on fossil fuels. Turkey hosts large numbers of tourists annually due to its attractions. These travelers add to the country's total carbon emissions. By consuming larger quantities of fossil fuels, Turkey would anticipate more carbon emissions and environmental pollution.

According to Climate Change Performance Index there are 61 countries responsible for nearly 90% of world's total $CO_2$ emissions. Turkey ranks in 51st due to its climate protection performance [23]. The country suffers from a lack of viable energy policies. Its consumption of fossil fuels in the energy industry and inferior energy efficiencies contrast with those of many other countries [24]. As developing nations strive for financial advancement and destitution reduction, they tend to support industrialization and monetary development to a greater extent than ecological impacts. Our study is important given the connections between Turkey's environmental degradation and its larger focus on the growth of its financial and industrial sectors.

This article investigates the causality between Turkey's environmental degradation and financial development in a multivariate framework using economic growth and fuel consumption as additional determinants of environmental degradation. Time series data have been chosen covering the period of 1960-2011. To explore this relationship, our study proposes the model $CO_2$ = f (GDP, FUEL, FD), in which $CO_2$

is a dependent variable while gross national product (GDP), FUEL, and financial development (FD) are independent variables. Because Turkey's economy was unstable, had volatile data (especially with its GDP), and had structural breaks during the period of 1960-2011, Zivot and Andrews [25] unit root tests are employed to reveal the integration order of the data. The primary reason for choosing this methodology, rather than a conventional approach, is that conventional methodologies often fail to consider structural breaks and thus produce misleading results. After finding the number of integrating orders of data, the Johansen co-integration test is employed to explore whether variables are co-integrated in the long-run. After establishing the long-run connection between variables, it is required to determine the level (or long-term) coefficients of our proposed model and its error correction model (ECM) in order to obtain short-term coefficients and the error correction term (ECT). Finally, the Granger causality test based on the vector error correction model (VECM) is conducted to reveal the direction of the causality between variables.

This article includes a brief literature review, discussion of the data, presentation of the proposed model, and discussion of the methodologies used in this study. Lastly, conclusions and implications are summarized.

## LITERATURE REVIEW

The nexus between economic growth and energy consumption traditionally indicates that achieving greater economic growth requires countries to increase energy consumption. Kraft and Kraft first proposed the idea of the relationship between economic growth and energy consumption [7]. They investigated the nexus between GNP and energy consumption in the United States from 1947-1974. Findings showed that GNP prompts energy consumption. Following this seminal work, researchers have investigated this topic [3,26]. Many studies confirmed long run or causal relationships between these variables [27-30].

Energy consumption can lead countries to experience rapid economic development, but also can create environmental threats. Global warming and environmental degradation have become central concerns, and $CO_2$ is considered a major contributor to atmospheric greenhouse gases and climate change [31]. Studies on the causes of carbon emissions and their relationships to economic growth have been explored by academics throughout the world [see 32-35].

Because pursuing the connection between income and ecological degradation in a bivariate framework might create misleading results, researchers started to augment their studies by exploring the relationships among more variables simultaneously. Many scholars explored the possible causal connections between $CO_2$ emissions and income with energy consumption in a multivariate framework. Ang completed a pioneering study exploring the connections between income, energy consumption, and $CO_2$ emissions in France during 1960-2010 [36]. Using co-integration analysis and VECM modeling, the study established a long-run relationship among variables. The findings also showed a unidirectional causality from energy to output. Many researchers have followed Ang. Soytas, Sari, Ewing studied the economic-energy-environment debate and found no causality between economic growth and $CO_2$ emissions and a unidirectional causality from energy to $CO_2$ [37]. Ghosh using the case of India from 1971-2006 was unable to find any long-run equilibrium connection among the variables [10]. Lotfalipour, Falahi, and Ashena's study in 2010 on the connection between income, $CO_2$ emissions, and fossil fuel consumption in Iran supported the evidence of causality among the variables [38]. Chang in 2010 led a similar study using China as the case study; results showed that economic growth stimulates energy consumption, then $CO_2$ emissions [other examples include 3, 39-42].

Researchers often tend to expand their multivariate framework by adding extra variables. This might reduce the omitted variable bias (OVB) problem in econometric analyses [15]. To this aim, variables used to augment the models include foreign direct investment trade and urbanization as additional determinants [3,43]. Although the amount of a country's $CO_2$ emissions depend on the quantities of fossil fuels and other energy consumed in its industrial, commercial, and residential sectors, financial development may also be an imperative source [44]. Tamazian et al. explored the connections among financial development, economic growth, and environmental quality in Brazil, Russia, India and China [22]. They found financial development to be an imperative component for the reduction of $CO_2$ emissions. Tamazian and Rao found that financial development indicators have an obvious impact on $CO_2$ emissions in developing nations [45]. Other researchers have asserted that $CO_2$ emissions can be prompted by financial development factors [19,20,46,47]. The effects of financial development on $CO_2$ emissions have been a controversial subject among researchers in recent years.

There are several possible explanations for the lack of consensus. Differences in researchers' preferences when choosing pollutants create inconclusive results because every pollutant has a different turning point that is related to a country's per capita income. The empirical findings on the relationship between economic growth and $CO_2$ emissions offer mixed results compared to other pollutants [48]. Another criticism is related to cross-country analysis and pooled panel data collection, both of which can lead to heterogeneity problems and contradictory results. However, a time series analysis addressed the heterogeneity issue by enabling researchers to localize their analysis to a specific country [46].

Once Lindmark in 2002 noticed estimation localized into a single country, analysis would move closer to the dynamic [49]. This finding can emphasize the long-term aspects of the Environmental Kuznets Curve (EKC) for a development of an individual economy, which can mature toward different levels over time [50]. One important explanation of controversial findings can be OVB; because estimating the causality between environmental degradation and economic growth had been established in bivariate frameworks such as the EKC hypothesis, some studies suffered from OVB and results were spurious.

There is a multi-aspects requirement for considering Turkey's energy circumstances to obtain knowledge into the improvement of carbon emissions [51]. Turkey has been criticized for decades due to its environmental protection behaviors and its rapid economic growth, gaining the attention of researchers. Lise and Akbostanci et al. were unable to affirm the presence of an EKC [51,52]. However, Halicioglu found an inverted U-shaped connection between income and natural pollution [15]. Soytas and Sari observed unidirectional causality from $CO_2$ emissions to energy consumption [53]. Ozturk and Acaravci studied the relationships among economic growth, energy consumption, and $CO_2$ emissions by incorporating the employment ratio as an additional variable during the period of 1968-2005 [4]. The authors could not establish causality between the variables. However, most studies failed to consider financial development as a part of their analyses.

Although many studies in the academic literature have focused on an empirical examination of the financial-environment nexus, these studies are exceptionally restricted in the case of Turkey. Ozturk and Acaravci explored the long-run causal connection of economic growth, financial development, openness and energy in Turkey [54]. The study uncovered that there is a long-run connection among the variables. They also examined whether the EKC hypothesis is satisfied by the given variables. It was presumed that as income advances to an optimal level, emissions begin to decrease. Although the impact of financial development on $CO_2$ emissions is insignificant over the long run, the researchers proved that financial development does lead to energy consumption in the short run. A comparative study led by Gokmenoglu et al. inspected conceivable associations among $CO_2$ emissions, financial development, and industrialization in Turkey [44]. The findings of a Johansen co-integration test demonstrated that there is a long-run equilibrium relationship among the variables. Furthermore, the researchers found a unidirectional causality from FD to $CO_2$ emissions.

## DATA AND METHODOLOGY

Data used in this study include annual data which cover the years 1960 to 2011 in Turkey. The variables considered are $CO_2$ emissions, gross domestic product (GDP), fossil fuel consumption (FUEL) and financial development (FD). $CO_2$ data are listed in kg per 2005 USD of GDP. Constant 2005 USD are used for GDP data. FUEL comprises fossil fuels including coal, oil, petroleum and natural gas products. The percentage of bank credit to bank deposits has been chosen as a proxy for FD. Data were collected from the World Bank (2015) online database. All series are changed into their natural logarithmic form due to capture growth impacts.

### Methodology

In this study, methodology included three different stages of analysis. First, the Zivot and Andrews unit root test was employed to test the integration order of the variables [25]. Second, the Johansen and Juselius co-integration test was used to investigate the possible long-run equilibrium relationship between variables [55]. Last, the Granger causality test was applied for proving the existence and revealing the causality direction among series. To establish the relationships among $CO_2$, GDP, FUEL and FD, the following model is proposed:

$$CO_2 = f(GDP, FUEL, FD) \quad (1)$$

This model suggests that GDP, FUEL and FD might be determinates of $CO_2$ in a case of Turkey. In other words, $CO_2$ is a function of GDP, FUEL and FD. The variables are transformed into their logarithmic form to capture growth impacts. The functional model can be shown as follows:

$$InCO_2t = \beta_0 + \beta_1 \, lnGDP_t + \beta_2 \, InFUEL_t + \beta_3 FD_t + \varepsilon_t \quad (2)$$

where at period *t*, $lnCO_2$ is the natural log of carbon dioxide emissions; lnGDP is the natural log of the real income; lnFUEL is the natural log of fossil fuel energy consumption; lnFD is the natural log of financial development indicator and error term is shown by ε. The $\beta_1$, $\beta_2$, and $\beta_3$, coefficients provide the elasticity of GDP, FUEL and FD respectively in the long run.

**Unit Root Test**

Unit root tests determine whether data are stationary or non-stationary. Prior to analysis, unit root tests must be undertaken to identify the number of integrating order of variables. Various unit root tests are accessible in finance and economics to examine the integration order of the variables [see 56-60]. The main problem with these tests is connected to their power and size. When the process is stationary with a root near the non-stationary boundary, the power of these tests is low. For example, augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests are not strong enough to determine if $\phi = 1$ or $\phi = 0.95$, especially in small sample sizes. These tests yield spurious, one-sided findings when they lack data about all possible structural break points in the series. For example, Turkey's economy has witnessed several fluctuations and transformation towards a more liberal system. These economic impacts reflect some structural changes, and it is crucial to consider these breaks when performing unit root tests. According to Figure 1, we tend to believe that there are structural breaks in the series.

To consider these structural breaks in unit root analysis, Zivot and Andrews constructed three models to examine the stationary attributes of the variables in the existence of a structural break point in the series [25]. The first model permits a one-time change in the series at the level form. The second model permits an exogenous change in the slopes of

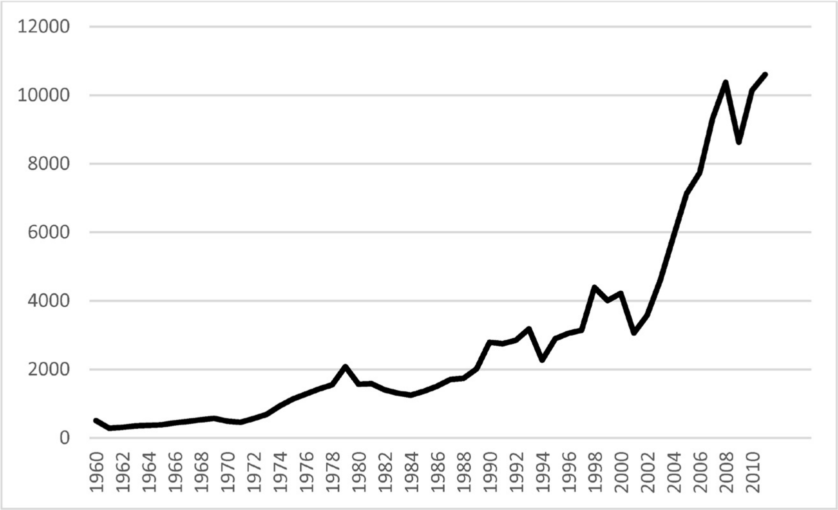


**Figure 1. Gross domestic product per capita (USD) 1960-2011.**
**Source: World Bank (2015).**

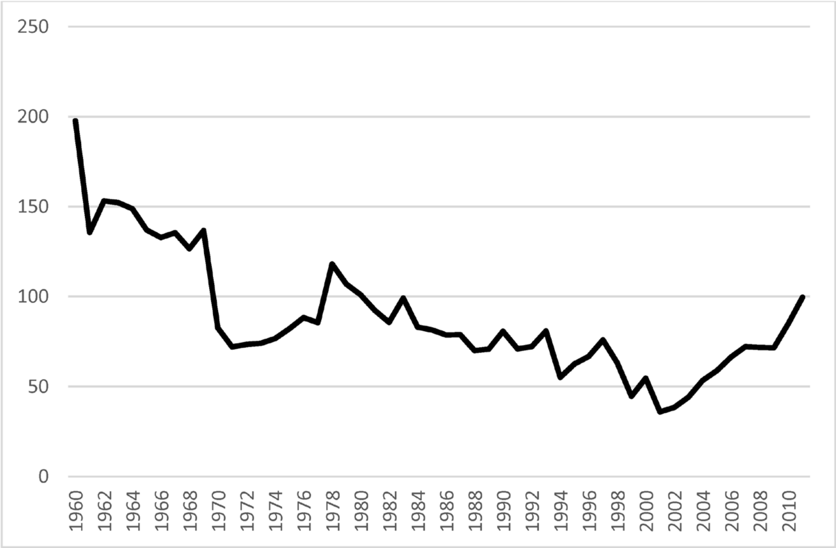


**Figure 2. Bank credit to bank deposit (%).**
**Source: World Bank (2015).**

the series, and the third model combines the previous two models, with changes in both the trend and intercept functions of the series. Zivot and Andrews pursued three models in an effort to determine the hypothesis of exogenous structural break points in variables as follows:

$$\Delta X_t = \alpha + \alpha x_{t-1} + bt + cDU_t + \sum\nolimits^{k}_{j=1} d_j \Delta x_{t-j} + \mu_t \quad (3)$$

$$\Delta X_t = b + bx_{t-1} + ct + bDT_t + \sum\nolimits^{k}_{j=1} d_j \Delta x_{t-j} + \mu_t \quad (4)$$

$$\Delta X_t = c + cx_{t-1} + ct + dDU_t + dDT_t + \sum\nolimits^{k}_{j=1} d_j \Delta x_{t-j} + \mu_t \quad (5)$$

Where, $DT_t$ shows dummy variables indicating that a mean shift occurred at every point with time break; however, trend shift series are indicated by $DT_t$. Therefore,

$$DU_t = \begin{cases} 1 \ldots if \;\; t > TB \\ 0 \ldots if \;\; t < TB \end{cases} \quad \text{and} \quad DU_t = \begin{cases} t - TB \ldots if \;\; t > TB \\ 0 \ldots if \;\; t < TB \end{cases}$$

The null hypothesis in this test is the that variables are not stationary without any structural break point. The alternative hypothesis states that the series are stationary with one incognito time break.

**Co-integration Tests**

Because the variables were determined to be integrated of order one, co-integration between variables must be examined, and any possible long-run equilibrium relationship should be investigated. For this purpose, our study applied the Johansen co-integration test which assumes that all variables have the same order of integration. To have co-integration among variables, a minimum of one co-integrating vector is required. The Johansen [61] and Johansen and Juselius [55] methodologies provide ways to find the number of co-integrating vector among the variables. Because the Engel and Granger approach has some pitfalls that may create unreliable results during estimation, the Johansen approach addresses these issues [62]. The following equation demonstrates the Johansen approach and is based on vector autoregressive (VAR) modeling:

$$y_t = \mu + A_1 y_{t-1} + \cdots + A_p y_{t-p} + \varepsilon_t \quad (\text{for } t = 1, \ldots, T) \quad (6)$$

Where $y_t$, $y_{t-1}$, …, $y_{t-p}$ are vectors of level and lagged values of P variables respectively which are I(1) in the model; $A_1$, … $A_p$ are coefficient matrices with (PXP) dimensions; μ an intercept vector; $\varepsilon_t$ is a vector of random errors [63]. Assumption of non-auto-correlating error terms control the number of lagged values. The rank of $A$ shows the co-integrating equations number which are found by estimating if the values of Eigen ($\lambda_i$) are statistically significant. Johansen [61] and Johansen and Juselius [55] suggest the trace statistics are determined by utilizing the Eigen values [63]. Following formula demonstrate the estimation of the trace statistic ($\lambda_{trace}$):

$$\lambda_{trace} = -T\sum \ln(1-\lambda_i)\ ,\ i = r+1, \ldots, n-1 \quad (7)$$

The null hypotheses are stated as follows:

$H_o: \nu = 0 \qquad H_1: \nu \geq 0$

$H_o: \nu \leq 1 \qquad H_1: \nu \geq 2$

$H_o: \nu \leq 2 \qquad H_1: \nu \geq 3$

**Error Correction Model**

After establishing the long-run equilibrium connection among variables, the error correction model (ECM) was estimated in the instance that the $CO_2$ in the equation (model) may not instantly acclimate to its long-run equilibrium level after an adjustment in any of its determinants. Error correction term (ECT) demonstrates the speed of adjustment indicating how rapidly series rebound to the long-run equilibrium and it ought to have a negative sign coefficient which is statistically significant. Following equation demonstrate the general ECM model:

$$\text{InCO}_{2t} = \beta_0 + \sum^{n}{}_{i=1} \beta_1\Delta\ \text{InCO}_{2t-j} + \sum^{n}{}_{i=0} \beta_2\Delta\ \text{InGDP}_{t-j} + \sum^{n}{}_{i=0} \beta_3\Delta\ \text{InFUEL}_{t-j} + \sum^{n}{}_{i=0} \beta_4\Delta\ \text{InFD}_{t-j} + \beta_5\beta_{t-1} + u_t \quad (8)$$

Where Δ indicates the change in the $CO_2$, GDP, fossil fuel, and bank credit variables and $\beta_{t-1}$ show the one period lagged ECT which is derived from the residuals by estimating the equation's co-integration model.

**Granger Causality Tests**

Johansen co-integration tests only prove the absence or presence of the long-run relationships between series and are unable to illustrate the direction of causality between variables. Therefore, Granger causality tests were undertaken in our study to reveal these directions among variables. Granger emphasizes that when the variables are co-integrated, then the causality test should be determined based on vector error correction modeling (VECM) instead of VAR models which are used to capture the linear interdependencies among multiple time series [64]. Engle and Granger caution that the Granger causality test, which is led in the first difference variables by a means of VAR, report confusing results in the existence of co-integration [62]. Thus, it is important to incorporate the ECT as an extra variable to the VAR framework. The direction of causality can be recognized toward VECM of long-run co-integration. Furthermore, VECM is utilized to estimate the velocity of short-run values approach focused on long-run equilibrium values. Granger's outlook indicates that ECM are required to be an augmented form of simple causality tests with the error correction framework. ECMs are contained from the main co-integration model residuals and can be formulated as in the following equations:

$$\text{In}Y_t = \text{C}_\text{o} + \sum\nolimits^{\text{k}}{}_{i=1} \beta_i \Delta \text{ In Y}_{t-i} + \sum\nolimits^{\text{k}}{}_{i=1} \alpha_i \Delta \ln X_{t-i} + \phi_i \text{ ECT}_{t-i} + u_t \tag{9}$$

$$\Delta \text{ In}Y_t = \text{C}_\text{o} + \sum\nolimits^{\text{k}}{}_{i=1} \gamma_i \Delta \ln X_{t-} + \sum\nolimits^{\text{k}}{}_{i=1} \varsigma_i \Delta \ln Y_{t-i} + \theta_i \text{ ECT}_{t-i} + \varepsilon_t \tag{10}$$

The estimating variables are $X$ (independent variable) and $Y$ (dependent variable); $\theta_i$ and $\theta_i$ measure the error correction term by standing as coefficients for $ECT_{t-1}$; $\Delta$ demonstrates that the variables are in their first differences. According to the first model, when $\phi_i$ become statistically significant in first equation suggesting that $X$ Granger causes $Y$ while in the second model $\theta_i$ become statistically significant $Y$ Granger causes $X$. F-stat shows the examination of combined null hypothesis which is $\alpha_i = \varsigma_i = 0$ and the significance of the error correction coefficient is determined by the $t$-stat.

## EMPIRICAL RESULTS

The Zivot and Andrews (ZA) unit root test for stationarity is undertaken to better understand the integration order of the variables. The findings of the ZA unit root test are reported in Table 1. It is observed that the null hypothesis for all variables cannot be rejected at

**Table 1. Zivot and Andrews unit root test [25].**

| | *Statistics (level)* | | | *Statistics (first difference)* | | | |
|---|---|---|---|---|---|---|---|
| | $ZA_B$ | $ZA_T$ | $ZA_I$ | $ZA_B$ | $ZA_T$ | $ZA_I$ | Conclusion |
| $lnCO_2$ | -3.677 | -3.590 | -3.679 | -10.615* | -6.380* | -10.716* | I(1) |
| Break year | 1971 | 1986 | 1970 | 1974 | 2002 | 1974 | |
| lag length | 0 | 0 | 0 | 0 | 1 | 0 | |
| lnGDP | -4.074 | -4.653 | -3.440 | -7.318* | -7.211* | -7.404* | I(1) |
| Break year | 1979 | 1976 | 1999 | 1977 | 1981 | 1978 | |
| lag length | 0 | 3 | 0 | 0 | 0 | 0 | |
| lnFuel | -4.226 | -3.808 | -2.997 | -9.008* | -8.184* | -8.000* | I(1) |
| Break year | 2001 | 1970 | 2004 | 1982 | 1979 | 1974 | |
| lag length | 1 | 0 | 0 | 0 | 0 | 0 | |
| lnFD | -4.628 | -3.915 | -2.986 | -9.400* | -9.116* | -9.235* | I(1) |
| Break year | 2001 | 2003 | 2003 | 1998 | 2002 | 2002 | |
| lag length | 0 | 0 | 0 | 0 | 0 | 0 | |

*Note*: $CO_2$ is carbon dioxide emissions; GDP is gross domestic product; FUEL is fossil fuel consumption; FD is financial development. All of the series are at their natural logarithms. $ZA_B$ represents the model with a break in both the trend and intercept; $ZA_T$ is the model with a break in the trend; $ZA_I$ is the model with a break in the intercept. * denotes the rejection of the null hypothesis at 1 percent level of significance. Tests for unit roots were carried out in E-VIEWS 8.0.

their level; however, it can be rejected for all the variables at their first differenced form. In other words, the findings reveal that the series is I(1).

Since the variables are integrated at order one, co-integration analysis must be applied to verify the possible equilibrium long-run relationship among variables.

**Co-integration Analysis**

The Johansen co-integration test was undertaken in this study to identify the long-run equilibrium relationship among variables. This test assumes that all variables in the model are integrated at the same order. The findings of the Johansen co-integration test are reported in Table 2. The trace statistics show that there are at most two co-integrating vectors in the proposed model. Given the results, the long-run equilibrium relationship could be proven among the variables.

**Error Correction Model Estimation**

Co-integration results illustrated that variables were co-integrated and they had a long-run equilibrium relationship. Due to this, it is required to determine the long-term coefficients of the proposed model, its ECM (to obtain short-term coefficients) and ECT. The results are provided in Table 3. In Table 3, $\varepsilon_{t-1}$ indicates the ECT and measures the speed of adjustment toward equilibrium.

ECT is negative and significant, meaning the ECM is valid. The coefficient of the ECT; –0.1697%; indicated that $CO_2$ moves toward its long-run equilibrium level with 16.97% speed of adjustment by the contribution of GDP, FUEL and FD. GDP has a short-term coefficient on $CO_2$ at lag 1, which is statistically significant at 0.05. It means that when GDP rose by 1%, $CO_2$ increased by 0.4625 in the short-run. The short-term coefficient of FUEL on $CO_2$ was statistically significant at $\alpha = 0.05$; hence, when FUEL increased by 1%, $CO_2$ decreased by 1.53% in the short run. The short-term coefficient of FD on $CO_2$ at lag 1 was statistically significant at $\alpha = 0.01$, indicating that if there was a 1% increase in FD, $CO_2$ decreased by 0.157% in the short run. Also, the level equation table shows that, while GDP increases by 1%, $CO_2$ reduces by 0.69% in long-term. On the other hand, if the FUEL variable increases by 1% then $CO_2$ increases by 2.82%, while if there is an increase in FD by 1%, $CO_2$ decreases by 0.015%.

**Table 2. Johansen test for co-integration.**

| Hypothesized no. of CE(s) | Eigenvalue | Trace statistics | 5 percent critical value | 1 percent critical value |
|---|---|---|---|---|
| None ** | 0.686810 | 94.29606 | 53.12 | 60.16 |
| At most 1 * | 0.360054 | 36.24886 | 34.91 | 41.07 |
| At most 2 | 0.186041 | 13.93033 | 19.96 | 24.60 |
| At most 3 | 0.070177 | 3.638061 | 9.24 | 12.97 |

*Note*: Trace test indicates 2 co-integrating equation(s) at the 5% level and 1 co-integration vector at the 1%level. *(**) denotes rejection of the hypothesis at the 5%(1%) level.

**Table 3. Error correction model.**

| *Regressor* | *Coefficient* | *Standard error* | *t-Value* |
|---|---|---|---|
| $\varepsilon_{t-1}$ | -0.169797 | 0.06998 | -2.42635 |
| lnGDP(-1) | -0.069772 | 0.17365 | -4.01803 |
| lnFuel(-1) | 2.827275 | 0.97451 | 2.90123 |
| lnFD(-1) | -0.015893 | 0.15570 | -0.10207 |
| Intercept | -0.043997 | 0.02063 | -2.13265 |
| R-squared | 0.597097 | Akaike AIC | -3.755833 |
| Adj. R-squared | 0.244557 | Schwarz SC | -2.881266 |
| S.E. equation | 0.031751 | Akaike info. criterion | -14.04559 |
| F-statistic | 1.693699 | Schwarz info. criterion | -10.38831 |
| Mean dependent | 0.009607 | S.D. dependent | 0.036531 |

*Note*: Lag number is five. Dependent variable: ln$CO_2$ long-run covariance estimate (Barlett Kernel, Newey-West fixed bandwidth = 4,000).

**Granger Causality Tests**

After establishing the long-run equilibrium relationship between series and estimating the long-run and short-run coefficients based on error correction modeling, Granger causality tests should be employed under the VECM. Table 4 illustrates the findings of Granger causality tests based on the Block Exogeneity Wald test. Findings in Table 4 indicate that there is uni-directional causality running from real income and financial development to carbon dioxide emissions (GDP, FD → $CO_2$), and from real income, financial development and carbon dioxide emissions to fossil fuel consumption ($CO_2$, GDP, FD → FUEL).

## CONCLUSION

Industrialization and rapid economic growth, enable improved living conditions, yet increase the demand for energy, most of which has been satisfied by fossil fuel consumption. This ultimately leads to greater $CO_2$ emission, environmental degradation and global warming. Turkey is a fast-developing country with a rapidly growing financial sector. It has been criticized by international organizations for its lack of sufficient environmental regulations. With these concerns in mind, our study augments conventional economic growth-carbon emission models. We studied Turkey's financial development and fuel consumption from 1960 to 2011, refraining from omitted variable bias, to gain a better understanding of the long-run and the causal relationships among the variables under investigation.

The Zivot and Andrews (1992) unit root test indicated that variables were integrated at the same order (I[1]) [25]. The Johansen co-integration test revealed that the variables under investigation are co-integrated in the long-run. ECT suggests that by the contribution of GDP, FUEL, and FD, the short-run values of $CO_2$ moved toward its long-run equilibrium level with a 16.97% adjustment speed. To understand the existence of causality among these variables, a Granger Causality test based on a VECM model was undertaken. According to the results, unidirectional causalities ran from FD and GDP to $CO_2$ and FUEL, and from $CO_2$ to FUEL.

No prior study has investigated the relationships among financial development, $CO_2$ emissions, fossil fuel consumption, and economic growth for Turkey. Our results are only partially comparable with other

**Table 4. Granger causality tests under block exogeneity approach.**

| *Dependent variable* | *$X^2$-Statistics [prob.]* | | | | |
|---|---|---|---|---|---|
| | $\Delta lnCO_2$ | ΔlnGDP | ΔlnFUEL | ΔlnFD | Overall $X^2$-stat [prob.] |
| $\Delta lnCO_2$ | - | 10.36*** [0.065] | 9.19 [0.101] | 17.68* [0.003] | 26.75 [0.0308] |
| ΔlnGDP | 3.16 [0.6745] | - | 4.61[0.464] | 3.61 [0.606] | 15.60 [0.408] |
| ΔlnFUEL | 14.11** [0.014] | 16.32* [0.006] | - | 35.44* [0.000] | 67.21* [0.000] |
| ΔlnFD | 1.31 [0.932] | 2.70 [0.745] | 3.91 [0.561] | - | 7.51 [0.941] |

*Note:* *, ** and *** denote rejection of the hypothesis at 1%, 5% and 10% recpectively.

studies. Some studies focused on the relationship between economic growth and $CO_2$ emissions without considering the impact of financial development. Our results are compatible with some recent studies [see for example 65].* Recently, other studies have considered the impact of financial development on $CO_2$ emissions. Long term causal relationships have been confirmed by these studies as well [see 44,54].

This study has revealed that environmental degradation in Turkey is prompted mainly by financial development, and this result has policy implications. As Turkey prepares to meet EU enrollment criteria, it should see expanded energy effectiveness. EU climate legislation aims to protect the ozone layer and reduce carbon emissions. If Turkey wishes to join the EU, it must increase efforts to comply with these rules. Turkey must pave the way for better financial development and optimize its growth capacity to meet EU standards and eventually accept binding requirements to reduce future $CO_2$ emissions.

There will be many opportunities to improve, and Turkey's cautiousness in protecting the environment will be crucial to its economic and financial development. If natural gas gains prevalence over more carbon-intensive fuels, it will diversify Turkey's energy supply and provide relief from urban contamination and $CO_2$ emissions. By enacting separate taxes to advance the use of cleaner forms of energy, particularly low-sulfur fuel oil, Turkey can achieve lower $CO_2$ emissions. Turkey's government and economy will further benefit from consistent public education about the advantages of energy conservation plus support renewable commercial energy projects.

Turkey's financial regulatory bodies must consider practical ways to channel financial development into environmentally friendly and sustainable systems. Financial institutions should take the initiative in protecting the environment [44]. For example, they can recommend special loans with low interest rates for investments that produce products with lower carbon emissions; such a policy may encourage investors to begin using renewable energy. While renewable energy sources have made extraordinary advances in Turkey's energy market, more innovative work on renewable energies is needed to expand their usage. Although hydroelectric energy is being produced, the broad use of wood fuels in family homes has added considerably to urban air contamination and has also created deforestation issues. Furthermore, Turkey

*For counter findings see references 15 and 53.

needs to increase the price of conventional fuels to market levels, which would broaden and expand the use of other energies for transportation such as electricity-based railways.

Developing nations like Turkey, in their mission for financial advancement and destitution reduction, are required to choose industrialization and monetary development before considering ecological issues. Therefore, convincing developing nations like Turkey to pursue ecological objectives, especially lessening $CO_2$ emissions, requires economic support from developed nations and international organizations to offset the economic losses connected with diminishing pollution. By supporting fundamental ecological norms and prioritizing natural ventures, Turkey can coordinate feasible arrangements into its plans for financial improvement, protecting its environment well into the future.

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