Economic growth, openness, industry and CO_2 modelling: are regulatory policies important in Turkish economies?

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Abstract

As a result of economic growth, demand for energy increases as well as raw materials. The fact that energy sources are mostly fossil fuels has increased interest in causation between growth and environmental pollution. As global warming and climate changes gain importance in recent years, environmental pollution continues to be discussed in the economic literature. As Turkey's economy grows rapidly, its increasing energy needs are often met with fossil fuels because they are cheaper than other options. This study analyzes the availability of the environmental Kuznets curve (EKC) hypothesis, which analyzes an inverse U-shaped relation among carbon dioxide (CO_2) emissions per capita and output for Turkey in the period 1961–2018. The study used the autoregressive distributed lag to demonstrate the short- and long-term relationship between CO_2 emissions per capita, real income per capita, industry and trade openness. The conclusions do confirm that there is a quadratic relation between income and CO_2 emissions, supporting EKC relation in the long term. The results also demonstrate that the CO_2, which is a major component of greenhouse gases, are mainly specified by income in the long term and short term. The contribution of industry to CO_2 is minimal in the long run, while trade openness does not have any effect.

Keywords: EKC; ARDL bound test; CO_2 emissions; Turkey

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1. INTRODUCTION

Energy is an essential input into goods and services and fundamental to economic growth. Economic and technological developments are linked with shifts in sources of energy. The Industrial Revolution in the 18th century used non-renewable resources like coal in massive amounts, which made large impacts on the environment. The 21st century is characterized by major shifts in energy sources from coal to oil and then to natural gas. Up until now, fossil fuels have continued to dominate as our energy resource and intensive industrial usage of fossil fuels caused emissions and environmental pollution. The world needs renewable clean energy like solor power, replacing fossil fuels for decreasing emissions. But the cost of clean energy is too high to be affordable for most emerging and under-developed countries around the world. The goal of the whole world is to achieve economic growth. Therefore, the structure of the relationship between economic growth and environmental quality should be thoroughly examined.

Especially with the increase of industrialization, energy is an important input of production. Global energy demand continues to increase due to the accelerated population growth and global Gross Domestic Product (GDP). Consequently, the rise in energy demand and the rise in the use of fossil fuels in production have led to the amount of greenhouse gases in the atmosphere. Consequently, climate changes and global warming in the world have been a major problem for human life for some time. CO_2, an important component of greenhouse gases, is considered one of the major causes of this problem [16]. Naturally, different climatic conditions such as recently melting glaciers, rising sea level, irregularities in temperature and rainfall are noteworthy.

The work by Dinda [13], a conceptually fundamental study of the environmental Kuznets curve (EKC), provides an overview of the methodological, conceptual and political aspects of the EKC

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literature. According to him, many people became concerned with the deterioration of environmental quality and this led to an effort to better understand the causes of environmental degradation. Therefore, the common point of empirical studies can be expressed in two ways. First, some studies claim that environmental quality worsens in the early stages of economic growth, and in the latter stages there is improvement as economic growth accelerates.

Following the global warming discussion, the United Nations Framework Convention on Climate Change (UNFCCC), the first international agreement to reduce environmental pollution, was adopted at the Rio World Summit in 1992. Thereafter, the Kyoto Protocol in 1997, aimed at reducing CO_2 emissions and greenhouse gases in the atmosphere, was signed by 160 countries. The aim of the countries that have signed this protocol is to reduce the release of CO_2 and five other gases that cause a greenhouse effect. According to the protocol, developed countries with the most industrial activity are liable for the current high greenhouse gas emissions in the atmosphere. Therefore, the protocol placed a heavier burden on developed countries than on developing countries. The Kyoto Protocol is later replaced by the more comprehensive treaty on climate change, the Paris Treaty. The Paris Climate Treaty is an environmental agreement agreed by nearly every country in 2015 to mitigate climate change and its adverse effects. The agreement envisages reducing the pollution of the countries that emit the most greenhouse gases and strengthening their obligations in the agreement over time. Two benefits of the Paris Agreement are intended. One is to assist emerging countries in the efforts of developed countries to adapt climate control. The other is to follow countries' climate goals transparently and to do reporting.

If the agreement is not followed and current trends continue, many people around the world will face the negative consequences of climate change, such as temperature increase, sea level rise, plant and animal extinctions and ocean acidification. Both natural factors and human activities cause climate change. Especially since the beginning of the 20th century, the most important factor in the composition of the atmosphere is human activities. These activities include burning fossil fuels such as petroleum, gas, coal and oil CO_2, from car exhausts, increasing livestock production, nitrogen-containing fertilizers and fluorinated gases and reducing forest and urbanization [18]. The CO_2 emissions generated by human beings account for 64% of all carbon emissions. Despite climate change mitigation agreements, the level of CO_2 emissions is increasing day by day. The density in the atmosphere in recent times is 40% higher than when industrialization began [59]. A few big economies, such as China, the USA and India, account for almost half of the total emissions in the world. According to the 2018 World Environmental Performance Index data [15], China is ranked 120th among 180 countries.

Table 1 shows the top 20 countries emitting the most CO_2 around the world in 2016. In general, developed and large developing countries are the leading sources of total CO_2 emissions as mentioned Kyoto Protocal. Saudi Arabia, with the highest per capita emissions (16.3 T), has relatively low population size. On the other hand, most populated countries with the highest per capita emissions are Australia (16.2 T), the USA (15.0 T) and Canada (14.9 T). We can say that there is a strong relation among income and per head CO_2 emissions. Conversely, China and India are important players in the total emission ranking although they have low CO_2 emission per capita in 2016 because of high population size. The five main emission source sectors include energy-based emissions, industrial action and product usage, agricultural activities, land use, land use change and forestry and waste administration.

Turkey is the 17th biggest economy in the world and the fastest growing Organisation for Economic Co-operation and Development (OECD) economy. With growing economy, population and urbanization, energy demand in Turkey has increased rapidly. Economic growth and high levels of energy consumption, together with a road-dominated transport system, have caused large increases in green house gas (GHG) and air pollutant emissions. The growing energy need is mostly met by fossil fuels, which account for 88% of the energy mix [37]. This causes an increase in the total amount of emissions. Turkey is one of the largest emitter and was liable for emissions of 338.8MT of CO_2 in 2016 as seen in Table 1. The country has experienced the export-oriented industrilazation since 1980. Turkey joined the Kyoto Protocal in 2009 but has not assured any activity before 2020 at the UNFCCC. Although Turkey has not yet ratified the Paris Treaty, it has adopted its nationally designated intended contribution (INDC) in 2015, with an aim to GHG emissions up to 21% below 'business-as-usual' level by 2030. But consistent with an independent analysis based on government predictions, present policies are inadequately sufficient to meet Turkey's INDC and the country has an ongoing investment in increasing coal power production [54].

As the rate of economic growth increases, the energy requirement increases and this leads to an increase in environmental pollution. So what is the effect of environmental pollution on economic growth in the next period? Our motivation in working is that it is important that the environmental conditions that we leave to future generations can also affect their economic well-being. In his study, Kuznets (1955), revealed an inverse U-shaped connection with per head income and income inequality. This view is admitted in the literature as the Kuznets curve and was later used by environmental economists to depict the connection among per head income and environmental corruption. In the literature, Grossman and Kruger [20] have revealed the inverse U relation among environmental corruption and economic growth, known as the EKC hypothesis. According to this hypothesis, environmental damage first rises with income, then stagnates and then decreases. The level of environmental pollution will increase with economic growth, but when per capita income attains a certain level (i.e. inflection point), environmental pollution will increase with economic growth. This nonlinear relationship among the pollution and income levels can be clarified by two factors: scale composition and technical affects [19]. The scale effect is likely to increase pollution with economic growth resulting from expansion into new markets. The compositional

Table 1. *2016 Ranking of the top 20 countries by per capita emissions*

Rank	Country	2016 Total CO_2 emissions from fuel combustion (MT)	2016 Per capita CO_2 emissions from fuel combustion (T)
1	Saudi Arabia	527.2	16.3
2	Australia	392.4	16.2
3	USA	4833.1	15.0
4	Canada	540.8	14.9
5	South Korea	589.2	11.6
6	Russian	1438.6	9.9
7	Japan	1147.1	9.0
8	Germany	731.6	8.9
9	Poland	293.1	7.7
10	South Africa	414.4	7.4
11	Islamic Republic of Iran	563.4	7.1
12	China	9056.8	6.4
13	UK	371.1	5.6
14	Italy	325.7	5.4
15	France	292.9	4.5
16	Turkey	338.8	4.2
17	Mexico	445.5	3.6
18	Brazil	416.7	2.0
19	Indonesia	454.9	1.7
20	India	2076.8	1.6

Source: Union of Concerned Scientists, 2019 [55]. MT, metric megatons; T, metric tons.

effect arises from the liberalization of trade in the economy. The compositional effect affects pollution depending on whether a country has comparative advantage sources and a comparative advantage, especially in pollution-intensive production. Finally, production techniques also affect the pollution–income relationship. An improvement in production techniques can decrease the quantity of pollutant emissions per production.

The paper consists of the following sections: the next section will contain a literature review, where econometric methodologies and data will be presented, and the last section will include political inferences and discussion.

2. LITERATURE REVIEW

Significant growth of the global economy over the past few decades has provided many benefits, such as income growth, technological development and an increase in social welfare. Despite all these benefits, environmental pollution has been one of the world's major problems due to increasing energy needs. In addition to rapid population growth in the world, rapid industrialization increases the need for energy. Economic growth, known as remain in per capita income, increases production. The production increase also increases the demand for energy. But current energy systems are dominated by fossil fuels or non-renewable energy resources (gas, oil and coal) that produce CO_2 and other GHG. These GHGs are the fundemental driver of global and dangerous climate change. Many variables such as economic growth, urbanization, trade, agriculture, transport, industrial structure, financial development, tourism and energy use are linked to the emission of CO_2. Increases in GHG have many short- and long-term negative effects.

The connection of energy use and economic development has been greatly examined in environmental economics by taking into account the threat of GHG emissions. The EKC hypothesis has been widely applied in the literature over the past three decades in the field of energy economics. This hypothesis is known as the inverse relationship between income and environmental degradation, as previously stated. That is, environmental degradation begins to increase first as income rises and then decreases after income exceeds a certain threshold level. In the literature, the validity of this hypothesis has been applied with many econometric approaches and different country concepts. The results of these studies showed different results for reasons such as time period, explanatory variables and methodological adaptation [51]. In studies, researchers have used many different variables in the models in order to eliminate the variable bias. These variables are tourism, financial development, urbanization, foreign trade opening, energy prices, energy consumption, economic globalization and foreign direct investment.

There have been studies in a fairly extensive range of literature with empirical evidence for the EKC. If one looks at the evidence of empirical studies, three types of conclusions about the EKC hypothesis emerge. The first part of the study claims that the hypothesis is inverse U-shaped, the second part of the study rejects this relationship and the last part of the study claims that the relationship is N-shaped. If we have a third-order polynomial and the coefficients continue consecutively in reverse, we are talking about a cubic function or an N-shaped state. Some studies agree with the EKC hypothesis [3, 7, 21, 24, 26, 28–30, 32, 35, 47–49, 51, 58] and several other studies have also yielded two different results. Some supported the hypothesis, while others had mixed results [1, 22, 23, 25, 31, 38, 43, 44, 52, 53, 56, 57]. The validty of the EKC hypothesis for Turkey was tested and found mixed results [2, 21, 38, 56]. There are also studies that find N-shaped relationships [4, 5, 42, 45].

Keho [29] has applied the effect of economic growth and energy consumption on CO_2 emissions for five panels of 59 countries. The results of the study, which was applied in numerous countries such as sub-Saharan, Americas and Europe, ensure evidence supporting the EKC hypothesis for Asian and MENA countries. Sinha and Shahbaz [51] tested the autoregressive distributed lag (ARDL) methodological approach for the EKC hypothesis of CO_2 emissions in India during the era 1971–2015. The findings in the study support the opposite U-shaped result. It also concluded that renewable energy and trade variables have a meaningful negative affect on CO_2 emissions. Yurttagüler and Kutlu [56] investigated the relationship among income and CO_2 emissions by using the data for period 1960–2011 for Turkey. The findings of the study found out that there was a cointegration connection among variables, but it does not support the EKC hypothesis. Another important inference of the results is that the shape of the relationship is N-shaped. Lau et al. [32] empirically focused on EKC hypothesis for Malaysia with foreign direct investment and trade openness variables in the period 1970–2008. They applied the boundary test and the Granger causality approach in order to test the relationships of variables to each other. The results of the study proved that the inverse U-shaped connection exists among economic growth and CO_2 emissions in both short and long-term in Malaysia. Mugableh [35] analyzed the availabilty of the EKC hypothesis for the Malaysian economy in the period 1971–2012, and the ARDL results reveal its long-term existence cointegrated relation among per head gross domestic product and per head CO_2 emissions.

Kasman and Duman [28] demonstrated the causality relation between variables such as CO_2 emissions, trade openness, energy consumption, urbanisation and economic growth for new EU members and applicant countries in the term 1992–2010. Panel unit root test, panel cointegration approach and panel causality testing were used for the relation between variables in the study. The major results offered inferences supportive of the EKC hypothesis. Causality results show that there is short-term, one-way panel causality, from energy consumption, urbanization, trade deficit to CO_2, from GDP to energy consumption, from GDP, energy consumption and urbanisation to trade openness, from urbanization to GDP and from urbanization to trade openness. Long-term causality results are as follows: energy consumption, CO_2 emissions, GDP and lagged trade openness are meaningful and the estimated parameters of error correction term in the equation of these variables play a significant role in CO_2 emission. Jebli et al. [26] conducted the review in the context of a panel data of 25 OECD countries for the causal relationship of CO_2 emissions, per head GDP, renewable and non-renewable energy consumption over the period 1980–2010. They used the econometric approaches of altered Ordinary Least Squares and Dynamic Ordinary Least Squares in long-term analysis. Their results point out that the inverse U-shaped EKC hypothesis has been confirmed. They also demonstrated that rising non-renewable energy consumption rises CO_2 emissions. The interesting result is that increased trade or renewable energy decreases CO_2 emissions. According to these implications, greater use of trade and renewable energy is the most important method in combating global warming in these countries. They point out the ARDL bounds approach to find a long-term connection with the relevant variables in the period 1980–2009. The results show that international trade (exports or imports) and non-renewable energy have a positive effect on CO_2 emissions. Halicioğlu [21] studied the dynamic causality relation among CO_2 emissions, export and import revenue and energy consumption for Turkey in the term 1960–2005. Bound test results confirm a long-term relation between variables.

Halicioglu and Ketenci [22] analyzed environmental quality and international trade links for 15 transition countries. The study estimated energy use, carbon emissions, trade deficit and income variables by means of the ARDL and Generalized Method of Moments approaches. Results from applied econometric techniques show that the EKC hypothesis applies only to three transition countries: Uzbekistan, Turkmenistan and Estonia. The affect of trade on environmental factor results vary in different transition countries. In this context, the displacement hypothesis has been confirmed for Latvia, Armenia, Kyrgyzstan, Estonia and Russia. Al Sayed and Sek [3] analyzed the existence of EKC in two groups of economies, i.e. developed versus emerging economies using the panel data method and different environmental variables. The findings show that the EKC does hold in most cases. CO_2 and SPM10 are good help for environmental variables in EKC analysis. The turning point in developed countries is higher than in emerging countries. Grossman and Kruger [20] analyzed the reduced-form relation between several environmental factors which are urban atmospheric pollution, the state of the fecal contamination of river, oxygen regime in river and contamination of river by heavy metals and per capita income. They failed to present any evidence of deterioration in stability among economic growth and environmental variables. Saboori and Soleymani [43] focused on the dynamic relation for economic growth, CO_2 emissions, foreign trade and energy consumption variables for Indonesia in the term 1971–2007. Findings like the previous study do not promote the EKC hypothesis. Fodha and Zaghdoud [17] focused on the connection with economic growth and pollutant emissions for Tunisia during the period 1961–2004. The analyses investigated whether the EKC hypothesis is valid, employing time series data and cointegration analysis. The variables used in the study are organized in two main groups: environmental factors (CO_2 and SO_2) and economic indicators (GDP). The results suggest the existence of an integrated relationship between these variables in the long run. Furthermore, an inverse U-shaped relationship was found between SO_2 emissions and GDP. Vo et al. [57] used data on economic growth, energy consumption and renewable energy use. The results show that while environmental degradation occurs in Malaysia, Indonesia and Myanmar, it does not occur in Thailand and the Philippines. Another striking result confirms the validity of the EKC in Myamar, but has not been confirmed in Indonesia and Malaysia. Khan et al. [31]

demonstrated the effect of economic factors, globalization and energy consumption on CO_2 emissions in Pakistan for the period 1971–2016 using the ARDL method, which is dynamic data analysis. The findings, trade, globalization, financial development, energy consumption and foreign direct investment have a positive effect on CO_2 emission, while urbanization suggest that CO_2 has a negative impact on innovation and economic growth. Suri and Chapman [53] have proven that exports of manufactured goods in emerging countries are the major determinant of the raised energy consumption that leads to the rapid growth of pollution. On the other hand, developed countries have reduced their energy needs and avoided pollution through the importation of goods produced in industrializing countries.

Iskandar [23] examined the EKC hypothesis on the dynamic relation among CO_2 emission and economic growth in Indonesia with the ARDL model for the years 1981–2016. The results do not prove the existence of the ekc hypothesis. Soytas et al. [52] and Ozturk and Acaravci [38] concluded that there is no inverse U-shaped relationship between income and carbon emissions for the Turkish economy. Shahbaz et al. [48] presents empirical demonstration of the EKC hypothesis for Portugal by applying the ARDL approach during the term 1971–2008. The results of the traditional revenue emission model with variables such as trade openness, urbanization and energy consumption support demonstration of the EKC hypothesis, both in the short and long terms. All variables except the trade opening that has a negative sign show expected signs. Ketenci [30] focused on the relationship among CO_2 and their basis determiner in the Russian Federation for the term 1991–2016. Inferences in the study suggest the existence of the EKC hypothesis. Empirical evidence implies that levels of real income, education, energy consumption and urbanization are important determiner of carbon emissions, but trade openness has no impact in Russia. He and Lin [60] use the panel smooth transitive automatic regression model to determine the effect of income levels on environmental pollution in China in 2003–2017 and the EKC threshold of energy density. The inverse U-shaped circumferential Kuznets curve was approved, and the energy density was 0.7670. The threshold value is compared by comparison to the energy density. If the energy density is higher (lower) than the threshold, the income elasticity of CO_2 emission is positive (negative).

3. RESEARCH METHODOLOGY AND DATA

The main goal of this study is to exhibit the existence of a long-term connection between CO_2 emissions and economic growth using time series and cointegration analysis. On the basis of the EKC hypothesis, it is possible to construct a linear quadratic relation among environmental degradation and economic growth. However, to eliminate the neglected variable bias, we consider the effects of industrial value added and trade opening on CO_2 emissions in Turkey. Annual time series data cover the period 1961–2018. The data series is derived from World Development Indicators (WDI). Table 2 shows the definitions of variables and the data source.

The study identified the following linear logarithmic quadratic functional form for the long-term relationship among carbon emission (CO_2), economic growth (GDP) and the square of GDP (GDPSQ), industry (IND) and trade deficit (deficit) in the context of Turkey. GDPSQ is included in the model to check whether CO_2 emissions decrease after a given point of GDP. By extending the EKC analysis, the model is specified as follows:

$$CO2_t = f\,(GDP_t, GDPSQ_t, IND_t, OPEN_t) \quad (1)$$

In the log-linear form the model is written as follows:

$$lnCO2_t = \beta_0 + \beta_1 lnGDP_t, + \beta_2 GDPSQ_t + \beta_3 IND_t + \beta_4 OPEN_t + \mu_t \quad (2)$$

The EKC hypothesis requires that $\beta_1 > 0$ *and* $\beta_2 < 0$.We expect industry and trade openness to increase pollutants: $\beta_3 > 0$ *and* $\beta_4 > 0$. The expectable sign of the coefficient of trade is mixed depending on a level of a country in economic development phase. This sign can be expected to be negative for developed countries. Because developed countries prefer clean and service-intensive production while importing pollution-intensive products from other countries. On the other hand, in developing countries this sign is positive. This result is likely because it is a net exporter of pollution-intensive goods [20].

Cointegration analyses were put forward by [14, 27, 41]. Pesaran et al. [39, 40] employed the ARDL model. This method has many advantages over other cointegration methods. The base advantage of the ARDL method is that it does not need to determine the order of integration of variables. But this is not the case in the approach of Engle-Granger[14] and Johansen[27]. ARDL can be performed irrespective of whether the variables are stationary in level I(0) and/or in first difference level I(1). The ARDL approach gives strong results both in small samples [39] and allows the optimal delay lengths of variables to vary.. In this study ARDL bounds testing approach is employed to analyze the long-term relation among CO_2 emissions, economic growth, industry and trade opennes.

ARDL framework of Equation (2) of the baseline estimation model is as follows:

$$\begin{aligned}\Delta \ln CO2_t = {} & \alpha_0 + \sum_{k=1}^{n} \alpha_{1k} \Delta \ln CO2_{t-k} + \sum_{k=0}^{n} \alpha_{2k} \Delta \ln GDP_{t-k} \\ & + \sum_{k=0}^{n} \alpha_{3k} \Delta \ln GDPSQ_{t-k} + \sum_{k=0}^{n} \alpha_{4k} \Delta IND_{t-k} \\ & + \sum_{k=0}^{n} \alpha_{5k} \Delta OPEN_{t-k} + \delta_1 \ln CO2_{t-1} + \delta_2 \ln GDP_{t-1} \\ & + \delta_3 \ln GDPSQ_{t-1} + \delta_4 IND_{t-1} + \delta_5 OPEN_{t-1} + \varepsilon_t \end{aligned} \quad (3)$$

Table 2. *Variables for the ARDL model (1961–2018)*

Symbol	Definition and units of measurment	Source
GDP	GDP per capita (constant 2010 US$)	WDI, WB
GDPSQ	GDP per capita square (constant 2010 US$)	WDI, WB
CO_2	CO_2 emissions measured as metric tons per capita	WDI, WB
OPEN	Trade openness ratio (imports and exports of goods and services (% of GDP)	WDI, WB
IND	Industry (including construction), value added (% of GDP)	WDI, WB

In quation (3), Δ is the first difference symbol, α_0 is constant, εt is white noise error term, $\alpha1$–$\alpha5$ are error correction dynamics, and the second parts of the equation from $\delta1$ to $\delta5$ demonstrate the long-term relation among the variables in the model. The null hypothesis of no cointegration or no long-term relation, $H_0 : \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = 0$, tested against its altenative, $H_1 : \delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq \delta_5 \neq 0$. If the calculated F-statistic is greater than the upper bound critical value (UCB), then the zero hypothesis of cointegration is rejected, and if the lower bound is less than the critical value (LCB), the hypothesis is accepted, and if the calculated value stays between these two values, it is inconclusive. At this stage the optimum delay of variables is selected according to the information criterion (AIC).Once a long-term relation among the series has been confirmed, an error correction model (ECM) can be predicted as follows:

$$\Delta \ln CO2_t = \alpha_0 + \sum_{k=1}^{n} \alpha_{1k} \Delta \ln CO2_{t-k} + \sum_{k=0}^{n} \alpha_{2k} \Delta \ln GDP_{t-k} + \sum_{k=0}^{n} \alpha_{3k} \Delta GDPSQ_{t-k} + \sum_{k=0}^{n} \alpha_{4k} \Delta IND_{t-k} + \sum_{k=0}^{n} \alpha_{5k} \Delta OPEN_{t-k} + n_1 ECT_{t-1} + \varepsilon_t \quad (4)$$

The ECT (Error Correction Term) demonstrates the speed of the adjustment. That means how quickly these variables convergence to equilibrium in the long term.

4. EMPIRICAL RESULTS

Our assumptions in the study are as follows:

H1: The relation among economic growth and environmental pollution variables is not linear, the relationship is in the inverse U-shape.

The first hypothesis tests the validness of the EKC hypothesis, which means that the relationship between the relevant variables is in the inverse U-shape. The GDP variable represents the scale of the economic activity. An increase in the scale of economic activity increases economic pollutions. Because during the structual change of economy, the energy intensive industrial sector grows while the share of agriculture declines. That is why the coefficient of GDP is anticipated to have a positive sign. At the higher stage of development, the share of industry begins to fall and non-pollution-intensive service sector rises. And also an increase environmental awarness and regulations pushes the economy toward overall energy intensity. Then the coefficient of GDPSQ is expected to have a negative sign [53].

H2: Trade openness causes higher CO_2 emissions.

Some studies mention that the relation between free trade and pollution is a positive relationship under certain conditions [6, 12]. For example, [12] have shown that the high-income country chooses stronger environmental conservation and specializes in relatively clean products. It has also demonstrated that free trade rises world pollution by isolating the scale, composition and technical affects of international trade on pollution. Some other studies focus on the fact that the effect of commercial liberalization on pollution is partly less than other variables [9, 21, 25, 26, 32, 44, 53]. Suri and Chapman[53] emphasize that the trade and pollution relationship is positive after a certain threshold level. Many studies suggest that trade openness seems to cause higher CO_2 emissions [8, 33, 34, 36, 46, 50]. Managi et al. [34] discovered a positive effect of trade openness on CO_2 emissions for non-OECD countries but trade has been found to be environmentally beneficial in OECD countries. Li et al. [33]have presented some evidence that trade can disrupt environmental factors in both the short and long term. Developing countries, in accordance with Hecksher-Ohlin theory, specialize in natural resource and labor-based production and export. If the country's comparative advantage is pollution-intensive production and environmental regulations are inadequate, environmental pollution can occur. The sign of the trade variable is mixed relying on the level of a country's economic development. This could be negative as developed countries have restrictive environmental protection rules [24] and clean and service intensive production. On the other hand, the expected trade mark could be positive as developing countries become a net exporter of pollution-intensive goods [20]. A positive sign is expected for Turkey.

H3: Manufacturing industries and construction produce more CO_2.

When we look at the emission profile in Turkey, the bulk of SO_2 emissions is produces by power generation (60%), followed far behind by industrial combustion (23%). Also, more than half

Table 3. *Descriptive of statistics of data*

	LNCO2	LNGDP	LNGDPSQ	OPEN	IND
Mean	0.830413	8.805864	77.72027	31.97743	25.90831
Median	0.980851	8.787950	77.22860	33.66098	26.17267
Maximum	1.566530	9.617584	92.49793	60.40272	32.97471
Minimum	-0.483082	8.050313	64.80754	8.333333	16.95279
Std. Dev.	0.543091	0.424426	7.511098	16.25757	4.180061
Skewness	-0.602296	0.189973	0.267258	-0.119359	-0.294974
Kurtosis	2.430339	2.121368	2.150574	1.527208	2.468433
Jarque-Bera	4.290923	2.214521	2.434144	5.379750	1.523956
Probability	0.117014	0.330463	0.296096	0.067889	0.466742
Sum	48.16394	510.7401	4507.776	1854.691	1502.682
Sum Sq. Dev.	16.81202	10.26781	3215.745	15065.59	995.9559
Observations	58	58	58	58	58

Table 4. *Unit root tests*

	ADF test statistic		PP test statistic	
Variable	Constant	Constant and trend	Constant	Constant and trend
lnCO2	−3.507 (0.011)*	−3.46 (0.053)*	−4.02 (0.002)*	−3.546 (0.043)*
lnGDP	0.036 (0.957)	−2.133 (0.516)	0.040 (0.958)	−2.312 (0.420)
lnGDPSQ	0.358 (0.979)	−1.753 (0.714)	0.365 (0.979)	−1.836 (0.673)
OPEN	−0.498 (0.883)	−3.903 (0.018)	−0.925 (0.773)	−2.281 (0.436)
IND	−1.997 (0.287)	−1.788 (0.697)	−1.988 (0.291)	−1.759 (0.711)
ΔlnCO2	-	-	-	-
ΔlnGDP	−7.418 (0.000)*	−7.366 (0.000)*	−7.418 (0.000)	−7.366 (0.000)*
ΔlnGDPSQ	−7.373 (0.000)*	−7.362 (0.000)*	−7.373 (0.000)	−7.362 (0.000)*
ΔOPEN	−6.239 (0.000)*	−4.209 (0.008)*	−6.998 (0.000)	−6.771 (0.000)*
ΔIND	−7.433 (0.000)*	−7.502 (0.000)*	−7.436(0.000)	−7.511 (0.000)*

*5% of significance level. The lag length has been preferred based on the AIC for ADF test and the bandwidth is selected using the Newey–West method for PP test. The maximum number of lags is set to be 10 (Automatic, based on AIC, maxlag = 10).

of NOx emissions come from road transport (16%) and power stations (43%). On the other hand, industrial processes and product use, especially cement factories, are primarily responsible for PM10 (particulate matter) emissions (68%) in Turkey [37]. Cement is involved in every aspect of our lives such as roads, buildings, factories, bridges. Approximately 8% of the world's carbon emissions come from this sector.

First of all, Table 3 shows our explanatory values consisting of values such as mean, minimum–maximum values, median and skewness.

In the boundary test approach [40], we focus on unit root tests of our series in the first phase of our analyses as the series are I(0) and I(1). Unit root test results which are given in Table 4 that the CO_2 variable is I(0), while all other variables are stationary at level I(1). These results therefore confirm the employment of cointegration boundary tests.

The next step after specifying the order of integration of variables is to test whether there is a long-term and cointegration connection among variables. For this, the ARDL boundary test is applied. Therefore, the first step in order to apply this test (ARDL boundary) is to estimate quation 3 stated above. In order get a reliable and consistent results, it is identified an appropriate lag order. ARDL model in which lnCO2 is the dependent variable and lnGDP, lnGDPSQ, IND and OPEN are the independent variables suggests ARDL(1,1,0,0,0) for case 2 (Figure 1). Then the calculated F-statistics is compared against the upper bounds I(1) (UCB) and lower bounds I(0) (LCB) critical values supplied by [40].

The ARDL outcomes are summarized in Table 5. *F*-test indicates that there is cointegration relation among variables as shown in Table 5, Panel A. The F-bounds test statistics demonstrates that in the chosen lag lengths the computed F-statistics (9.766) is bigger than the upper bound critical value of 3.49 at the 5% significance level and support cointegration.

The long-run results of ARDL model are given in Table 5, Panel B. Interpretation of elasticity coefficients is also possible because the model is in log-linear shape. The long-term elasticity of CO_2 emissions in terms of income is 11.77. The coefficients of lnGDP and lnGDPSQ in the long-term cointegration equation are statistically meaningful at 5% level. Because $\delta_2 > 0$ *and* $\delta_3 < 0$, there is an inverted U-sahape relation between per capita CO_2 emissions and per capita real GDP for Turkey. That is, the level of environmental pollution initially rises with income, until it arrives its stabilization point, then decreases. Trade openness affects the CO_2 emissions positively in the long run, but it is statistically insignificant. The elasticity of CO_2 emissions with respect to industry ratio in the long run is 0.006 and statistically significant offering the contribution of industry to CO_2 is minimal during

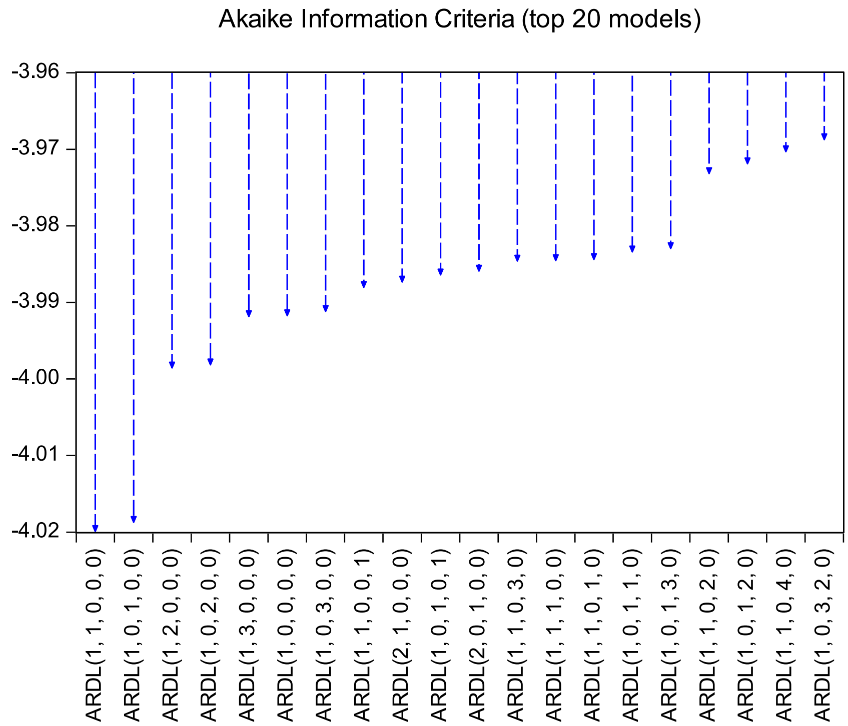

Figure 1. *Optimal model selection.*

the prediction period. A 1% rise in industrial value added raise CO_2 emissions by 0.006%.

The short-term coefficients of the model are reported in Table 5, Panel C. A 1% increase in real GDP per capita raises CO_2 emissions by 7.79% at the 5% level in the short term. The short-run coefficient of real GDP per capita is smaller than the corresponding long-run coefficient. In addition to this, because nonlinear terms of real GDP per capita are not calculated in the short term, one cannot say that the EKC is supported in the short term. The error correction term (ECT) demonstrates the speed of the adjustment. This indicates the speed at which variables return to equilibrium over the long term. Since the coefficient of ECT $(-1) = -0.64$ has a negative sign and is statistically significant at 5% significance level, this reconfirms a powerful cointegration among the variables in the long term. It also shows that deviations from the long-term equilibrium level of CO_2 are adjusted by 64% within the first year and that it takes about 1.5 periods to return to the long-term equilibrium level.

The diagnostic test results of the ECM are given in Table 5 below. Diagnostic test statistics do not indicate that any serial correlations exist and heteroskedasticity problems. The predicted model also managed diagnostic tests of normality and functional form. The diagnostic test implies that the estimated models are stable over the sample period. The high R2 is indicative of the good explanatory power of the model. So as to control the stability of the coefficients CUSUM and CUSUM of squares are also employed. Figures 2 and 3 show CUSUM and CUSUM of squares, respectively. As shown in the figure below, residual values are located between two straight lines bounded by the level of significance of 5%. If the limits of the 5% level are exceeded at any point, the null hypothesis of steady parameters is declined. The fact that the graphs of both statistics are inside critical limits means that all coefficients in the ECM are stable.

The results of the study are accordant with the results of many studies in the literature [3, 21, 26, 28, 32, 51, 56]. Ketenci [30] expressed that environmental degradation occurs due to economic growth.

5. CONCLUSION

There have been many important studies examining the relationships between production and environmental pollution variables, especially in the development and energy economics literature. Economic growth is a phenomenon closely connected to energy consumption through an increase in per capita income. Energy is one of the major important factor inputs for production. Fossil fuels are still the cheapest and most reliable sources of energy for developing countries due to the high cost of renewable energy sources. That is, the developing countries cannot fight climate change as their economies grow. Balancing the challenge between development and environment is an important problem for the developing countries. The wealthy nations should reduce emissions and use more renewable energy, otherwise, if this is not done, the whole world will have to endure the harms of climate change risks. Global warming comes across as a 'threat multiplier' as it increases the likelihood of other current threats such as extensive drought, rising poverty, hunger, wars and the

Table 5. *ARDL results for cointegration*

Panel A: F-bound test				
Selected model: ARDL (1, 1, 0, 0, 0) selecte on the basis of AIC. Case 2: Restricted constant and no trend	F-bounds test statistics	Significance	I(0)	I(1)
	9.766	%5	2.56	3.49
		%1	3.29	4.37
Panel B: ARDL coefficients for the long run Dependent variable: LnCO2				
Variable	Coefficient	Std. Error	t-statistic	Prob.
lnGDP	11.77607	1.008195	11.68035	0.0000
lnGDPSQ	−0.603176	0.055315	−10.90441	0.0000
IND	0.006007	0.002688	2.234254	0.0300
OPEN	0.001783	0.001182	1.508107	0.1378
C	−56.18690	4.536791	−12.38472	0.0000
EC = LNCO2 - (11.7761*LNGDP -0.6032*LNGDP3 + 0.0060*IND + 0.0018*OPEN -56.1869)				
Panel C: ARDL error correction model				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(lnGDP)	7.798187	0.855748	9.112711	0.0000
ECT(−1)*	−0.648833	0.080815	−8.028581	0.0000
**P*-value incompatible with t-bound distribution				
Panel D: Diagnostic test statistics				
			Test statistics	Prob.
R-squared: 0.66				
Durbin–Watson stat: 1.92				
Heteroskedasticity test: Breusch–Pagan–Godfrey			Obs*R-squared = 7.513	Pr. (6) = 0.276
Heteroskedasticity test: ARCH			Obs*R-squared = 2.011	Pr. (1) = 0.156
Breusch–Godfrey serial correlation LM test			Obs*R-squared = 0.001	Pr. (1) = 0.969
Jarque–Bera normality test			0.516	Pr. = 0.772
Ramsey RESET test			F-test = 0.793	Pr. = 0.377

global crisis Davey [62]. Therefore, developed countries should assist developing countries in their efforts to adapt climate control as reported in the Paris Agreement. Today, the world needs an important and concerted dialogue on energy resources toward a sustainable future, avoiding dangerous climate changes. Therefore, balancing the challenge between development and the environment is required for all nations. The COVID-19 pandemic crisis we have experienced today makes it clear as to why such a consensus is necessary.

This paper examinated the long term and causality relation among economic growth and CO_2 emissions based upon the EKC hypothesis for Turkey during the term 1961–2018. Cointegration analysis was performed by employing the ARDL method. The study's long-term results demonstrate that income is the most ismportant variable in explaining CO_2 emissions in Turkey followed by industry. While there is a quadratic connection with income and CO_2 emissions in the long term, there is no such relationship in the short term. These results are in line with the findings of the following: Jalil and Mahmud [24] for China; Al Sayed and Sek [3] for developed and emerging economies; Mugableh [35], Shahbaz et al. [47] and Lau et al. [32] for Malaysia; Apergis and Ozturk [7] for Asian countries; Shahbaz et al. [48] for Portugal; Shahbaz et al. [49] for selected African countries; Kasman and Duman [28] for new EU members; Jebli et al. [26] for 25 OECD countries; Keho [29] for the 5 panels of 59 countries; Ketenci [30] for Russia; and Sinha and Shahbaz [51] for India. However, the findings contradict the results of Fodha and Zaghdaud [17] for Tunisia, Iskandar [23] for Indonesia, Soytas et al. [52] for the USA and Ozturk and Acaravcı [38] for the Turkey. The trade deficit is statistically insignificant, although it positively affects CO_2 emissions in the long term. In the long term, the flexibility of CO_2 emissions relative to the industrial rate has a fairly small effect with 0.006. The stability of the variables in forecasted model proposes that the estimated model is steady over the study period.

The results of this study and many previous studies suggest that in the long run the main (statistical) cause of CO_2 emissions in the world is income growth. Increasing population and use of technology increases production and energy demand which is mostly met by fossil fuels that create environmental pollution in the world. That is why it is not easy to accept a reduction in income levels to reduce emissions. On the other hand, environmental pollution has an important effect on global warming which raises the sea level, brings drought, increases hurricanes,

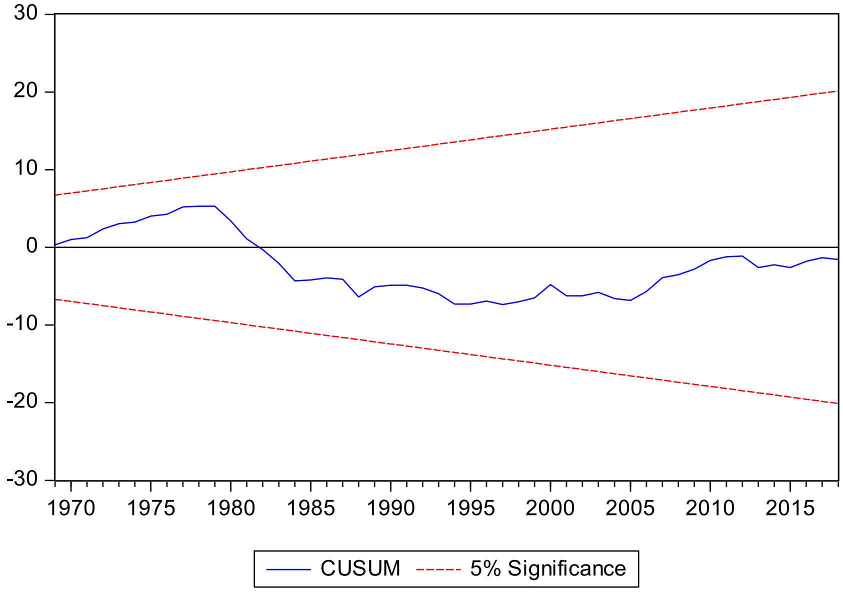

Figure 2. *CUSUM.*

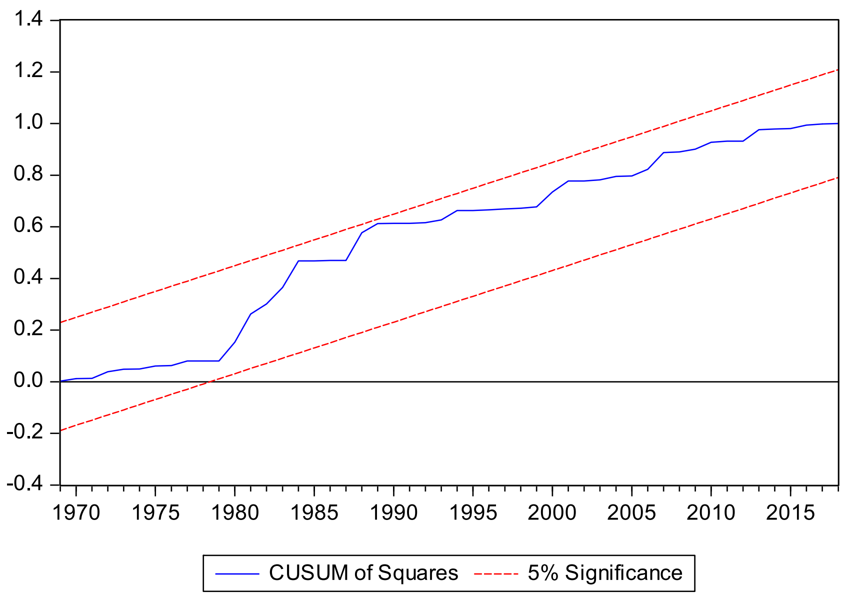

Figure 3. *CUSUM of squares.*

tornadoes and floods and causes the spread of diseases. Given the fact that there is a positive relationship between production and energy, countries should turn to cleaner energy sources (wind, solar, natural gas) instead of fossil fuels. Otherwise, epidemics, health expenditures and food and water shortages will start to become the most important problems of the world. Cole et al. [10] have found a correlation between the level of air pollution and the number of COVID-19 cases in the Netherlands. Conticini et al. [11] also conclude that the atmospheric pollution in Northern Italy should be considered an additional co-factor of the high level of lethality. Indeed, future study could investigate the causality and cointegration relationship among air pollution, economic growth, the number of COVID-19 cases, healthcare costs and urban population.

The Turkish government should develop alternative renewable energy sources to reduce environmental degradation while ensuring economic development. Although Turkey has made progress on the problem of waste, increasing the population and economic growth puts pressure on this issue [37]. The growth of Turkey's energy demand is among the highest in the OECD and fossil fuels represent 88% of the energy mix. According to Turkey's 2014 National Renewable Energy Action Plan, it aims to have at least 20% of renewable energy sources for overall energy consumption by 2023. Turkish government also wants to increase natural gas and nuclear energy capacity and promote energy effiency. Turkey has important wind, water, geothermal and solar resources.

Therefore, Turkish political authorities should increase the investments in these sources to investigate the potential of renewable energy, to achieve sustainable economic growth and to reduce emissions. On the other hand, it is very important that Turkey focuses and invests on public transportation system rather than a road-dominated transport system. However, it is necessary for all countries to make efforts for clean energy investments and even to create a global fund for this because the problem is global.

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