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The Relationship Between Renewable Energy, Agriculture And Carbon Emissions: The Case of Turkey

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Abstract

In this study, the relationship between renewable energy consumption, agriculture, and carbon emissions (CO2) is investigated. Time series boundaries cover the period 1990-2019 for Turkey. Economic growth and urbanization were added to the model as explanatory variables. The prediction model has been tested by the ARDL boundary value test and the direction of the variables is determined by the Granger(1969) causality test. The findings show that the variables are cointegrated in the long term and that while renewable energy consumption reduces carbon emissions, the agricultural sector increases carbon emissions. According to another finding, economic growth and urbanization variables have a positive effect on carbon emissions. Finally, a one-way relationship between the agricultural sector and economic growth to carbon emission has been identified. On the other hand, a one-way causality has been found between renewable energy consumption in the agricultural sector and urbanization. In addition, it has been found that there is a bidirectional causality between urbanization and urbanization and between economic growth and urbanization. These results show that renewable energy consumption, the agriculture sector, and carbon emissions interact in Turkey.

Keywords: *Renewable Energy; Agriculture; Carbon Emissions; Turkey*

Introduction

Globalization has brought about climate change as a pressing issue that has captured the attention of academics, politicians, governments, and civil society organizations. Climate change not only leads to economic problems but also poses various challenges in society, technology, environmental quality, human psychology, global warming, and ecological imbalance. The increase in greenhouse gas emissions is a fundamental cause of these issues. Consequently, the reduction of greenhouse gases has become a key agenda for global societies (Liu et al., 2017).

The Kyoto Protocol has played a significant role in the struggle to reduce greenhouse gases, with a focus on carbon dioxide (Zhang and Da, 2015). According to Heede (2010), 80% of global carbon emissions stem from urban human activities. It is well-known that human activities, such as burning fuel during transportation and electricity generation, release a substantial amount of carbon dioxide into the environment. Additionally, the increasing construction activities and other industrial operations, parallel to population growth, are acknowledged to contribute significantly to the carbon emission problem. Therefore,

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international researchers have extensively focused on carbon emissions. Planning and seeking methods to reduce carbon emissions continue, and monitoring carbon emissions in different regions is considered a crucial roadmap for guiding environmental strategies, policies, and initiatives aimed at decreasing carbon emissions (Beydeera, 2019).

The increasing interest in the significant changes occurring in global climate change has become a profound research topic at the country level. When viewed at the sectoral level, although the industrial sector stands out in terms of greenhouse gas emissions, it has been emphasized that the agricultural sector has an augmenting effect on carbon emissions (Xu and Lin, 2017). Nearly two-thirds of the growing global population makes their living in the agricultural sector, with the majority of this population residing in the Asia region (FAO, 2017). Therefore, the agricultural sector holds dominance in the region and plays a crucial role, especially in developing countries. Concerns on a global scale, such as water pollution, biodiversity loss, resource depletion, and deforestation, underscore the necessity for increased investment in agriculture (Aydoğan and Vardar, 2017: 336).

In recent years, research studies based on agriculture have gained popularity. Like other sectors, the agricultural sector is crucial for sustainable development and the continuity of life. The sector utilizes non-renewable energy sources such as fossil fuels, electricity, coal, and natural gas for operating machinery and equipment, heating and cooling buildings, and producing fertilizers, machinery, and chemicals for farm lighting. These activities contribute to the emission of greenhouse gases from agriculture. Given the growing concerns about environmental consequences and the potential of the agricultural sector to increase greenhouse gas emissions, the use of renewable energy sources does not emerge prominently as a factor in world energy consumption (Reynolds and Wenzlau, 2012). The utilization of renewable energy sources is crucial for increasing and improving agricultural production capacity, ensuring sustainable growth in developing countries (Li et al., 2016).

Countries, regardless of their levels of development, consistently require the agricultural sector for the sustainability of social life and economic structure. The agricultural sector is a fundamental component of the Turkish economy, playing a significant role in global agricultural rankings, with Turkey maintaining its leadership in the production of dried figs, hazelnuts, seedless raisins, and dried apricots. Approximately 20% of the workforce in Turkey is employed in the agriculture and food sector. Agriculture, contributing significantly to the Turkish economy, has positioned Turkey as a major agricultural product exporter in the region due to its high financial contribution (Okumuş, 2020: 22). As Turkey's economy grows and its population increases, so does its energy demand. Most of this energy demand is met from fossil resources (Kapçak, 2023). The spread of fossil resources increases the concentration of greenhouse gases, and the increase in greenhouse gases leads to the greenhouse effect and reduces the carbon storage capacity of the world. Therefore, this situation disrupts the natural balance of the atmosphere. Obtaining a large portion of the energy needed from alternative energy sources such as renewable energy sources instead of fossil fuels will make significant contributions to minimizing, if not completely eliminating, the negative effects of carbon emissions (Demir et al., 2023).

According to OECD (2020) data, greenhouse gas emissions in Turkey decreased by 8% between 2005 and 2016. However, the decrease in carbon emissions is occurring more slowly compared to other OECD countries, and Turkey stands as the country with the highest greenhouse gas emissions among OECD nations. The increasing sensitivity to environmental conditions has led to a positive (reducing) impact on climate change through the growing interest and investments in renewable energy sources (OECD, 2020). Rodolfo Lacy, the OECD Environmental Director, stated, "Turkey has made a good start in transitioning to cleaner energy. However, it needs to accelerate its efforts and invest more in geothermal, solar, wind, and biomass energy" (OECD, 2020). Table 1 presents sector-specific carbon emission data in Turkey.

Table 1. Total Greenhouse Gas Emissions (CO_2 Equivalent) By Sectors in Turkey

Year	Total	Energy	Industrial Processes and Product Use	Agriculture	Waste
2000	**298,8**	216,1	26,2	42,1	14,3
2001	**280,3**	199,2	25,9	39,7	15,5
2002	**286,0**	205,8	26,9	37,4	15,9
2003	**305,3**	220,3	28,2	40,5	16,2
2004	**314,7**	226,1	30,8	41,1	16,6
2005	**337,1**	244,0	33,6	42,2	17,3
2006	**358,3**	260,0	36,7	43,6	18,0
2007	**391,4**	290,8	39,2	43,2	18,3
2008	**387,6**	287,3	40,9	41,0	18,4
2009	**395,6**	292,5	**42,5**	**41,8**	18,8
2010	**398,9**	287,0	48,1	44,1	19,5
2011	**427,8**	308,7	52,8	46,6	19,8
2012	**447,3**	320,5	55,1	52,3	19,4
2013	**439,3**	307,5	58,1	55,5	18,2
2014	**458,4**	325,8	58,6	55,9	18,2
2015	**472,6**	340,9	57,1	55,8	18,8
2016	**497,7**	359,7	61,1	58,5	18,4
2017	**523,8**	379,9	63,6	62,8	17,4
2018	**520,9**	373,1	65,2	64,9	17,8
2019	**506,1**	364,4	56,0	47,7	17,2

Source: TURKSTAT, (2019) Total greenhouse gas emissions (CO_2 equivalent) by sectors, Access date: 25.02.2023

Table 1 illustrates sectoral total greenhouse gas emissions for Turkey, covering the period from 2000 to 2019. As seen in the table, the energy sector is the largest contributor to greenhouse gas emissions. Additionally, industrial processes and product use, as well as the agriculture sector, follow the energy sector as a significant sector producing greenhouse gas emissions. However, until 2009, the agricultural sector's emissions exceeded those of industrial processes and product use. After 2009, it was observed that the greenhouse gas emissions from industrial processes and product use surpassed those of the agricultural sector. Moreover, greenhouse gas emissions decreased with the contraction of production, except during crisis periods (2001, 2008). The transition from 2018 to 2019 reveals a noticeable decrease in greenhouse gas emissions across all sectors. While there are various reasons for this decline, it suggests a reduction in production and signals a significant crisis.

In recent years, researchers and various government officials worldwide have placed increased emphasis on carbon emission reporting and the determination of climate mitigation strategies, resulting in a significant surge in relevant research publications and studies. This study, which focuses on the example of Turkey, aims to fill a gap in the literature through a scientific and quantitative investigation by examining studies on global carbon emissions. The study incorporates several variables, with greenhouse gas emissions (CO_2) chosen as the dependent variable. The main independent variables are renewable energy consumption and the agriculture sector, while urbanization and economic growth are used as control variables. Within this framework, the study aims to enrich the environmental literature by analyzing the relationship between renewable energy consumption, agriculture, and CO_2. Lastly, the study's stages include a literature review, data and methods, findings, and conclusions. This work is intended to contribute to the environmental literature by exploring the relationship between renewable energy consumption, agriculture, and CO_2, and it follows the typical stages of a research study.

This study investigated the relationship between renewable energy consumption (REN), agriculture (AGR), and CO_2, which constitutes the focal point of the research. However, there is generally no consensus among the variables used. Authors such as Rafiq et al. (2015), Eyuboglu and Uzar (2020), Alam et al.(2023), Jebli and Youssef (2017b) and Waheed et al. (2018), Ngarava et al. (2019), Okumuş (2020), Dalli and Kütükçü (2023), Qiao et al. (2019), and Aydoğan and Vardar (2020) have conducted similar studies to this one. However, the findings obtained in this study differ (see Table 2). This indicates a lack of consensus on the subject.

Table 2. Literature Summary

Author	Region	Period	AGR-CO_2	REN-CO_2
Rafiq et al. (2016)	Low, middle, and high-income countries	1980–2010	(−)	(−)
Jebli and Youssef (2017a)	Tunisi	1980–2011	(+)	(−)
Liu et al. (2019)	ASEAN-4	1970–2013	(−)	(−)
Jebli and Youssef (2017b)	5 North African country	1980–2011	(−)	(+)
Rafiq et al. (2015)	53 country	1980-2010	(−)	-
Waheed et al. (2018)	Pakistan	1990–2014	(+)	(−)
Ngarava et al. (2019)	South Afica	1990-2013	(+)	-
Qiao et al. (2019)	G20	1990–2014	(+)	(−)
Eyüpoğlu and Uzar (2020)	Lucky 7 country	1995-2014	(+)	(−)
Aydoğan and Vardar (2020)	E7	1990–2014	(+)	(−)
Koondhar et al. (2021)	Chine	1998-2018	-	(−)
Naseem and Ji (2021)	SAARC region	2000-2017	-	(−)
Okumuş (2020)	Turkey	1968-2014	(+)	(−)
Dalli and Kütükçü (2023)	Turkey	1974-2019	(+)	(−)
Alam et al.(2023)	India	1990-2018	(+)	(−)

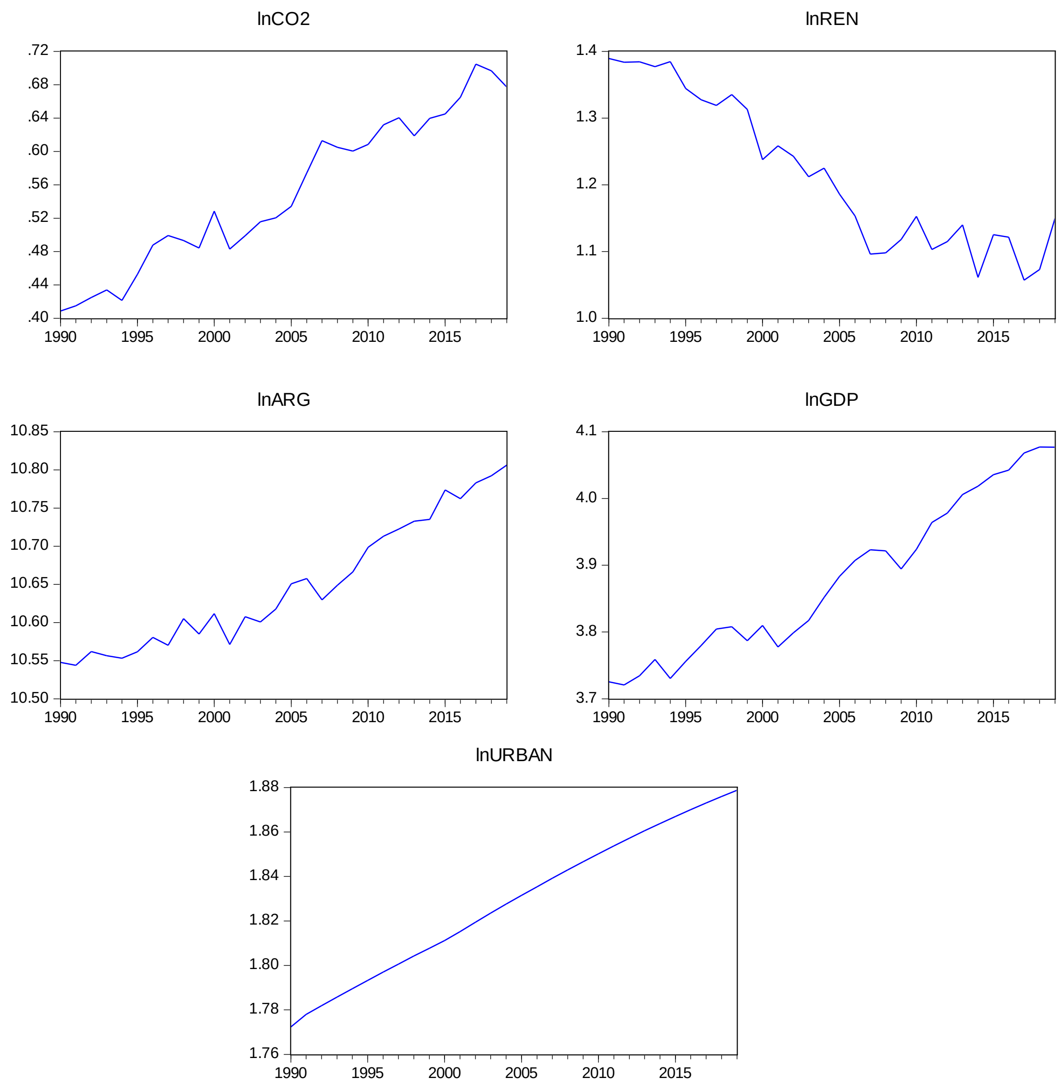
1. Data Set and Model

The focus of this study conducted in Turkey is to investigate the impact of renewable energy consumption (REN) on per capita carbon emissions (CO_2) in the agricultural sector (AGR). Simultaneously, the control variables are urbanization (URBAN) and economic growth (GDP). Additionally, the logarithms of the variables have been included in the model. The predicted model equation is shown in Equation 1. Equation 1 has been prepared taking inspiration from previous studies by authors such as Koondhar et al. (2021), Jebli and Youssef (2017b), Aydoğan and Vardar (2020), and Qiao et al. (2019).

$$\text{ln}= \beta_0 + \beta_1 lnREN + \beta_2 lnAGR + \beta_3 lnURB + \beta_4 lnGDP + u_t \quad 1$$

The study covers the period from 1990 to 2019. Moreover, the variables of renewable energy consumption (as a percentage of total energy), agricultural sector (per capita value added, in US dollars), carbon emissions (per capita metric tons), urbanization (percentage of total population), and economic growth (per capita US dollars, 2015) were obtained from the World Bank database. Finally, it is expected in the study that renewable energy consumption will reduce greenhouse gas emissions, while the agricultural sector will increase greenhouse gas emissions. Figure 1 illustrates the trends over time for renewable energy consumption (lnREN), the agricultural sector (lnARG), carbon emissions ($lnCO_2$), urbanization (lnURBAN), and economic growth (lnGDP).

Figure 1. The Course of Variables Over Time (1990-2019).



Descriptive statistics and matrix data for the variables to be used in the study are shown in Table 3.

Table 3. Descriptive and Matrix Values of Variables

Test	$lnCO_2$	lnREN	lnAGR	lnGDP	lnURBAN
Average	0.505	1.216	10.648	3.899	1.878
Median	0.531	1.198	10.623	3.868	1.879
Std.Deflection	0.091	0.113	0.083	0.117	0.032
Minimum	0.704	1.389	10.806	4.076	1.878
Maximum	0.408	1.056	10.543	3.720	1.772
Distortion	0.029	0.253	0.481	0.313	-0.080
Kurtosis	1.734	1.595	1.883	1.753	1.754
	$lnCO_2$	lnREN	lnAGR	lnGDP	lnURBAN
$lnCO_2$	1				
lnREN	-0.948	1			
lnAGR	0.954	-0.859	1		
lnGDP	0.978	-0.904	0.984	1	
lnURBAN	0.979	-0.946	0.960	0.974	1

1.1. Unit Root Tests

Before conducting a cointegration analysis, it is necessary to test whether unit roots exist in the variables. There are various types of unit roots in the literature related to carbon emissions, energy economics, and other different topics. Non-stationary variables imply that the mean and variance of time series are unstable over time and that their autocovariance changes over time (Perron, 1989: 1363). In simpler terms, if the conditional probability distributions of stochastic processes change over time, these variables are called non-stationary variables (İşleyen et al., 2017). The problem of non-stationarity of variables is often encountered when working with time series. When the relationship between variables is estimated in a model with a non-stationary data set, a statistically significant relationship between variables that does not exist in reality may be observed. Therefore, stationarity is very important in time series (Demir and Görür, 2020). However, in the ARDL approach, the series are not necessarily subjected to stationarity tests, but only unit root tests are applied as a precaution against the possibility of stationary behavior in the second difference. In the current study, the most commonly used traditional ADF, PP, and KPSS unit root tests have been employed.

1.2. Cointegration and Method

Cointegration tests, which are widely used in economics and form the basis of time series analysis, aim to reveal possible relationships between time series. Developed by Granger (1981) and Engle and Granger (1987), cointegration has an important weight among econometric models, which has not lost its validity today (Demir, 2021b). In this study, the lagged autoregressive distributed frontier test (ARDL) introduced by Pesaran et al. (2001) is used to test the cointegration relationship between renewable energy consumption, agriculture and carbon emissions. In addition, it has some alternative advantages, unlike the traditional cointegration tests used in previous empirical studies (Engle and Granger (1987); Johansen (1988, 1995); Johansen and

Juselius, 1990). The first advantage of the ARDL bounds test is that it can be used in the model regardless of whether the variables are stationary at both level 1(0) and first difference 1(1) (Pesaran et al., 2001: 290; Demir, 2021a: 184). In addition, since the bound test does not depend on the preliminary test of the order of integration of the variables, it eliminates ambiguity with the variables. The second advantage is that it makes long and short-term predictions about variables. The third advantage is that it provides more reliable results even when the number of observations is less (Odhiambo, 2009). The ARDL analysis equation is shown in Equation 2.

$$\Delta lnCO_{2t} = \alpha_0 + \sum_{i=1}^{q} \alpha_{1i}\, \Delta lnCO_{2t-i} + \sum_{i=0}^{q} \alpha_{2i}\, \Delta lnREN_{t-i} + \sum_{i=0}^{q} \alpha_{3i}\, \Delta lnAGR_{t-i} + \sum_{i=0}^{q} \alpha_{4i}\, \Delta lnURBAN_{t-i} + \sum_{i=0}^{q} \alpha_{5i}\, \Delta lnGDP_{t-i} + \beta_5 lnCO_{2t-1} + \beta_6 lnREN_{t-1} + \beta_7 lnAGR_{t-1} + \beta_8 lnURBAN_{t-1} + \beta_9 lnGDP_{t-1} + \varepsilon_t \quad (2)$$

For analysis, cointegration between variables must occur. H0 = β_5= 〖β〗_6 = 〖β〗_7 = 〖β〗_8 = 〖β〗_9 = 0 (there is no cointegration) hypothesis H1 ≠ β_5≠β_6 ≠ 〖β〗_7 ≠ β_8 ≠ β_9≠ 0 (there is cointegration) It is analyzed in comparison with the hypothesis. Verification of a long-term relationship between variables is tested with the F and Walt test. If the F statistic value is greater than the upper critical value (F-stat>I(1)critical), H0 is rejected, indicating that cointegration exists. However, if the F statistic value test is lower than the lower critical value (F-stat<I(0)critical), the H1 hypothesis is rejected and indicates that there is no cointegration between the variables. However, if the F statistic value is between the upper limit and the lower limit (I(0)critical<F-stat<I(1)critical), it shows that uncertainty occurs (Pesaran et al. 2001; Özen et al., 2023: 363). After the long-term relationships of the variables were determined, the causality test developed by Granger in 1969 was used to determine the direction (Ahmad et al. 2016:32).

2. Empirical Findings

ADF, PP, and KPSS unit root test results of the variables within the scope of the current study examining the relationship between renewable energy consumption, agriculture, and carbon emissions (CO_2) in the Turkish economy are presented in Table 4.

Table 4. ADF, PP, and KPSS Unit Root Test Results

Variables	**Level**		**First difference (1st)**	
Increased Dickey-Fuller	**Constant**	**Constant-trend**	**Constant**	**Constant-trend**
$lnCO_2$	-0.831	-3.422	-5.802***	-5.938***
lnREN	-1.462	-1.952	-5.755***	-6.454***
lnAGR	1.149	-1.535	-9.285***	-9.967***
lnGDP	0.231	-1.503	-5.451***	-5.383***
lnURBAN	-2.314	2.449	-5.927***	-9.930***
Phillips-Perron				
$lnCO_2$	-0.728	-2.283	-8.394***	-8.050***
lnREN	-1.452	-1.853	-5.446***	-6.401***
lnAGR	1.609	-2.637	-9.407***	26.960***
lnGDP	0.896	-1.517	-6.067***	-6.748***
lnURBAN	-3.123	-2.852	-5.261***	-5.981***
Kwiatkowski-Phillip-Schmidt-Shin				
$lnCO_2$	0.702***	0.740***	0.248	0.214
lnREN	0.669**	0.226**	0.142	0.118
lnAGR	0.688***	0.548***	0.500	0.220
lnGDP	0.695***	0.163**	0.200	0.124
lnURBAN	0.713***	0.253*	0.534	0.107

***, **,* represent levels of 1%, 5%, and 10% respectively.

It can be seen in Table 4 that the variables contain unit root tests and are not stationary, but become stationary when their first differences are taken. The long-term relationship of the variables was analyzed with the ARDL bounds test. However, before starting the boundary test, the appropriate crossover length must be determined for the operation of the model. The delay length is determined by the Var model and Final Prediction Error (FPE), Akaike (AIC), Schwarz (SC), and Hanna-Quinn (HQ) information criteria. The appropriate lag length of the variables used in the model for the period 1990-2019 was determined as 4 according to the Akaike (AIC) information criterion.

In this study examining the Turkish sample, cointegration, long-term coefficients, and diagnostic tests of the ARDL bound test are given in Table 5. The results show that the variables are cointegrated in the long run since the variables are significant at 1%, 5%, and 10% critical value and the F statistic value (7.67664) is higher than the upper critical value of 1(1).

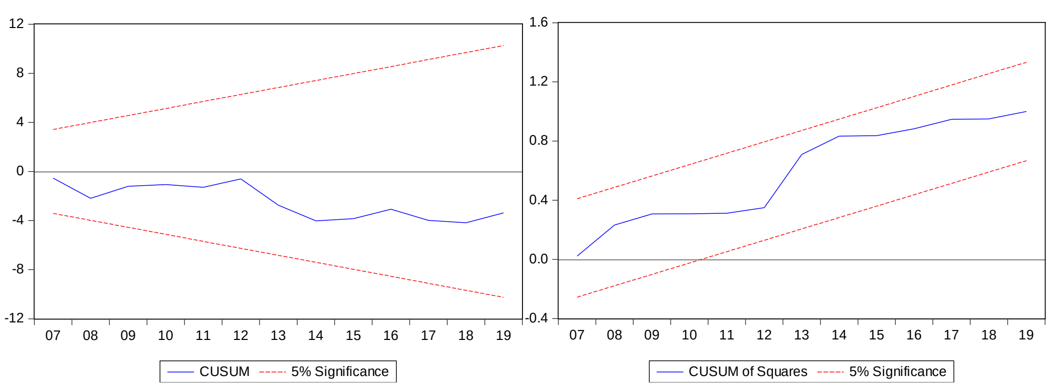
Table 5. ARDL Limit Test Results

Appropriate Delay Length ARDL Model (4,2,3,3,3)							
Cointegration Test Result	**F stat.** Critical Value						
	7.67664	**%10**		**%5**		**%1**	
		I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
		2.45	3.52	2.86	4.01	3.74	5.06
Long-Term Coefficients	**Variable**	**Coefficient**		**St.eror**	**t stat.**	**Possibiliy**	
	lnREN	-0.475051		0.06781	-7.00495	0.0004	
	lnAGR	0.023951		0.19827	0.12079	0.0078	
	lnGDP	0.347712		0.13480	-2.57936	0.0418	
	LnURBAN	1.587516		0.55760	2.84703	0.0293	
Diagnostic Tests	**Statistical Test**				**Possibility**		
	Jarque—Bera normality test				0.932		
	Breusch-Godfrey Autocorrelation test				0.296		
	Breusch-Pagan-Godfrey Heteroscedasticity test				0.852		
	Ramsey Reset test				0.265		

In Table 5, which shows the long-term coefficients, the main independent variables, renewable energy consumption, and the agricultural sector, were found to be significant in explaining the dependent variable, carbon emissions (CO_2). Additionally, other control variables were also found to be significant. While a 1% increase in renewable energy consumption reduces carbon emissions by 0.475, a 1% increase in the agricultural sector, economic growth, and urbanization variables increase carbon emissions (CO_2) by 0.02, 0.34, and 1.58, respectively. In line with the results obtained, the results meet the theoretical expectations. On the other hand, in the long term, Turkey needs to increase its renewable energy consumption and invest in clean energy technologies. The use of clean energy will contribute to the creation of a cleaner and healthier ecological environment. This situation may have a positive impact on Turkey's economic performance in the long term.

As a result diagnostic tests, it shows that while the variables are normally distributed, there is no problem with autocorrelation and heteroskedasticity. Ramsey-Reset statistical value shows that the model is established appropriately and reliably. The significance and stability of the coefficients were confirmed by analyzing CUSUM and CUSUM Square tests. Figure 2 shows the CUSUM and CUSUM Square tests.

Figure 2. CUSUM and CUSUM Square Tests



Finally, Granger's (1969) causality test was preferred to determine the direction of the variables. Considerable care should be taken in applying the Granger causality test. Because the method is very sensitive to the delay lengths used. This situation affects the results. Since delay lengths have an impact on all historical information, it may be more meaningful to use longer delay lengths (Takım, 2015). In this regard, using annual data for the period 1990-2019, Table 6 shows the Granger (1969) causality results of the variables.

Table 6. Granger Causality Results

Direction of Causality	Chi-Square	Probability	Result
$lnREN \Rightarrow lnCO_2$	3.304	0.4917	No causality
$LnCO_2 \Rightarrow lnREN$	3.514	0.4737	No causality
$lnAGR \Rightarrow lnCO_2$	7.937	**0.0317****	No causality
$lnCO_2 \Rightarrow lnAGR$	3.318	0.1200	There is causality
$lnGDP \Rightarrow lnCO_2$	5.469	**0.0424****	There is causality
$lnCO_2 \Rightarrow lnGDP$	5.362	0.2521	No causality
$lnURBAN \Rightarrow lnCO_2$	10.902	**0.0277****	There is causality
$lnCO_2 \Rightarrow lnURBAN$	9.078	**0.0887***	There is causality
lnAGR ⇒lnREN	3.769	0.4343	No causality
lnREN ⇒lnAGR	10.428	**0.0338****	There is causality
lnGDP ⇒lnREN	6.122	0.1902	No causality
lnREN ⇒lnGDP	5.798	0.2147	No causality
lnURBAN ⇒lnREN	2.507	0.6433	No causality
lnREN ⇒lnURBAN	18.826	**0.0008*****	There is causality
lnGDP ⇒lnAGR	5.944	0.2033	No causality
lnAGR ⇒lnGDP	9.675	**0.0232****	There is causality
LnURBAN ⇒lnAGR	11.847	**0.0185****	There is causality
lnAGR ⇒lnURBAN	11.364	**0.0228****	There is causality
lnGDP ⇒lnURBAN	10.939	**0.0266****	There is causality
lnURBAN ⇒lnGDP	8.079	**0.0887***	There is causality

***,**,* they show critical levels of 1%, 5% and 10% respectively. CO_2 = Carbon Emissions, REN = Renewable Energy Consumption, AGR = Agricultural Sector, GDP = Economic Growth, URBAN = Urbanization.

Table 6 shows the direction of causality between carbon emissions, renewable energy consumption, agriculture, economic growth, and urbanization. According to the results, a unidirectional relationship between the agricultural sector and economic growth to carbon emissions was detected. Thus, it can be said that the agricultural sector and economic growth are the cause of carbon emissions. On the other hand, a unilateral causality was found from renewable energy consumption to the agricultural sector and urbanization. It has been found that there is a one-way relationship between the agricultural sector to economic growth, and it has been concluded that it is the cause of economic growth in the agricultural sector, like many sectors. Finally, bidirectional causality was found between urbanization and carbon emissions and between economic growth and urbanization.

Result and Evaluation

Today, the harms of carbon emissions on the environment and society have reached a macro level. Various technological methods and some restrictive measures have been used to ensure environmental quality and reduce carbon emissions. The majority of greenhouse gases originate from energy sectors (fossil fuels). However, in many countries, significant changes have been made in energy policies to reduce greenhouse gases and ensure environmental quality. Awareness of clean and cheap renewable energy sources such as solar, wind, geothermal, and biomass as alternatives to fossil fuels has increased in recent years. Waheed et al. stated that the agricultural sector is an important sector for the continuity of life and the supply of healthy foods, but also has an increasing effect on carbon emissions. (2018), Ngarava et al.

It has been proven in the studies of authors such as (2019) and Qiao et al. (2019). In this study, the relationship between renewable energy consumption, the agricultural sector, and carbon emissions was analyzed with the ARDL bound test. The empirical results obtained in the study are listed as follows: First, it was found that the variables were cointegrated in the long run. Secondly, renewable energy consumption reduces carbon emissions; It has been concluded that the agricultural sector increases carbon emissions.

The increasing effect of the agricultural sector on greenhouse gas carbon emissions is mostly due to the use of fossil energy resources. Thirdly, it has been found that urbanization and economic growth, which are control variables, increase greenhouse gas emissions. On the other hand, a unidirectional relationship between the agricultural sector and economic growth to carbon emissions has been determined. A unilateral causality was found between renewable energy consumption in the agricultural sector and urbanization. It has been found that there is a one-way relationship between the agricultural sector to economic growth, and it has been proven that it is the cause of economic growth in the agricultural sector, like many sectors. Finally, bidirectional causality was found between urbanization and carbon emissions and between economic growth and urbanization. These results show that renewable energy, agricultural sector and greenhouse gas emissions interact in Turkey.

The empirical findings in the literature review reveal varying results. However, these differences can be influenced by various factors such as the methods employed and preferences in analyzing regions and communities. There are supporting results and similar studies that back the findings of this study. Researchers such as Jebli and Youssef (2017a), Waheed et al. (2018), Ngarava et al. (2019), Qiao et al. (2019), Okumuş (2020), Alam et al.(2023), Dalli and Kütükçü (2023) and Eyüpoğlu and Uzar (2020) provide empirical evidence that supports the results of the current study. On the contrary, Jebli and Youssef (2017b) reached a conclusion in their studies that the agricultural sector reduces carbon emissions, while renewable energy consumption increases carbon emissions.

The present study obtained results contrary to theirs, indicating an increase in carbon emissions from the agricultural sector in the long term. This result suggests important policy implications. However, it is known that the agricultural sector is indispensable, contributing to economic growth and fulfilling people's basic life needs. Throughout history, the role of the agricultural sector has been significant in every developmental stage of advanced countries.

To reduce agricultural carbon emissions, Turkey could invest more in renewable energy sources, as using clean energy sources can decrease the use of fossil fuels in agriculture, enabling healthier cultivation of agricultural products. It is essential to follow the modern agricultural policies of developed countries and improve irrigation facilities. This study sheds light on future research. While this study examines the relationship between renewable energy, agriculture, and carbon emissions (CO_2) on a single-country basis, future studies could include more countries for comparative analyses. Additionally, researchers can conduct analyses by altering data analysis methods and research approaches, as variations in these aspects across studies can lead to differences in the results obtained.

Contribution of the Authors

The authors declare that the contribution of the authors is equal.

References

Ahmed, S., Mahmood, A., Hasan, A., Sidhu, G. A. S., & Butt, M. F. U. (2016). A comparative review of China, India and Pakistan renewable energy sectors and sharing opportunities. *Renewable and sustainable Energy reviews*, *57*, 216-225.

Alam, M. S., Duraisamy, P., Siddik, A. B., Murshed, M., Mahmood, H., Palanisamy, M., & Kirikkaleli, D. (2023). The impacts of globalization, renewable energy, and agriculture on CO_2 emissions in India: Contextual evidence using a novel composite carbon emission-related atmospheric quality index. *Gondwana Research*, *119*, 384-401.

Aydoğan & Vardar (2017). Evaluating the role of renewable energy, economic growth and agriculture on CO_2 emission in E7 countries. *Internatıonal Journal Of Sustaınable Energy, 39*(4), 335–348. ttps://doi.org/10.1080/14786451.2019.1686380

Beydeera, L.H.U.W., Mesthrige, J.W. & Samarasinghalage, T. I. (2019). Global research on carbon emissions: A scientometric review. *Sustainability*, 11, 1-25.

Dallı, T., ve Kütükçü, E. (2023). Türkiye'de tarım, yenilenebilir ve yenilenemez enerji tüketimi, doğrudan yabancı sermaye girişi ve CO_2 emisyonu ilişkisi: ARDL analizi. *Osmaniye Korkut Ata Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 6*(3), 2154-2170.

Demir, Y. (2021a). Analyzing the effect of employment in the agricultural and industrial sectors on economic growth with the ARDL bounds test. *International Journal of Contemporary Economics and Administrative Sciences*, XI(1), 178-192. https://doi.org/10.5281/zenodo.5136851

Demir, Y. (2021b). Eğitim, sağlık ve AR-GE harcamaları ile ekonomik büyüme arasındaki ilişkinin ARDL sınır testi ile belirlenmesi. *Manas Sosyal Araştırmalar Dergisi*, 10(3), 1758-1770.

Demir, Y., ve Görür, Ç. (2020). OECD ülkelerine ait çeşitli enerji tüketimleri ve ekonomik büyüme arasındaki ilişkinin panel eşbütünleşme analizi ile incelenmesi. *Ekoist: Journal of Econometrics and Statistics,* 32, 15-33. https://doi.org/10.26650/ekoist.2020.32.0005

Demir, Y., İşleyen, Ş., & Özen, K. (2023). Determining the effect of selected energy consumptions on carbon dioxide emissions by ardl limit test. *Van Yüzüncü Yıl University the Journal of Social Sciences Institute*, 59, 80-107.

Dickey, D., & Fuller, W. (1979). Distribution of the estimators for autoregressive time series with a Unit Root. *Journal of the American Statistical Association*, 427-431.

Engel, R.F., & Granger, C.W.J. (1987). Cointegration and error correction representation, estimation and testing. *Econometrica,* 55, 251 – 276.

Eyuboglu, K., & Uzar, U. (2020). The impact of tourism on CO_2 emission in Turkey. Current Issue Tourızm, 23,1631–1645. https://doi.org/10.1080/ 13683500.2019.1636006

FAO. (2017). The future of food and agriculture – trends and challenges. Rome. http://www.fao.org/3/a-i6583e.pdf

Granger, C. (1969). Investigating causal relations by econometric models and Cross-spectral Methods. *Econometrica*, 424-438.

Heede, R. (2014). Tracing anthropogenic carbon dioxide and methane emissions to fossil fuel and cement producers, 1854–2010. *Climate Change,* 122, 229–241.

İşleyen, Ş., Altun, Y. ve Görür, Ç. (2017). The causalıty relatıonshıp between interest rate and income wıth investment in Usa: 1965-2016, *Akademik Sosyal Araştırmalar Dergisi,* 5(60), 146-163.

Jebli, M.B., & Ben Youssef, S. (2017a). The role of renewable energy and agriculture in reducing CO_2 emissions: Evidence for North Africa countries. *Ecological Indicators*, 74, 295-301.

Jebli, M.B., & Youssefi S.B. (2017b). Renewable energy consumption and agriculture: evidence for cointegration and Granger causality for Tunisian economy. *International Journal of Development World Ecology*, 24:149–158.

Johansen, S. (1995). Likelihood-Based Inference in Cointegrated Vector Autoregressive Models. Oxford Univ. Press, Oxford.

Johansen, S., (1988). Statistical analysis of cointegrating vectors. *Journal of Economic Dynamics and Control,* 12, 231 – 254.

Johansen, S., Juselius, K., 1990. Maximum likelihood estimation and inference on cointegration with applications to the demand for money. *Oxford Bulletin of Economics and Statistics* 52, 169 – 210.

Kapçak, S. (2023). Gelişmekte olan ülkelerde mutluluk ve ekonomik büyümenin ekolojik ayak izi üzerindeki etkisi. *Avrasya Sosyal ve Ekonomi Araştırmaları Dergisi*, *10*(2), 136-146.

Koondar, M. A., Shahbas, M., Öztürk, I., Randhava, A., & Kong, R. (2021). Revisiting the relationship between carbon emission, renewable energy consumption, forestry, and agricultural financial development for China. *Environmental Science and Pollution Research*, 28, 45459–45473.

Li, T., Balezentis, T., Makuteniene, D., Streimikiene, D., & Krisciukaitiene, I. (2016). Energy-related CO_2 emission in European Union agriculture: Driving forces and possibilities for reduction. *Applied Energy*, 180, 682-694.

Liu, D.; Guo, X., & Xiao, B. (2019). What causes growth of global greenhouse gas emissions? Evidence from 40 countries. *Science of the Total Environment*, 661, 750–766.

Liu, X., Zhang, S., & Bae, J. (2017). The impact of renewable energy and agriculture on carbon dioxide emissions: İnvestigating the Environmental Kuznets Curve in four selected ASEAN countries. *Journal Clean Productıon*, 164, 1239–1247.

Naseem, S. & Ji, T. G. (2021). A system-GMM approach to examine the renewable energy consumption, agriculture and economic growth's impact on CO_2 emission in the SAARC region. *Journal Clean Productıon,* 86:2021–2033. ttps://doi.org/10.1007/s10708-019-10136-9(0123456789

Ngarava, S., Zhou, L. Ayuk, J., & Tatsvarei, S. (2019). Achieving food security in a climate change environment: Considerations for environmental Kuznets Curve use in the South African agricultural sector. *Climate*, *7*(108), 1-17.

Odhiambo, N. M. (2009). Energy consumption and economic growth nexus in Tanzania: An ARDL bounds testing approach. *Energy Policy*, 37, 617–622.

OECD (2020). https://www.oecd.org/turkiye/turkey-needs-to-step-up-investment-in-renewables-to-curb-emissions.htm

Okumuş, İ. (2020). Türkiye'de yenilenebilir enerji tüketimi, tarım ve CO_2 emisyonu ilişkisi. *Uluslararası Ekonomi ve Yenilik Dergisi*, *6*(1), 21-34.

Özen, K., İşleyen Ş. & Görür, Ç. (2023). Investıgatıon of the relatıonshıp between the use of selected energy types and agrıcultural area utılised by ardl bound test: the case of turkey. *Van Yüzüncü Yıl Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, 8(16). 354-372. DOI: 10.54831/ vanyyuiibfd. 1389475

Perron, P. (1989). The great crash, the oil price shock, and the unit root hypothesis. Econometrica: *Journal of the Econometric Society,* 1361-1401.

Pesaran, M. H., Shin, Y., & Smith, R. J., (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics,* 16, 289 – 326.

Phillips, P., & Perron, P. (1988). Testing for a Unit Root in Time Series Regression. *Biometrika*, 335-346.

Qiao, H., Zheng, F., Jiang, H., & Dong, K. (2019). The greenhouse effect of the agriculture-economic growth-renewable energy nexus: evidence from G20 countries. *Science of Total Environment*, 671, 722–731.

Rafiq, S., Salim, R., & Apergis, N. (2015). Agriculture, trade openness and emissions: an empirical analysis and policy options. *Australian Journal of Agricultural and Resource Economics,* 60, 348-365.

Reynolds, L., & Wenzlau, S. (2012). Climate-friendly agriculture and renewable energy: working hand-in-hand toward climate mitigation. worldwatch Institute. https://www.renewableenergyworld.com/articles/2012/12/ climate-friendly-agriculture-and-renewable-energy-working-hand-in-hand-toward-climate mitigation.html

Takım, A. (2015). Türkiye'de ekonomik büyüme ile işsizlik arasındaki ilişki: Granger Nedensellik Testi. *Dumlupınar Üniversitesi Sosyal Bilimler Dergisi*, 27.

Waheed, R., Chang, D., Sarwar, S., & Chen, W. (2018). Forest, agriculture, renewable energy, and CO_2 emission. *Journal of Cleaner Production,* 172: 4231-4238.

Xu, B., & Lin, B. (2017). Factors affecting CO_2 emissions in China's agriculture sector: Evidence from geographically weighted regression model. *Energy Policy*, 104, 404-414.

Zhang, Y. J., & Da, Y. B. (2015). The decomposition of energy-related carbon emission and its decoupling with economic growth in China. *Renewable and Sustainable Energy Reviews,* 41, 1255–1266.