IWEC

3. International World Energy Conference

FULL TEXTS BOOK

EDITORS
Mustafa Serdar GENÇ
Gamze GENÇ
Şükrü Taner AZGIN
Saltuk Buğra SELÇUKLU



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December 4-5, 2023 / Kayseri, Türkiye



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EFFECT OF ENERGY CONSUMPTION AND GREENHOUSE GAS EMISSIONS ON ECONOMIC GROWTH IN TURKEY: EMPIRICAL EVIDENCE FROM THE AGRICULTURAL SECTOR

Hakan SÖNMEZ

PhD, Dokuz Eylül University, Efes Vocational School, Department of Transportation Services, Izmir-Turkey
ORCID: 0000-0001-6126-3275

ABSTRACT

The agricultural sector involves intensive energy usage in various stages, including soil cultivation, irrigation, harvesting, and product storage. Thus, planning the energy use in agriculture efficiently is crucial for reducing costs, minimizing environmental impacts, and ensuring the sustainability of agricultural productivity. The aim of this study is to determine the impact of energy consumption and greenhouse gas emissions on growth in Turkey within the agricultural sector between 1998 and 2020. The agricultural gross domestic product data has been used to represent the variable of economic growth in the agricultural sector. Data that represent total energy consumption in the agricultural sector, measured in tera joules for energy consumption, and data indicating total greenhouse gas emissions in the agricultural sector, measured in million tons of CO2 equivalent for carbon emissions, have been utilized. The results of the unit root tests have indicated that the variables used in the model have been stationary at different levels which is I(0) and I(1). Thus, the Autoregressive Distributed Lag Bound Test approach, which has been employed and provides consistent and unbiased results in small samples for series with different levels of stationarity, has been used to examine short and long-term relationships between variables. Moreover, the long term coefficient results indicate that a 1% increase in energy consumption in the agricultural sector corresponds to a 0.24% increase in the agricultural gross domestic product value. Furthermore, the vector error correction model coefficient, which has been calculated as 0.62, indicates that short-term imbalances have been corrected within 1.67 periods. Also, greenhouse gas emissions from the agricultural sector have had a positive and significant impact on agricultural gross domestic product. It has been considered that to reduction of fossil fuel use and increase in renewable energy sources, increase in incentives for the use of high-energy efficiency smart agricultural technologies.

Keywords: Agricultural sector, energy consumption, greenhouse gas emissions, economic growth, ARDL bounds testing approach,

Introduction

The agricultural sector is gaining more importance with the increasing world population. Also, the sector significant that supplies raw materials to the food industry and service sector. Energy consumption, on the other hand, is one of the most important production factors used in the production process of all goods and services today. However, energy usage is a crucial factor with a critical role in economic activity, production, and the environment. With the increasing use of machinery and technology in the agricultural sector, energy consumption is also on the increase consistently. Especially with the transition from traditional farming methods to modern agricultural techniques, energy is needed for numerous processes, which include irrigation, fertilization, tractor usage, harvesting, and cold storage. Thus, the consideration of energy usage in the agricultural sector in terms of sustainability and efficiency is important. Moreover, the increased use of fossil fuels necessitates global measures for environmental issues caused by climate change. In this regard, analyzing the impact of increasing greenhouse gas emissions on the environment along with economic growth becomes essential. Evaluating how agricultural economic growth and increased greenhouse gas emissions will be affected by the growing demand for energy in the agricultural sector forms the fundamental motivation of this study. Determining the degree of factors affecting energy usage in Turkey on a sectoral basis and analyzing their impact on the environment is important. Furthermore, policymakers consider the economic growth and environmental impact of sectoral distributions in determining investment and incentive decisions. Therefore, the distribution of sectoral consumption is important in addition to total energy consumption. For these reasons, energy consumption in the agricultural sector needs to be evaluated both environmentally and economically.

There are numerous studies that investigate the relationship between economic growth, energy consumption, and the environment in the literature. However, assessments need to be examined at the sectoral level, within the framework of individual countries and country groups due to variations in economic structures from country to country and different time periods. Studies explaining the relationship between energy consumption and economic growth have been grouped under specific categories in the literature review. Some studies suggest that energy consumption has no impact on Gross Domestic Product (GDP), while others indicate a unidirectional causality from GDP to energy consumption, and still others suggest a bidirectional effect. Thus, it is not possible to make a definitive inference about the relationship between the two variables. The observed variations are considered to be rooted in differences in the examined periods, regional levels, and levels of economic development. Additionally, the studies show variations in the methodology used, with micro-level and single-country studies employing different time series analyses. Moreover, cointegration analyses, causality tests, and error correction models are prominently featured. Furthermore, panel data analysis methods are preferred. From this perspective, it is possible to categorize the relevant literature into three main groups in studies conducted for country groups.

The relationship between economic growth and energy consumption varies from country to country and across different time periods in studies focusing on a single country. Some studies have identified a unidirectional causal relationship (Shiuand & Lam, 2004; Narayan & Singh, 2007; Odhiambo, 2009; Abosedra, et al., 2014; Alshehry & Belloumi, 2015). On the other hand, a bidirectional causality relationship indicating a mutual relationship between variables has been determined in some of the researchs (Paul & Bhattacharya, 2004; Fuinhas & Marques, 2012; Tang & Tan, 2013; Osigwe & Arawomo, 2015; Arora & Shi, 2016; Rathnayaka, et al., 2018). In a limited number of studies, it has been concluded that the impact of economic growth on energy consumption is consistent with the neutrality hypothesis (Soares, et al., 2014). The first group of studies primarily examines sectoral analyses based on a single country and micro-level data. The relationship between energy consumption and economic growth has been analyzed in the agriculture, industry, service, manufacturing, housing, and transportation sectors in sectoral studies. For instance, Tsani (2010), who conducted Toda-Yamamoto causality tests for the transportation, industry, and housing sectors in Greece between 1960 and 2006, reached different results. According to the study findings, a bidirectional causality relationship has been identified between energy consumption and GDP in the industry and housing sectors. Yet, There has no causality relationship found in the transportation sector. Bernard & Kenneth (2016) have found that the amount of energy consumed in industry, transportation, and housing in Nigeria has had a positive impact on economic growth. Mirza & Kanwal (2017) have investigated the relationship between energy consumption and economic growth in Thailand and Pakistan between 1971 and 2009 using cointegration and ARDL models. The findings have indicated a bidirectional causality relationship between the variables, and long-term cointegration has been confirmed. Fan & Hao (2020) have explored the relationship between economic growth, renewable energy consumption, and foreign direct investments in the Chinese economy from 2000 to 2015. The study result have been identified a unidirectional causality relationship from renewable energy consumption to economic growth. Koç (2020) has investigated the transportation, service, industry, and agriculture sectors for a total of 132 countries from 2010 to 2016. According to the findings obtained using panel data analysis, a positive relationship has been found between the variables in all sectors.

There are numerous studies focusing on country groups that include many countries from the developed and developing country groups in the literature. Energy consumption is considered one of the fundamental elements of development, particularly for countries in the developing country group. In most studies, a relationship between these variables is identified, but different results are obtained regarding the direction of causality. This is thought to be mainly due to the differences in the levels of development among countries and the different evaluation methods selected during distinct time intervals. As an illustration, Le & Chang (2008) identify a unidirectional causality relationship between energy use and GDP in a panel cointegration model for 16 Asian countries during the period 1971-2002. Guvenek & Alptekin (2010) have examined the relationship between energy consumption and economic growth for 25 OECD countries using panel data analysis between 1980 and 2005. The study result conclude that there is a significant relationship between energy consumption and economic growth. Menegaki (2011) have found a weak negative relationship between renewable energy and GDP in selected 25 European countries between 1997 and 2007. Tiwari (2011) has reported the relationship between renewable and non-renewable energy sources with GDP using panel data analysis during the period 1965-2009. The analysis reveale that renewable energy has a positive impact on GDP. Ersoy (2012) has used panel data analysis to analyze real GDP and primary energy consumption variables for OECD countries between 1987 and 2007. The analyses conclude that the variables are cointegrated in the long term. Sebri &

Ben Salha (2014) have investigated the relationship between renewable energy consumption and economic growth in BRICS countries from 1971 to 2010 using the ARDL method. The findings indicate a positive impact of renewable energy consumption on economic growth. Aslan & Ocal (2016) have examined the impact of renewable energy consumption on economic growth for eight Europena Uninon countries from 1990 to 2019 using the ARDL approach. The analyses reveale a positive relationship between energy consumption and economic growth. Kahia et al., (2017) which has conducted panel data analysis for MENA countries from 1980 to 2012, separating energy use into renewable and non-renewable categories. The reseracher have been found that bidirectional causality between both energy types and economic growth. Ballı et al., (2018) have used panel cointegration and causality tests for CIS countries with annual data from 1992 to 2013. The results have been indicated a cointegration relationship between the variables and a positive impact of energy consumption on economic growth. Önder & Polat (2018) examine renewable and non-renewable energy sources for 35 OECD countries between 1996 and 2014. According to the findings, renewable energy sources have been positive effect on GDP, while non-renewable energy sources have been negative effect. Syzdykova (2018) has evaluated the relationship between per capita energy consumption and GDP using panel data analysis for Central Asian countries from 1991 to 2016. The study findings have concluded that there is a bidirectional causality relationship between the variables. Tuğcu & Topcu (2018) have been analyzed the long and short-term relationships between energy consumption and economic growth for G7 countries from 1980 to 2014 using the NARDL method. The findings have been denoted that there has been an asymmetric relationship between the variables in the long term. Erdogan et al., (2020) have found that energy consumption leads to economic growth which concluded using panel data analysis for eight MENA countries from 1990 to 2014. Ateş & Yağcı (2023) have been investigated the impact of energy consumption on economic growth in BRICS countries from 1990 to 2020 using panel data analysis. According to the study results, increase in energy consumption influences economic growth positively. Ayyıldız (2023) has been evaluated the impact of primary energy consumption on economic growth for G-7 countries from 1990 to 2021 using the panel quantile regression method. Study findings revealed that a 1% increase in primary energy consumption leads to a 2.29% increase in economic growth. Bozkaya & Aytekin (2023) have been examined the impact of energy consumption, inflation, and physical and human capital on economic growth for BRICS countries from 1990 to 2015. There has not been found relationship between energy consumption and economic growth according to the findings obtained from panel data analysis.

The literature includes recent studies conducted on Turkey. In the majority of these studies that have identified a causal relationship between energy consumption and economic growth, it has been concluded that there is cointegration between the variables in the long term. To illustrate, Erbaykal (2007) has been investigated the relationship between economic growth and energy consumption using the ARDL boundary test approach for the period 1970-2003. The findings denoted that there is cointegration between the series in the long term. Mucuk & Uysal (2009) have been analyzed the impact of energy consumption on economic growth using cointegration tests for the years 1960-2006. The research findings have indicated that the existence of cointegration between the series in the long term, and a unidirectional causality from energy consumption to economic growth has been identified. Aydın (2010) has been examined the relationship between primary energy sources used in energy consumption and economic growth from 1996 to 2004. Predictions result revealed that changes in energy consumption increase economic growth. Aytaç (2010) has been found a unidirectional causality relationship from energy consumption to economic growth using VAR analysis for the period 1975-2006. Korkmaz & Develi (2012) have been explored the relationship between primary energy usage and GDP using Johansen cointegration and Granger causality tests for the years 1960-2009. The study's findings have been asserted that bidirectional causality between the variables. Çetin & Seker (2012) have been evaluated data from 1970 to 2009 using the Toda and Yamamoto causality test. The study result showed that a positive relationship between energy consumption and economic growth. Şahbaz &Yanar (2013) have been investigated the relationship between total and sectoral energy consumption and GDP for the years 1970-2010. While no causality relationship has been identified in the industry and housing sectors; a unidirectional causality relationship has been found in the transportation and agriculture sectors. Ertuğrul (2013) has been employed a dynamic analysis approach to examine the energy consumption and economic growth relationship for the period 1970-2011. The study has identified cointegration between the variables in the long term. According to Kalman filter analysis, it has been determined that energy consumption had a negative effect on GDP until 2003, which has later turned positive. Tatlı (2015) has been used the ARDL boundary test approach to analyze short and long-term relationships for the years 1981-2013. Both short and long-term total energy consumption have been positively affected economic growth in the study. Lebe & Akbaş (2015) have been

conducted research for the years 1960-2012 using the impact-response analysis method based on FMOLS, DOLS, and SVAR models. The findings indicated structural breaks in the variables and cointegration in the long term. Yanardağ (2016) has been evaluated the energy consumption and economic growth relationship using cointegration and causality analysis methods for the annual data from 1998 to 2012. The findings have been showed that a unidirectional causality relationship from energy consumption to economic growth. Şimşek (2016) has been examined the relationship between total energy consumption and GDP for the years 1990 to 2014. According to the ARDL boundary test results, a unidirectional causality relationship has been identified from total energy consumption to economic growth. Usta (2016) has been used panel data analysis for 26 regions in Turkey from 2004 to 2011 and has found that regional energy consumption has positively influenced growth. Usta & Berber (2017) have been employed panel data analysis for Turkey from 1970 to 2012 and determined a bidirectional causality relationship between energy consumption and economic growth in the industrial sector, while no relationship has been identified in the agricultural and housing sectors. Polat (2017) has been examined the impact of energy consumption on economic growth using FMOLS, DOLS, and CCR methods for the years 1980-2013. The study result revealed that a positive relationship between the variables in the long term. Hanifi & Özen (2018) have been investigated the effect of energy consumption on economic growth in the main sectors of Turkey from 1971 to 2012 using panel data analysis. The findings indicated that a unidirectional relationship between variables in the agricultural and service sectors.

The demand for energy also inreases with the increase in economic growth. Also the consumption of fossil fuels increases along with the growing productionn a global scale. Thus, an increase in greenhouse gas emissions released into the atmosphere is expected in sectors with intensive energy consumption. In this context, where developing countries are taken into consideration, they are still in the early stages of development. It is known that the rapid depletion of natural resources occurs with the increase in production, affecting environmental pollution. However, as economic development advances, technologies that are initially insensitive to the environment are said to evolve over time towards environmentally friendly production structures. During the initial stages of growth, it has been believed that income has increased along with greenhouse gas emissions. Beyond a certain point, income growth is expected to lead to emissions reduction (Grossman & Krueger, 1991). In this regard, considering environmental factors alongside energy consumption is crucial in developing long term economic policies. This study examines the impact of economic growth in the agricultural sector on the environment, specifically through greenhouse gas emissions within this framework. Studies investigating the relationship between economic growth and the environment are predominantly conducted at the country group level using panel data analyses. Another notable finding is that the results of studies examining the relationship between energy consumption and greenhouse gas emissions (CO_2) vary. As evidenced by Apergis et al., (2010) have been examined the relationship between renewable energy consumption, CO_2 emissions, and economic growth for 19 developed and developing countries from 1984 to 2007 using the panel data analysis method. The findings of the study reveale that a positive relationship between CO_2 emissions and renewable energy consumption. Bekun et al., (2019) have been found that economic growth increased CO_2 emissions for 16 EU countries from 1996 to 2014 using panel data analysis. Kaymak (2022) has determined that the causal relationship between total energy consumption, greenhouse gas emissions, and GDP is not valid in the short term from 1990 to 2020. Miçooğulları (2023) has been investigated the causality relationship between carbon emissions and economic growth in Turkey from 1923 to 2018 using an extensive dataset. The study findings denoted that there is a causality relationship from CO_2 emissions to GDP in five different sub-periods, while only one sub-period showe a causality relationship from economic growth to CO_2 emissions. Akadiri & Adebayo (2022) have been analyzed for the period 1970-2018 using the Nonlinear Autoregressive Distributed Lag (NARDL) model in India. The study's results indicate that a positive shock in economic growth positively affect carbon emissions. Some studies focus on environmental issues for various country groups. As an illustration, Yıldırım & Akın (2023) have been examined the impact of renewable and non-renewable energies on CO_2 emissions for 23 OECD countries from 1990 to 2019 using the STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) model. According to the study findings, a 1% increase in energy intensity, non-renewable energy production, and renewable energy production increased CO_2 emissions by 1.129%, 1.047%, and 0.032% in the long term, respectively. Kazanasmaz et al., (2023) have been investigated the relationship between economic growth, electricity consumption, and carbon emissions in Turkey from 1967 to 2017. Causality test results have been revealed that a unidirectional causality relationship from electricity consumption to economic growth and carbon dioxide emissions. Moreover, the vector error correction model and cointegration analysis results indicate that the long term effect of electricity consumption on economic growth positive. Additionally,

a negative effect of CO_2 emissions on economic growth is determined. Karaca & Çımat (2023) have been examined the impact of per capita energy consumption, industrialization, and GDP on CO_2 emissions in Turkey from 1960 to 2015. The study result emphasize that GDP increases reduce CO_2 emissions, while energy consumption may increase CO_2 emissions, leading to environmental issue. This study dive into four main sections. The first part includes the introduction and literature review. The second section provides detailed information about the econometric method and the data set used, with a focus on literature studies. The third section extensively discusses the empirical findings. The final section presents the conclusions of the study along with possible policy recommendations.

Materials and Methods

This study covers annual data from 1998 to 2020. The agricultural gross domestic product (GDP) and greenhouse gas emissions data utilized in the study have been acquired from the Turkish Statistical Institute database. The GDP data have been categorized according to main economic activities and have been adjusted to real terms using the 2009 base year deflator before being incorporated into the model. The Total Energy Consumption data have been obtained from the International Energy Agency database. The total energy consumption in the agricultural sector has been included in the model in tera joules, and total greenhouse gas emissions have been included in million tons of CO_2 equivalent. The natural logarithms of all variables used in the study have been taken. Definitions of the variables used in the model are shown in Table 1.

Table 1. Variables and Their Descriptions

VARIABLE NAME	ABBREVIATION	SOURCE
Agricultural Gross Domestic Product (TRY)	GDPagricultural	The Turkish Statistical Institute
Total Energy Consumption in Agricultural Sector (Tera Joule)	ENERGYagricultural	International Energy Agency
Greenhouse gas emissions by sectors (CO_2 equivalent-Million tonnes)	GHGagricultural	The Turkish Statistical Institute

Unit root tests are commonly used to determine the stationarity of time series data. The construction of econometric models for time series analysis, the constancy of the mean, variance, and covariance of the relevant series over time indicates that the series is stationary. The use of non-stationary series leads to a spurious regression problem, where there is an assessment of a meaningful relationship between the series in the model. Additionally, the parameters of the model are misinterpreted due to this situation. Thus, it is essential to stationarize the series before including them in the model for the reliability of the estimated parameters (Baltagi, 2003; Gujarati, 2004). In this study, the Augmented Dickey-Fuller (ADF) unit root test has been employed to assess the stationarity characteristics of the series. The null hypothesis in the unit root test suggests that the series is non-stationary and contains a unit root. The stationarity of the series is evaluated with three different models: stationary without trend and intercept, stationary with a intercept, and stationary with a intercept and trend. The equations for the models and the test procedure for the ADF unit root test are given in equations (1), (2), and (3), respectively. Various criteria such as Akaike Information Criterion (AIC) and Schwarz Information Criterion (SC) are used in determining the appropriate lag length for the ADF unit root test. The value that minimizes the lag count according to both information criteria is considered as the optimal lag length.

$$\Delta y_t = \rho y_{t-1} + \sum_{i=1}^{k} \varphi_i \Delta y_{t-i} + \varepsilon_t \quad (1)$$

$$\Delta y_t = \alpha + \rho y_{t-1} + \sum_{i=1}^{k} \varphi_i \Delta y_{t-i} + \varepsilon_t \quad (2)$$

$$\Delta y_t = \alpha + \beta\, t + \rho y_{t-1} + \sum_{i=1}^{k} \varphi_i \Delta y_{t-i} + \varepsilon_t \quad (3)$$

The equation for the model created with the variables used in the study is as follows in equation 4. The dependent variable GDPagricultural represents the value of agricultural gross domestic product, while the independent variables ENERGYagricultural and GHGagricultural represent the total energy consumption and total greenhouse gas emissions in the agricultural sector in equation 4, respectively.

$$GDPagricultural_t = \beta_0 + \beta_1 ENERGYagricultural_t + \beta_2 GHGagricultural_t + \varepsilon_t \quad (4)$$

The ARDL model allows for cointegration testing when the series are stationary at different orders. To put it differently, it is not compulsory for the variables used in the model to be cointegrated at the same level. Moreover, in studies with limited datasets, this method tends to yield more consistent results, which is one of its advantages over other methods. The unrestricted error correction model prepared to determine the impact of energy consumption and greenhouse gas emissions in the agricultural sector on agricultural gross domestic product is given in equation 5 in line with the objective of the study.

$$\Delta \ln GDPagricultural_t = \beta_0 + \sum_{k=1}^{m} \beta_{1k} \ln GDPagricultural_{t-k} + \sum_{k=1}^{m} \beta_{2k} \ln ENERGYagricultural_{t-k} + \sum_{k=1}^{m} \beta_{3k} \ln GHGagricultural_{t-k} + \beta_4 \ln GDPagricultural_{t-1} + \beta_5 \ln ENERGYagricultural_{t-1} + \beta_6 \ln GHGagricultural_{t-1} \quad (5)$$

Symbol Δ represents the difference operator; m denotes the appropriate lag length; β_1, β_2, β_3 represent the error correction coefficients; β_4, β_5, β_6 represent the long-term coefficients; εt represents the error term; k indicates the number of lags for each variable in equation 11. F-test statistic is utilized to determine the existence of cointegration in the model. The null hypothesis tests for no cointegration ($H_0 = \beta_4 = \beta_5 = \beta_6 = 0$; No cointegration), while the alternative hypothesis tests for cointegration ($H_1 = \beta_4 \neq \beta_5 \neq \beta_6 \neq 0$; Cointegration exists).

The calculated F-statistic value is compared with lower and upper critical values to assess the presence of cointegration. If the calculated F-statistic value is less than the lower critical value provided in the studies by Pesaran et al. (2001), it is inferred that there is no cointegration among the series; if it is greater than the upper critical value, it is concluded that there is cointegration among the series. On the other hand, if the calculated F-statistic value falls between the lower and upper bounds, a definitive decision cannot be made regarding the presence of cointegration. After identifying the cointegration relationship for the long term, the short-term coefficients are estimated using the error correction model (ECM). The ECM is expressed in equation 6.

$$\Delta \ln GDPagricultural_t = \beta_0 + \sum_{k=1}^{m} \beta_{1k} \ln GDPagricultural_{t-k} + \sum_{k=1}^{m} \beta_{2k} \ln ENERGYagricultural_{t-k} + \sum_{k=1}^{m} \beta_{3k} \ln GHGagricultural_{t-k} + \varphi ECT_{t-1} + \varepsilon_t \quad (6)$$

The coefficient of the parameter φ, indicating the speed at which variables converge in the long run, is expected to be negative and statistically significant. The natural logarithm of all data is included in the analysis. The calculated coefficients have been interpreted as elasticity values for the variables. Critical values determined by Pesaran et al. (2001) have been used for predictions with the ARDL model. Eviews 12 software has been employed for model estimations.

4.Findings and Discussions

The stationarity and cointegration degrees of the series have been determined before estimating the ARDL model in the study. For this purpose, the Augmented Dickey Fuller (ADF) unit root test has been employed for all series. The results of the Augmented Dickey Fuller (ADF) unit root test statistics are presented in Table

2. According to the unit root test statistics, it has been found that the first difference of the GDPagricultural variable has become stationary when taken in models containing intercept, trend, and intercept at a 5% significance level.

The stationarity levels of the independent variables ENERGYagricultural and GHGagricultural have been determined to be I(0) and I(1). While the ENERGYagricultural variable has been stationary at the level in the model containing intercept, it has become stationary when the first difference is taken in the trend and intercept model. On the other hand, GHGagricultural variable has become stationary after taking the first difference in the model containing intercept but has become stationary both at the level and when the first difference is taken in the trend and intercept model. Since variables have been stationary at different levels, ARDL boundary test approach have been conducted next part of the study.

The maximum lag length in the ARDL model has been set to 4 since the data used in the study are annual. Also, the most suitable ARDL model has been selected using the Schwarz information criterion. Moreoever, the analysis results indicate that the most suitable model is the ARDL (2,0,0) model.

Table 2. Augmented Dickey Fuller (ADF) Unit Root Test Results

	INTERCEPT			TREND AND INTERCEPT		
	Test Statistics		Decision of Stability	Test Statistics		Decision of Stability
VARIABLE NAME	Level I(0)	First Difference I(1)		Level I(0)	First Difference I(1)	
Ln(GDPagricultural)	0.377 (0.977)	-7.567*** (0.000)	I(1)	-2.311 (0.408)	-7.799*** (0.000)	I(1)
Ln(ENERGYagricultural)	-6.323*** (0.000)	-1.767 (0.381)	I(0)	-0.883 (0.925)	-4.809** (0.011)	I(1)
Ln(GHGagricultural)	0.920 (0.993)	-3.152** (0.049)	I(1)	-5.653*** (0.003)	-3.593* (0.056)	I(0) I(1)

(**Notes:** ***, ** and * indicate significance at the 1%,5% and 10%level, respectively. The lag order determine using the Schwartz information criterion and the maximum delay length set to 9 numbers. Values in parentheses denote degree of stability) (**Source:** Author's own computation Using E-view 12)

Table 3 presents the results of the ARDL boundary test approach for cointegration analysis. The calculated F-statistic and relevant critical values for the ARDL model are provided in Table 3. The calculated F-statistic in the ARDL model is greater than the upper critical value at a 5% significance level; thus, the null hypothesis (H_o) is rejected. Consequently, there is evidence of a long term cointegrating relationship between GDPagricultural and the ENERGYagricultural and GHGagricultural variables. In a different manner, the variables move together in the long run.

Table 3. ARDL Bound F-Test Results for Cointegration

Dependent Variable: ln(GDPagricultural)				
			Bound Critical Values	
F Statistic Value	k	Significance Level	Lower Bound I(0)	Upper Bound I(1)
4.992**	2	10%	2.915	3.695
		5%	3.538	4.428
		1%	5.155	6.265

(**Note:** ***, ** and * indicate significance at the 1%, 5%, and 10% level, respectively. The critical values for the lower I(0) and upper I(1) bounds are obtain from Pesaran et al. (2001), Appendix: Case II (**Source:** Author's own computation Using E-view 12).

Table 4 presents the results of short and long-term coefficient estimates and findings related to diagnostic tests. Examining the diagnostic test results of the model, it is inferred that there is no autocorrelation in the model according to the Breusch-Godfrey Serial Correlation LM Test results; there is no changing variance in the model according to the White Heteroscedasticity Test test results; the model is correctly specified based on the Ramsey Reset Test results; and the assumption of normal distribution of the error term is valid according to the Jarque-Bera Normality test results.

Table 4. Long-Run and Short Run Coefficients Using the ARDL (2, 0, 0) Approach

LONG-RUN COEFFICIENTS

Dependent Variable: Δln(GDPagricultural)

Independent Variables	Coefficient	Standart Deviation	t-Statistic	Prob. Values
Constant	12.449***	1.147	10.847	0.000
ln(ENERGYagricultural)	0.242**	0.101	2.394	0.029
ln(GHGagricultural)	0.755***	0.083	9.038	0.000

SHORT RUN COEFFICIENTS

Variables	Coefficient	Standart Deviation	t-Statistic	Prob. Values
Δln(GDPagricultural)-1	-0.199	0.152631	-1.304856	0.2104
ECM(-1)	-0.616***	0.126688	-4.869835	0.0002

DIAGNOSTIC TESTS

	F Statistic	Prob. Values
Jargue-Bera Normality Test	0.072	0.964
Breusch–Godfrey Serial Correlation LM Test	0.001	0.966
White Heteroscedasticity Test	0.888	0.563
Ramsey Reset Test	0.661	0.428

(**Note:** ***, ** and * indicate significance at the 1%, 5%, and 10% level, respectively. Diagnostic tests results are based on F-statistic. (**Source:** Author's own computation Using E-view 12)

In addition to diagnostic tests, it has been determined that ENERGYagricultural and GHGagricultural variables move in the same direction as GDPagricultural in the long term in the agricultural sector in Turkey according to the obtained cointegration findings. To put it differently, an increase in energy consumption in the agricultural sector leads to an increase in agricultural growth. According to the long-term coefficient results, when ENERGYagricultural increases by 1%, GDPagricultural increases by 0.24%. This result is consistent with findings from studies by Tiwari (2011), Çetin & Seker (2012), Şahbaz & Yanar (2013), Sebri & Ben-Salha (2014), Tatlı (2015), Aslan & Öcal (2016), Polat (2017), Bernard & Kenneth (2016), Ballı et al., (2018), Koç (2020), Ateş & Yağcı (2023).

Moreover, it has been also found that the GHGagricultural variable has a positive and significant effect on GDPagricultural. Furthermore, an increase of 1% in GHGagricultural is determined to increase GDPagricultural by 0.75%. This finding is consistent with the results obtained from studies reporting a positive effect between GHGagricultural and GDPagricultural (Akadiri & Adebayo, 2022; Yıldırım & Akın, 2023; Kazanasmaz et al., 2023).

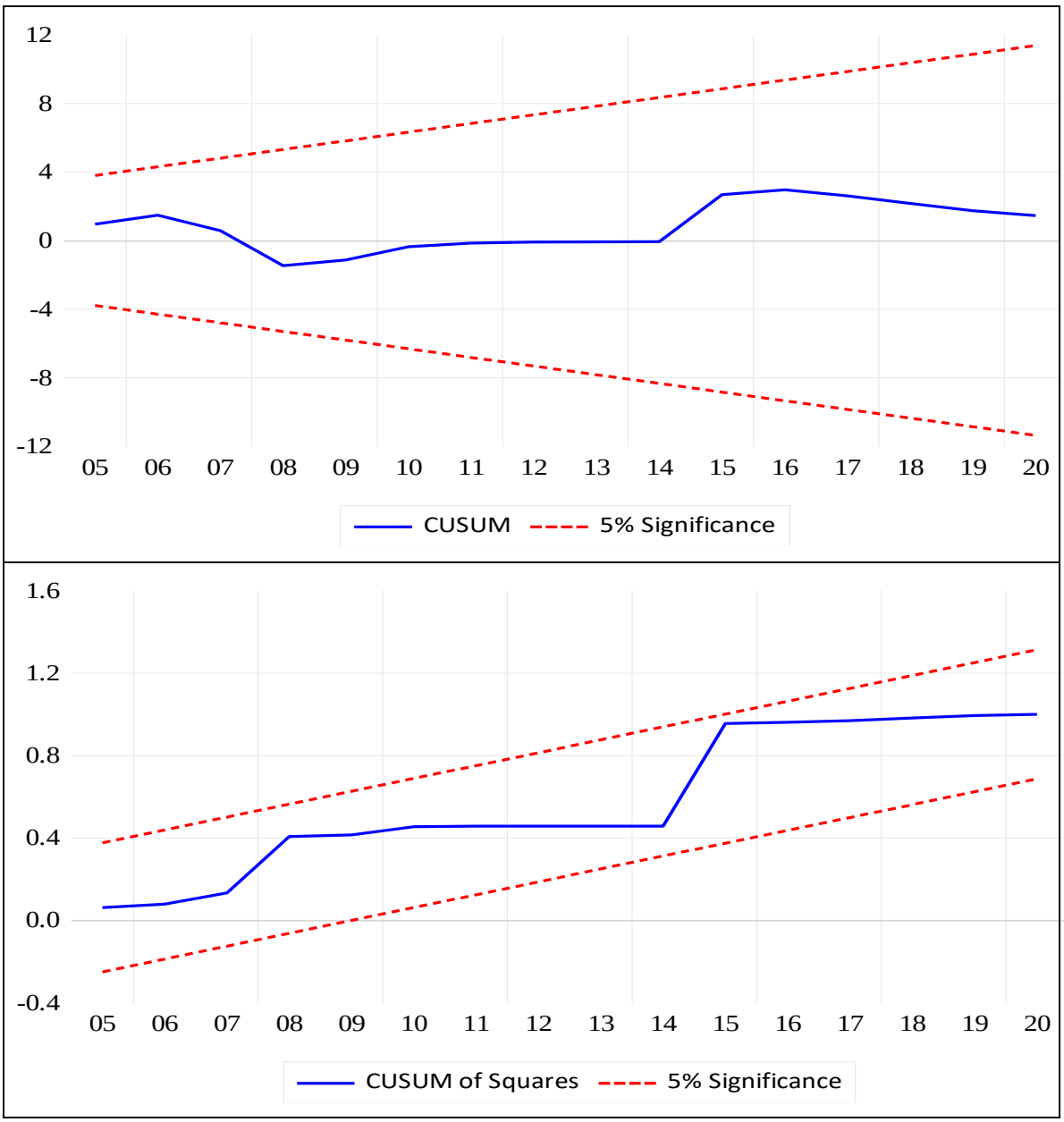


Figure 1. Plot of Cumulative Sum of Recursive (CUSUM) Residuals and Cumulative Sum of Square of Recursive CUSUMQ Residuals

(**Note:** The straight blue lines represent critical bounds at 5% significance level)

(**Source:** Author's own computation Using E-view 12)

After the long-term analysis, which aimed to identify short-term relationships between variables, the calculation of the error correction model coefficient ECM(-1) is required. The error correction term ECM(-1) coefficient (-0.92) has been estimated as negative and statistically significant at the 1% significance level in line with theoretical expectations. This result indicates that short-term imbalances in the model will return to equilibrium in 1.67 periods (1/0.62). In order to assess the stability and reliability of the model, CUSUM and CUSUM-SQ tests, which were proposed by Brown, Durbin, and Evans (1975), have been employed. The results of the CUSUM and CUSUM-SQ tests have been presented in Figure 1. In the model where GDPagricultural serves as the dependent variable, the movement of parameters within the specified limits at the 5% significance level has indicated the stability of the estimated coefficients in the model.

Conlusion and Recommendations

The need for nutrition is growing, and the importance of the agricultural sector plays a critical role in sustainable food production and global food security with the increasing world population. Although energy usage occurs most intensively in the industrial sector, it is also a crucial input for agriculture and other sectors. Moreover, agricultural activities involve a series of energy intensive processes from planting seeds to harvesting crops. Furthermore, the demand for energy in the agricultural sector has increased with the rise in the use of machinery, especially with the adoption of modern farming techniques over conventional ones, which has led to the widespread use of technology and machinery. Besides, the agricultural sector is interconnected with numerous industries such as food, textiles, chemicals, and tourism. Consequently, energy consumption in the agricultural sector is on the increase. Similar to other sectors, energy use in the agricultural sector plays a critical role in agricultural sustainability and environmental issues. Especially in developing countries, where the demand for energy is increasing, the environmental impact of greenhouse gas emissions associated with the use of fossil fuels becomes more pronounced. Thus, there is a need for sustainable and environmentally friendly agricultural policies that promote agricultural growth while controlling greenhouse gas emissions, mitigating environmental impacts, and prioritizing energy efficiency. This study has investigated the short and long-term relationship among energy consumption, greenhouse gas emissions, and agricultural growth in the agricultural sector in Turkey. Energy consumption in the agricultural sector has been examined in harmony with environmental factors, sustainability, and growth objectives in line with this objective. Annual data for the period 1998-2020 have been utilized in the study, and logarithmic transformations have been applied to all series. The agricultural gross domestic product (GDP) value has been employed as an indicator of economic growth in the agricultural sector. Also, total energy consumption in the agricultural sector, which is measured in tera joules, has been added to the model as an indicator of energy consumption. Moreover, total greenhouse gas emissions from the agricultural sector, which is measured in million tons, have been used as an indicator of greenhouse gas emissions. the investigation has focused on whether the variables contain unit roots by applying Augmented Dickey-Fuller (ADF) unit root tests to each variable in this context. To determine the short and long-term relationships between variables identified as stationary at different levels, the Autoregressive Distributed Lag (ARDL) boundary test approach and the Vector Error Correction Model (VECM) have been employed.

As a result of the study a cointegration relationship has been identified between energy consumption and agricultural GDP in the agricultural sector in Turkey according to the findings of the ARDL boundary test approach in the long run. When energy consumption in the agricultural sector increases by 1%, the agricultural gross domestic product (GDP) value increases by 0.24%. The short-term error correction coefficient has been found to be negative and statistically significant. This result indicates that the error correction mechanism is operating. To put it differently, short-term imbalances are corrected within 1.67 periods. Moreover, it has been determined that greenhouse gas emissions in the agricultural sector have a positive and significant impact on agricultural GDP. The effect of greenhouse gas emissions on agricultural GDP is noteworthy. When examining the long-term findings, it has been concluded that a 1% increase in greenhouse gas emissions leads to a 0.75% increase in agricultural GDP. Also, the results of the study indicate that greenhouse gas emissions affect agricultural GDP more than energy consumption. As a result, it is considered necessary to reduce the use of fossil fuels in agricultural production and increase the emphasis on environmentally friendly renewable energy sources. Furthermore it is suggested to enhance incentives for the use of smart agricultural technologies in the agricultural sector; promote the widespread use of energy-efficient buildings, machinery and equipment; implement energy management systems to optimize energy use, and organize national education programs on energy efficiency.

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