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Agriculture and Environmental Kuznets Curves in the case of Turkey: evidence from the ARDL and bounds test

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Abstract: The paper empirically analyses the long run relationship between agricultural performance and the carbon dioxide emission in Turkey by using the annual data covering 1968–2010. The Bounds test approach for the co-integration and ARDL (Autoregressive Distributed Lag) method are employed to show the existence of long-term relationship between the carbon dioxide emission and its determinants in this country. The results consistent with the Environmental Kuznets Curves (EKC) hypothesis show that the real GDP has a significant positive impact on the carbon emission and its square has a significant negative impact on the carbon emission both in the short run and long run. The results also show that agriculture has a significant negative impact on the carbon dioxide emission level in both periods. Consequently, the findings suggest that the policies or reforms that are increasing or supporting agricultural production may help to decrease the carbon dioxide emission levels of the countries.

Keywords: EKC, growth, CO_2 emission, ECM

Environmental economics is a growing field for both scientists and economists. The trending topics in this field are climate changes, increased temperature, and global warming caused by the increased greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). According to the World Bank (2012), agriculture is responsible for 15–35% of the global GHG emissions depending on whether it causes deforestation or not. On the other hand, agriculture sector and its development are very important for both developed and developing countries, like it is seen in Turkey with its climate, ecological and geographical conditions. According to the Ministry of Food Agriculture and Livestock of Turkey (2013), Turkey is among the top five with 30 products in the world agricultural product and with 20 products in exports in 2012, and the government defined the agriculture as a competitive and strategic economic sector rather than a social sector. From this point of view, the aim of this study is to determine how the Environmental Kuznets Curves (EKC), which examine the relationship between pollution (CO_2 emission) and economic development, are affected by agricultural sector in Turkey. According to the EKC hypothesis, higher income levels aid the economy transition from an agricultural economy to an industrial economy, which leads to higher emissions. After some time, economies with a higher income start to concentrate on service production rather than industrial production, which causes the reduction in emissions.

The environmental pollution and economic growth relation is examined in the literature many times by researchers and policy makers, especially after the 1990s. However, the relationship between environmental pollution and economic growth regarding specific sectors of the economy did not get enough attention, as it can be seen in the agricultural sector. The agricultural industry plays a crucial role for providing foods to societies on both developed and developing countries. While agriculture directly or indirectly contributes to these fields through different channels, such as creating investment opportunities, providing employment opportunities, stimulating other related industries etc., it is also very important in the terms of environmental deterioration due to the increasing energy consumption, land use, and affecting the carbon dioxide (CO_2) emissions. The expected environmental impacts of the overexpansion of agriculture may come up due to a higher energy consumption, the increased demand for raw materials, water and land use, on the other hand, it may decrease the CO_2 emission compared with the industrial sectors.

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In this regard, the researchers and/or policy makers, also engineers, managers and economists, have a great interest in the possible environmental impact of agriculture as well. Therefore, this research would be an improvement in agriculture and environment literature.

The literature focuses on two different approaches, while analysing the link between environmental pollution (as proxied by carbon dioxide (CO_2) emissions) and economic growth by using the Environmental Kuznets Curve (EKC), which hypothesized a conversed U shaped relationship between the environmental pollution and income growth. The first group of studies focuses on the economic growth and pollution nexus (Heil and Selden 1999; Halicioglu 2009; Soytas and Sari 2009; Shahbaz et al. 2013). Akbostanci et al. (2009) have investigated the relationship between income and environmental quality in Turkey for the years from 1968 to 2003 and the results concluded that there is an increasing relationship between CO_2 and income in the long run.

The second group of the studies emphasizes the link between the energy consumption and the economic output level of countries. Then, in turn it is expected to have a higher pollution mainly caused by the increasing energy used due to its nature based on fossil fuels that are the source of CO_2 emissions (Richmond and Kauffmann 2006; Pao and Tsai 2010; Alam et al. 2012; Dagher and Yacoubian 2012; Saboori and Sulaiman 2013). Most of the studies prove a significant relationship between the output level and energy consumption, the direction of the causality between them still remain unclear and varies from country to country depending on the time period and the methodology used in the studies.

This article uses the bound test approach to determine level relationship whether there existed a co-integration to examine the long run equilibrium relationship between the expansion of the agriculture sector and CO_2 emission in the case of Turkey, which is a candidate country to the European Union and emerging economy with a significant energy consumption and CO_2 emission in recent years.

Among the studies regarding Turkish economy, that of Gojayev et al. (2012) analysed the energy consumption, environmental quality, and the growth rate relationship of Turkey by using the ARDL bounds test for Turkey over 1970–2007, and found that reduction in the energy consumption reduces the growth rate of the country.

As mentioned above, the numbers of the studies in the literature about the impact of agriculture sector on growth and the energy consumption level are very limited. The common belief is that the environmental conditions (such as global warming, drought, and humidity) affect agriculture, and in turn, agriculture may effect environment by generating greenhouse gases through the direct use of fossil fuels, and indirectly by the use of energy. On the other hand, Pretty (2008) and Walls (2006) mentioned that agriculture may be an accumulator of carbon when the organic waste is aggregated in the soil, and when it is used as an energy source that substitutes for fossil fuels, thus avoiding carbon. The authors also concluded that the sustainable agriculture outcomes could be positive for the food productivity, reduced pesticide use and carbon balances. Onder et al. (2011) classify the effects of agricultural practices on environment under two main headings: the negative effects coming from the pesticide usage, chemical fertilizer usage, irrigation, soil tillage, plant hormone usage, stubble burning and animal wastes. Then, they mentioned that agriculture also has positive effects such as providing kinds of natural life, increasing oxygen production in the atmosphere through photosynthesis. According to the report regarding the world agriculture written by the Food and Agriculture Organization of The United Nations (2012), in the case of using the sustainable production methods, the negative impacts of agriculture on the environment can be attenuated in the long-term and actually, in some cases agriculture can play an important role in reversing them by storing carbon in soils. Another study by Stolze et al. (2000) explains the reasons of positive effects of organic farming on CO_2 emissions with (i) lower use of high energy consuming feedstuffs (ii) lower input of mineral fertilisers (iii) elimination of pesticides (p. 56). They also mentioned that there is no research available, which analysed the net balance of CO_2 emissions in agriculture.

However, this paper concentrates on the impact of the sector in CO_2 emission level of Turkey within the framework of the EKC hypothesis. Therefore, to our knowledge, the method used in this study would provide a new framework for the aim of the study due to including the agriculture proxy through embedding the EKC hypothesis. The study may be unique and important for the policy makers in Turkey as well, due to the country specific factors related to its demand for energy and the process of new reforms as a candidate country to the EU membership.

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THEORETICAL SETTING

Kuznets (1955), at the 67th annual meeting of the American Economic Association (AEA) in 1954, suggested that an increase in the per capita income leads to a higher-level income inequality at first, but then, after some turning point, it starts declining. This relationship is represented by an inverted U shaped curve known as the Kuznets Curve. In 1991, Grossman and Krueger (1991) used the Kuznets Curve to describe the relationship between the measures of economic growth (per capita income) and the measured levels of environmental pollution. The results show that the per capita income and environmental deterioration follow the same path (inverted U shaped) as does the income inequality and economic growth in the original Kuznets Curve. Therefore, this relationship between economic growth and environmental quality is known as the Environmental Kuznets Curve (EKC) in the literature. The EKC relationship suggest that the environmental damage increases due to a greater use of natural resources and relatively dirty technologies until the average income reaches a certain point, but then, the quality of life and environment improve.

While testing the existence of the EKC, CO_2 (carbon dioxide) emissions (kt) are used as a proxy of the environmental quality or pollution in the studies of the relevant literature. The main aim of this study is to test hypothesis that the agricultural sector could be the reason of environmental pollution (CO_2 emission level) for Turkey. Considering the EKC hypothesis as mentioned in the literature, the real income and energy consumption, as other determinants of CO_2 emission, are also included in this analysis

From these points of view in the literature, it would be right to use energy as a determinant of the CO_2 emission, with the real income. Therefore, the expansion of the agricultural sector is expected to increase the real income and energy used through different stages of its process and in turn, it would affect the environmental quality or the pollution level of the country.[1]

The following agriculture-induced EKC model can be suggested in the present study:

$$CO2 = f(GDP, GDP2, E, A) \tag{1}$$

where $CO2$ denotes the carbon dioxide emissions (kt), E represents the energy consumption (kt of oil equivalent), GDP is the real income, $GDP2$ is the square of real income, and A stands for the agricultural proxy.

The agriculture-induced EKC model in Equation (1) can be expressed in the logarithmic form to capture the growth impacts in the economic long-term period:

$$LCO2_t = \beta_0 + \beta_1 LGDP_t + \beta_1 LGDP2_t + \beta_3 LE_t + \beta_4 LA_t + \varepsilon_t \tag{2}$$

where at period t, $LCO2$ is the natural log of the carbon dioxide emissions, LE is the natural log of the energy consumption, $LGDP$ is the natural log of the real income, $LGDP2$ is the square of natural log real income, LA is the natural log of the agriculture proxy, and e is the error disturbance.

The dependent variable in Equation (2) may not immediately adjust to its long-term equilibrium level following a change in its determinants. Therefore, estimating the following error correction model can capture the speed of adjustment between the short-term and the long-term levels of the dependent variable:

$$\Delta LCO2_t = \phi_0 + \sum_{i=1}^{n} \phi_1 \Delta LCO2_{t-j} + \sum_{i=0}^{n} \phi_2 \Delta LGDP_{t-j} + \sum_{i=0}^{n} \phi_3 \Delta \mathrm{L}GDP2_{t-j} + \sum_{i=0}^{n} \phi_4 \Delta \mathrm{LE}_{t-j} + \sum_{i=0}^{n} \phi_5 \Delta LA_{t-j} + \phi_6 \varepsilon_{t-1} + u_t \tag{3}$$

where D represents a change in the CO2, E, GDP, GDP2, and ε_{t-1} is the one period lagged error correction term (ECT), which is estimated from Equation (2). The ECT (error correction term) in Equation (3) shows how quickly the disequilibrium between the short-term and the long-term values of the dependent variable (CO2) is eliminated each period. The expected sign of the ECT is negative.

[1]Drawing from previous researches and theories, especially considering the EKC, the following hypothesis were tested empirically in this study; (i) increase in the real income increases the CO_2 emission at early stages of growth (coefficient of GDP is expected to be positive), then (ii) after some point of time, the increase in real income decreases the CO_2 emission due to the change in environmental procedures and the change in production process (the coefficient of GDP2 is expected to be negative), (iii) higher energy consumption causes a higher CO_2 emission level (the coefficient of E is expected to be positive), and finally (iv) agricultural production as a share of the real income may negatively affect the CO_2 emission.

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This empirical paper uses the annual data covering the period 1968–2010. The carbon dioxide emissions (CO_2) (kt) are used as an environmental indicator in the model. As explanatory variables, the energy use (E) (kt of oil equivalent), the real GDP with the base year 2005 (2005 = 100) (GDP) and the squared constant GDP (2005 = 100) (GDP2) are taken into account. Additionally, the amount of agriculture (A) in Turkey is included in model. Data were obtained from the DataStream and the logarithmic forms of the variables were used in the analyses.

Although there are several alternatives to measure the agriculture proxy, such as the agricultural sector production indices or the land used in agriculture, the number of tractors or machinery in the agricultural sector, the agriculture variable of the present study was proxied by the real income from agriculture due to the data availability. On the other hand, from the most general form of the environmental Kuznets hypothesis in the literature, the environmental pollution variable is proxied by CO_2 emissions (kt) and energy use (kt of oil equivalent) is used as a measure of the energy consumption by in this study.

METHODOLOGY

To investigate the long run relationship between the variables, the bound test for co-integration with the ARDL modelling approach was adopted in this study. This model is recently developed by Pesaran et al. (2001) and provides some advantages in application; first, it can be applied even if the variables have a different order of integration (whether the regressors are integrated of order 1 and/or integrated of order 0); second, it is good to be preferred in small samples, while the Johansen approach for co-integration requires large data samples; and finally, it gives both the short run estimation with the error correction model and the long run estimations simultaneously. However, the main focus in this paper is to analyse the long run impact of Turkish agricultural sector on the CO_2 emission level of the country.

The ARDL approach has two stages. First of all, the long run relationship among the variables should be determined by using the bound test developed by Pesaran and Shin (1999). In the case of having any information on the direction of the relationship between the variables, the unrestricted conditional error correction model (UECM) is estimated in the bound test approach. While doing this, each variable is taken as a dependent variable and the UECM is defined as:

$$\Delta Y_t = \mu_0 + \mu_1 t + \lambda_1 Y_{t-1} + \sum_{i=1}^{4} \Theta_i V_{it-1} + \sum_{j=1}^{p} \gamma_j \Delta Y_{t-j} + \sum_{i=1}^{4}\sum_{j=0}^{p} \omega_{ij} \Delta V_{it-j} + \psi' D_t + \varepsilon_t \quad (4)$$

In this equation, $\boldsymbol{V_t}$ is the vector defined as $\boldsymbol{V_t}$ = (***LGDP, LGDP2, LE, LA***), $\boldsymbol{D_t}$ is the vector including exogenous variables such as the structural break dummies. Here, according to the Wald test, the null hypothesis asserts that there is no co-integration ($\boldsymbol{H_0}$: $\lambda_1 = \theta_1 = \theta_2 = \theta_3 = \theta_4 = 0$), while the alternative hypothesis asserts a long run relationship between the variables ($\boldsymbol{H_1}: \lambda_1 \neq \theta_1 \neq \theta_2 \neq \theta_3 \neq \theta_4 \neq 0$). While testing the null hypothesis, critical values provided by Pesaran et al. (2001) is used. They provide three different scenarios in their paper about the conclusions of the test results. When the calculated F statistics exceeds the upper bound critical value in the given significance, the null hypothesis is rejected and we can conclude that the variables have a long run relationship (co-integrated). In the light of the results, the ARDL approach to the estimation of level relations is adopted as below.

$$Y_t = \mu_0 + \sum_{j=1}^{p_i} \beta_j Y_{t-j} + \sum_{i=1}^{4}\sum_{j=0}^{q_i} \phi_{ij} V_{it-j} + \psi' D_t + u_t \quad (5)$$

Here, all variables are defined as above. The maximum of lags are determined by the Akaike Information Criteria (AIC) and the Schwartz Information Criteria (SIC) to determine the optimal ARDL specification. Then, the next step in the ARDL procedure is the estimation of the short run coefficients by using the conditional error correction model (ECM) as defined below:

$$\Delta Y_t = \mu + \sum_{j=1}^{p} \gamma_j \Delta Y_{t-j} + \sum_{i=1}^{4}\sum_{j=0}^{p} \omega_{ij} \Delta V_{it-j} + \vartheta ECM_{t-1} + \psi' D_t + \varepsilon_t \quad (6)$$

In this equation, whilst γ_j and ω_{ij} are the short-term parameters, ϑ shows the speed of adjustment through the long run equilibrium after a shock. The value of the speed of adjustment ranges between 0 (no convergence after a shock) and –1 (perfect convergence after a shock). The error correction term ($\boldsymbol{ECM_t}$) is defined in the following format:

$$ECM = Y_t - \hat{\beta}_0 - \hat{\beta}_1 LGDP - \hat{\beta}_2 LGDP2 - \hat{\beta}_3 LE - \hat{\beta}_4 LA \quad (7)$$

ECM_{t-1} is the error correction term and its sign must be negative and significant to ensure the convergence.

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Table 1. Unit Root Test Results

		Level		*First differences*	
		intercept	intercept & trend	intercept	intercept & trend
ADF	LCO2	–2.16307 (0)	–2.561395 (0)	–5.643853***(0)	–5.959869***(0)
	LGDP	–0.683098 (0)	–3.032990 (0)	–6.474824***(0)	–6.420911***(0)
	$LGDP^2$	–0.558317 (0)	–3.102052 (0)	–6.513925***(0)	–6.442881***(0)
	LE	–1.637790 (0)	–2.647038 (0)	–5.957666***(0)	–6.119246***(0)
	LA	–0.413010 (0)	–6.832241***(0)	–12.26794***(0)	–12.10964***(0)
PP	LCO2	–2.284785	–2.549054	–5.634307***	–5.941343***
	LGDP	–0.694010	–3.127886	–6.475038***	–6.421276***
	$LGDP^2$	–0.561423	–3.200633	–6.515188***	–6.442333***
	LE	–1.699232	–2.647219	–5.957666***	–6.108593***
	LA	–0.132151	–7.074686***	–29.13224***	–28.79954***
KPSS	LCO2	0.827069***	0.187876**	0.339180	0.057188
	LGDP	0.827925***	0.063218	0.053044	0.034815
	LGDP2	0.827960***	0.051731	0.043417	0.034625
	LE	0.829020***	0.159787**	0.210001	0.050215
	LA	0.828017****	0.127978*	0.149808	0.181946**

*, ** and *** denote rejection of the null hypothesis at the 1%, 5% and 10% levels, respectively

To ascertain the goodness of fit of the ARDL model, the diagnostic tests are conducted to examine the heteroscedasticity, autocorrelation, and functional form associated with the model as well.

EMPIRICAL RESULTS

The Augmented Dickey Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) Unit roots tests are also employed to ensure that none of the variables are integrated of order 2 and the results are given in Table 1. According to the unit root test results, all variables are non-stationary at their levels but become stationary at their first differences, which means integrated of order 1.

Now, considering the stationary of variables in first differences for Turkey, Table 2 gives the bound test results for the co-integration between the LGDP, LGDP2, LE, LA and LCO2 under three different scenarios suggested by Pesaran et al. (2001). These are the model without deterministic trends (F_{iii}), the model with restricted deterministic trends (F_{iv}), and the model with unrestricted deterministic trends (F_v). This procedure starts with determining the appropriate lag order. The maximum lag order (p) is determined as 1 according to both the Akaike Information Criteria (AIC) results and the Schwartz Information Criteria (SIC) results. Therefore, the maximum lag length is set to 1. Then, by using the F statistics suggested by Pesaran and Shin (1999), the presence of the long run relationship in the model is tested. Since k = 4 (number of independent variables), the 0.05 critical value bounds are (2.86, 4.01), (–2.86, –3.99), (3.05, 3.97), (3.47,4.57) (–3.41, –4.36) for F_{iii}, t_{iii}, F_{iv}, F_v, and t_v, respectively. For p = 1, the tests lie outside the 0.05 critical value bounds and reject the null hypothesis, so that there exists no level equation in both cases without or with the deterministic trend. Hence, it can be concluded that there is the co-integration between the CO_2 emission and the independent variables.

Table 3 shows the results of the level equations (long run estimation) for the agriculture-induced EKC hypothesis. Coefficients of all variables in the equation have the expected sign and they are highly significant. Coefficients in the long run equation also represent the estimated long run elasticities

Table 2. Bound Test Results

			I(0)	I(1)
Without Deterministic Trends				
k = 4	F_{iii}	5.013962	2.86	4.01
	t_{iii}	–4.451562	–2.86	–3.99
With Deterministic Trends				
k = 4	F_{iv}	4.061947	3.05	3.97
	F_v	4.842953	3.47	4.57
	t_v	–4.203810	–3.41	–4.36

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Table 3. ARDL level equations

Variable	Level equation with constant				Level equation with constant and trend			
	Dependent variable: LCO2				Dependent variable: LCO2			
	coefficient	Std. Error	*t*-statistic	prob.	coefficient	Std. Error	*t*-statistic	prob.
LGDP	8.505030	2.200828	3.864468	0.0004	8.460986	2.275518	3.718268	0.0006
LGDP2	–0.145877	0.037476	–3.892539	0.0004	–0.144952	0.039281	–3.690142	0.0007
LE	0.451078	0.260385	1.732350	0.0913	0.455351	0.266271	1.710100	0.0954
LA	–0.482513	0.226077	–2.134287	0.0393	–0.480435	0.229219	–2.095962	0.0428
C	–113.7692	29.45717	–3.862189	0.0004	–113.2971	30.20012	–3.751545	0.0006

For the Level equation with constant model; R2 = 0.99, S.E. of Regr. = 0.0216, AIC = –4.7145, SBC = –4.5097, *F*-stat. = 8022.803, *F*-prob. = 0.000, DW stat. = 1.2096
For the Level equation with constant and trend model: R2 = 0.99, S.E. of Regr. = 0.0217, AIC = –4.6906, SBC = –4.4448, *F*-stat. = 6392.598, *F*-prob. = 0.000, DW stat. = 1.2473

of the respective variables. According to the EKC hypothesis, we are expecting a higher CO_2 emission at the lower levels of GDP, and then after a certain level of living standard, such as the per capita income, it started to decrease. Therefore, in line with the EKC hypothesis, whilst the expected sign for GDP is positive, the expected sign for GDP2 is negative. From the Table 3, the coefficients of these variables have a highly significant correct sign, and the results are supporting the EKC hypothesis. The coefficient of GDP is highly elastic and statistically significant (8.51 in the constant model; 8.46 in constant with the trend model; on both $p < 0.01$). And the coefficient of GDP square is negative (–0.15) and highly significant ($p < 0.01$) as well on both constant and constant with the trend model. These results are consistent with the inverted U-shaped EKC hypothesis. And also, energy used variable (LE) has the correct sign, positive (0.45) and significant ($p < 0.10$) in both models. This shows that the energy consumption has a long run relationship with the carbon dioxide emission at 10% significance level. The positive coefficient sign of the energy consumption reveals that an increase in energy used in the long run will increase the carbon dioxide emission in Turkey, as discussed in the introduction section of the study.

Table 4. Estimation of ECM with constant and short-term coefficients

Dependent Variable: DLNCO2				
Variable	Coefficient	Std. Error	*t*-statistic	Prob.
DLCO2(–1)	–0.083031	0.059581	–1.393578	0.1725
DLGDP	14.03127	3.086950	4.545349	0.0001
DLGDP2	–0.259047	0.057860	–4.477147	0.0001
DLE	0.924807	0.099625	9.282850	0.0000
DLA	–0.295350	0.071957	–4.104547	0.0002
C	–0.000511	0.004638	–0.110159	0.9129
ECMC(–1)	–0.703262	0.130763	–5.378159	0.0000
R-squared	0.910949	Mean dependent var		0.049719
Adjusted *R*-squared	0.895234	S.D. dependent var		0.052782
S.E. of regression	0.017084	Akaike info criterion		–5.147072
Sum squared resid	0.009924	Schwarz criterion		–4.854511
Log likelihood	112.5150	Hannan–Quinn criter.		–5.040537
F-statistic	57.96738	Durbin–Watson stat		2.069274
Prob (*F*-statistic)	0.000000			

Breush-Godfrey Serial Correlation LM test: $F(2, 32) = 0.1522$ ($p = 0.8594$); Heteroskedasticity Test: Breusch-Pagan-Godfrey: $F(6, 34) = 0.9680$ ($p = 0.4614$), Ramsey RESET test {residual squares}: $F(1, 33) = 1.0138$ ($p = 0.3213$)

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Table 5. Estimation of ECM with Trend and Constant and Short-term Coefficients

Dependent Variable: DLNCO2				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
DLCO2(−1)	−0.085160	0.059471	−1.431963	0.1613
DLGDP	14.06063	3.088609	4.552415	0.0001
DLGDP2	−0.259540	0.057887	−4.483542	0.0001
DLE	0.925573	0.099614	9.291595	0.0000
DLA	−0.295563	0.071969	−4.106792	0.0002
C	−0.000774	0.004653	−0.166267	0.8689
ECMT(−1)	−0.704366	0.130969	−5.378103	0.0000
R-squared	0.910948	Mean dependent var		0.049719
Adjusted R-squared	0.895233	S.D. dependent var		0.052782
S.E. of regression	0.017084	Akaike info criterion		−5.147062
Sum squared resid	0.009924	Schwarz criterion		−4.854501
Log likelihood	112.5148	Hannan–Quinn criter.		−5.040528
F-statistic	57.96678	Durbin–Watson stat		2.063880
Prob (F-statistic)	0.000000			

Breush-Godfrey Serial Correlation LM test: F (2, 32) = 0.1403 (p = 0.8696); Heteroskedasticity Test: Breusch-Pagan-Godfrey: F (6, 34) = 0.9274 (p = 0.4879), Ramsey RESET test {residual squares}: F (1, 33) = 1.0297 (p = 0.3176)

Other important variable that determines the CO2 emission (CO_2) of Turkey is agriculture in this study. It has a negative impact on the carbon dioxide emission with the coefficient –0.48 ($p < 0.05$) in both models, which suggests that 10% increase in the agricultural production would lead to 4.8% change in the carbon emissions in opposite direction. It means that an increase in the agricultural production in Turkey will lead to a lower level of CO_2 and pollution in turn. However, this study does not explain the reason of this relationship between agricultural production and CO_2 emission. It might be due to the agricultural production diversity, a lower use of high energy consuming feedstuffs, a lower input of mineral fertilisers, and the elimination of pesticides etc. This should be examined in future studies.

The results of the ECM regressions are also provided in Table 4 and Table 5. The ECT term is –0.70 and highly significant ($p < 0.01$) in both ECM regression with the constant and ECM regression with trend and constant. This means that carbon dioxide emission converges to its long-term equilibrium by 70% speed of adjustment through the channels of real income, energy consumption and growth in agricultural sector. The short-term coefficient of GDP is again positive (14.03), and statistically significant ($p < 0.01$) in both cases. Again, the short-term coefficient of the GDP Square is negative, as expected, (–0.26) and statistically significant ($p < 0.01$). This is another proof of the inverted U shaped EKC even in the short-term in Turkish economy. The coefficient of energy consumption is positive (0.92 and 0.93), and significant ($p < 0.01$). It is seen from the ECM model that the coefficient of agricultural production as an indicator of the agricultural sector has again the negative coefficient (–0.30), and is statistically significant ($p < 0.01$), even in the short-term.[2]

[2]Diagnostic tests for the serial correlation, functional form, and heteroscedasticity were also conducted and the results were also reported in Table 4 and Table 5. These tests include the Breusch-Godfrey Serial Correlation LM test (H_0 = No serial correlation in the residuals) (p-values are 0.8594 and 0.8696 for the models with constant and the model with constant and trend, respectively), the Breusch-Pagan-Godfrey Heteroskedasticity test (H_0 = Homoskedasticity) (p-values are 0.4614 and 0.4879 respectively), and the Ramsey RESET test (H_0: ε–N(0, σ^2 I), H_1: ε–N(μ, σ^2 I), $\mu \neq 0$) (p-values are 0.3213 and 0.3176 respectively). All statistics do not reject the null hypothesizes for the respective tests which means that the results show that the models are well specified; there is no autocorrelation and heteroscedasticity as well. All these results confirm that all necessary conditions for the short run ECM model are met. And also, the cumulative sum (CUSUM) procedure is employed to test the stability of the long run estimates. It indicates that the residuals fall within the 5% critical boundaries, which means that the estimated coefficients are stable at 5% level.

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CONCLUSION

The main aim of this study is to test the hypothesis that the agricultural sector could be the reason of environmental pollution (CO_2 emission level) for Turkey by using the bound test and the ARDL approach based on the annual data covering 1968–2010 period. The results of bound test confirm the co-integration between the variables consistent with the EKC hypothesis.

The main contribution of the paper is to analyse the impact of the Turkish agricultural sector by using the up- to- date sectorial data rather than focusing on only one variable related to the EKC in general. The focus of this paper is to see whether agriculture is the reason of the carbon dioxide emission in Turkey. The relationship between environmental pollution and economic growth with specific sectors in an economy did not get enough attention. Therefore, this research would be an improvement in the agricultural and environment literature.

The results indicate that in the long run, an increase in the agricultural output level would affect the carbon dioxide emission level in the opposite direction for Turkey. However, in this study only the carbon dioxide emission is considered due to the data availability. The emission of other GHGs such as the nitrous oxide (N_2O) and methane (CH_4) or the land use and the number of machines used in agriculture, as a proxy of the agricultural sector could not be considered because of the lack of the data availability for Turkey.

The results conclude that a better agricultural management and changes in cropping patterns might contribute to a lower level carbon emission. Therefore, the projects that focus on the improved agricultural production, afforestation, and conservative organic farming can reduce net the volumes of CO_2 and thus play an essential role in mitigating the climate change. According to the Kyoto protocol for international agreement on stabilization of GHGs in the atmosphere, "the net change in greenhouse gas emissions by sources and removals by sinks resulting from direct human-induced land-use change and forestry activities, limited to afforestation, reforestation and deforestation since 1990, measured as verifiable changes in carbon stocks, shall be used to meet the commitments under this Article of each party". However, the protocol is unclear regarding the future potential of these settings. Therefore, the studies analysing the country specific efforts on agriculture and the GHGs emission may be used as a case study by some countries to learn from other positive experiences in these fields, like it is seen in Turkey. However, every country may have different carbon dioxide balances due to its agricultural structure.

As a result of this study, while the economic growth and energy consumption create significant shifts in the carbon dioxide emission levels of Turkey, now we know that the agricultural activities may help to reduce the CO_2 level in the atmosphere. From this point of view, countries may try to find appropriate policies and actions regarding their agricultural sectors to reduce the carbon dioxide emission, such as reducing the fuel consumption, choosing suitable crops and energy saving machineries, using fertilizers efficiently, and using alternative energy sources such as the solar and wind power etc. In terms of the future research, policy makers and scientists should focus on the specific evaluations in agricultural production and carbon dioxide to develop more reliable estimates for the CO_2 emission. It may also differ according to regional characteristics and crop diversification. Therefore, further studies need to be conducted on these differences and different kinds of GHG emissions from the agricultural production as well to understand how to minimize the impact of agriculture on the environment while maximizing the agricultural share of income.

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