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Does Increasing Number of Livestock Affect Climate Change? Evidence from Türkiye

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ABSTRACT

The Agricultural Sector is one of the sectors that cause the most significant greenhouse gas emissions due to using fertilizers, agricultural mechanization, paddy cultivation, and especially animal husbandry. Although the agricultural sector causes climate change, it is one of the sectors most affected by climate change. Reducing greenhouse gas emissions from agricultural production is essential for the sustainability of agriculture and the food security of people. This study analyzes long and short-term cointegration between agricultural greenhouse gas emissions and livestock activities in Türkiye using data covering 1990-2019. According to the analysis results, using the Autoregressive Distributed Lag (ARDL) bound testing method, a positive and statistically significant relationship was found between the number of cattle, bovine animals, poultry, and CO_2 emissions. In the long run, a 1% increase in the number of bovine animals (BA), sheep and goats (SG), and poultry (P) in Türkiye will increase CO_2 emissions by 0.87, 0.09, and 0.09%, respectively. In the short term, only a positive and significant relationship was found between the number of bovine animals and CO_2 emissions. These results reveal that policymakers should evaluate people's efforts to increase animal production to ensure food security and policies to reduce greenhouse gas emissions.

Hayvan Sayısında Artış İklim Değişikliğini Etkiler mi? Türkiye Örneği

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ÖZ

Tarım sektörü; gübre kullanımı, tarımsal mekanizasyon, çeltik yetiştiriciliği ve özellikle hayvancılık nedeniyle en önemli sera gazı salınımına neden olan sektörlerden birisidir. Tarım sektörü iklim değişikliğine neden olmakla birlikte iklim değişikliğinden en çok etkilenen sektörlerin başında gelmektedir. Tarımsal üretimden kaynaklı sera gazı salınımının azaltılması tarımın sürdürülebilirliği ve insanların gıda güvencesi açısından önemlidir. Bu çalışmada Türkiye'de tarımsal sera gazı emisyonu ile hayvancılık faaliyeti arasında uzun ve kısa dönemli eşbütünleşme, 1990-2019 yıllarını kapsayan veriler kullanılarak analiz edilmiştir. Ayrıca, doğrudan hayvancılık faaliyetinden kaynaklı sera gazı emisyonlarını azaltma stratejileri tartışılmıştır. Autoregressive Distributed Lag (ARDL) bound testing yöntemi kullanılarak yapılan analiz sonuçlarına göre, büyükbaş hayvan sayısı, küçükbaş hayvan sayısı ve kümes hayvanları sayısı ile CO_2 salınımı arasında pozitif ve istatistiki olarak anlamlı bir ilişki bulunmuştur. Uzun dönemde, büyükbaş, küçükbaş ve kümes hayvanı sayısında meydana gelecek %1'lik bir artış

CO_2 salınımında, sırasıyla %0.87, %0.09 ve %0.09'luk bir artışa neden olmaktadır. Kısa dönemde ise sadece büyükbaş hayvan sayısı ile CO_2 salınımı arasında pozitif ve anlamlı bir ilişki bulunmuştur. Bu sonuçlara göre, insanların gıda güvencesi sağlamak için hayvansal üretimi artırma çabalarını sera gazı salınımını azaltacak politikalar ile birlikte değerlendirmesi gerektiği ortaya çıkmaktadır.

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1. Introduction

Global warming and the resulting climate changes are important problems that closely concern all countries in terms of their effects and consequences. The main reason for global warming is seen as the increase of greenhouse gas (GHG) concentration in the atmosphere above the required level due to economic activities.

The agriculture sector is among the main sectors affected by climate change. Agriculture has an important place especially in the economies of developing countries in terms of national income, employment, foreign trade, and agriculture-based industry. Also, the agricultural sector is very important in terms of food security, as it is a sector that produces essential foodstuffs for people.

Climate change changes crop yield and amount, production cost, agricultural losses, harvest time, grazing efficiency in terms of meadows and pastures. In animal production, on the other hand, it affects animal deaths, feed consumption rate, live weight gain, milk production, pregnancy rate, and therefore production costs.

The livestock sector undergoes considerable negative climate effects in animal productivity, yields of forage and feed crops, animal health and reproduction, and biodiversity. Climate change weakens food security, nutrition, poverty reduction, and sustainability (FAOFao, 2017a).

The agricultural sector is both affected by climate change caused by greenhouse gas emissions and agricultural activities that cause greenhouse gas emissions. On the one hand, it is a dilemma to engage in agricultural production with the use of more inputs to ensure food security, and on the other hand, to endanger food security by increasing climate change through greenhouse gas emissions.

Food security is defined as people's continuous physical and economic access to sufficient, healthy, safe, and nutritious food to meet their nutritional needs for a healthy life. There are four dimensions of food security and these four dimensions must be provided simultaneously for food security: These are food availability, access to food, food utilization, and stability of food supplies. Climate change weakens the four dimensions of food security in different ways (FAOFao, 2017a).

Due to the loss of yield in plant and animal production, food availability will be endangered, and while the global food demand will increase, it will cause an increase in international food prices. Climate change will create problems in terms of food access by affecting the purchasing power of consumers, especially poor people. Climate change affects food utilization with its impact on food safety. Often, climate change reduces food security due to the rise of foodborne diseases. In terms of stability of food supplies, food and nutrition security worsens as agricultural production is negatively affected as a result of the frequency and increase of climate-related events (excessive precipitation, drought, flood, etc.). Climate change is directly affecting the diet of millions of people, undermining current efforts to address malnutrition and hitting the poor most, especially women and children.

The agricultural sector is considered an important source of GHG emissions because agricultural techniques are not sustainable enough to improve productivity and enhance food security. Therefore, the agriculture sector has responsibilities toward reducing its greenhouse gas emissions while ensuring food security.

Effects of climate change are observed by the concentration of GHG for many sectors including agriculture which generally comes second in size after the energy sector. GHGs such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are counted among the causes of climate change as a result of agricultural activities. When all sectors are considered in general, the most problematic greenhouse gas is CO_2. In terms of the agricultural sector, on the other hand, CH_4 in animal production and N_2O in plant production are the most important greenhouse gases. The energy used during agricultural activities and the processing and transportation of agricultural products is the main source of CO_2 emissions.

Agricultural greenhouse gas emission sources can be listed as enteric fermentation, manure management, rice cultivation, synthetic fertilizers, manure applied to soil, manure left on pasture, crop residues, burning-crop residues, drained organic soils, and energy use.

It is possible to observe that enteric fermentation (39.8%) originating from animal husbandry ranks first among agricultural greenhouse gas emissions in the world. It is followed by manure left on the pasture (15.5%), chemical fertilizer consumption (12.2%), rice cultivation (10.2%), and manure management (6.8%) (FAO, 2021). Enteric fermentation and manure left on the pasture in the first two ranks show that the livestock sector is the most important source of agricultural greenhouse gas emissions.

The total emission value calculated for agriculture is 68 million tonnes (Mt) CO_2 equivalent for the year 2019 which is 13.4% of all emissions in Türkiye. The overall emission value for agriculture increased 47.7% during the 30 years after 1990. The biggest increase among categories for the emissions is observed in the enteric fermentation category, where the emissions increased by around 49% for the same period. Emissions for rice cultivation increased by around 162.6% whereas the emissions for field burning of agricultural residues decreased by 52.5% between 1990 and 2019 (TURKSTATTurkstat, 2021).

Furthermore, the biggest category in agriculture is enteric fermentation with a 49.1% share for 2019. Manure management's share shows a more stable increasing trend, starting from 11.8% in 1990 and reaching 13% in 2018 before falling back to 12.6% in 2019 while having an average of 12.1% for all years. For 2019, the remaining categories, which are rice cultivation, field burning of agricultural residuals, and urea application, had emission shares of 0.4%, 0.2%, and 1.9%, respectively (TURKSTATTurkstat, 2021).

Türkiye is increasing its number of animals to ensure animal food security of its population, however, GHG emissions are increasing every year due to the increase in its production level. The main objective of this study is to examine the short and long-run cointegration between climate change and livestock numbers in Türkiye over the period 1990 to 2019. Therefore, this study focuses on the following questions: a) Does Türkiye's increasing livestock number have a positive (or negative) impact on its CO_2 emissions? b) Which of the bovine animals, sheep and goats, and poultry has taken as variables in the study cause more CO_2 emissions?

This study also aims to recommend policies to reduce the impact of livestock on environmental pollution in Türkiye. On 11 December 2019, the European Union adopted the European Green Deal as a strategy for transforming the economy into a resource-efficient and competitive economy to combat climate change and that strategy will ensure that there are no net greenhouse gas emissions until 2050, economic growth will be decoupled from resource use, and no person and no place will be left behind. Türkiye strives to adapt to this strategy of the EU, which is the most important trade and investment partner. Also, at a time when Türkiye has just approved the Paris agreement dated November 4, 2016, there is a need for policies to reduce greenhouse gas emissions in the agricultural sector, as in every sector.

2. Methodology

In this study, An Autoregressive Distributed Lag (ARDL) model was used to determine the effect of the number of bovine animals, sheep and goats, and the number of poultry in the short and long term on CO_2 emissions and therefore climate change.

In order to determine the effect of bovine animals, sheep-goats and poultry on agricultural GHG emissions, the time series covering the years 1990-2019 was taken from the Turkish Statistical Institute (TURKSTAT) database. GHG emissions are calculated by TURKSTAT using the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines. As the dependent variable, CO_2 emission, which is an indicator of environmental pollution and climate change, was used. CO_2 emission values represent the total equivalent of CO_2, CH_4 and N_2O gases resulting from enteric fermentation, manure management, rice cultivation, synthetic fertilizers, manure applied to soil, manure left on pasture, crop residues, burning-crop residues, drained organic soils and energy use.

While CO_2 was used as the dependent variable, three variables were used as independent variables: the number of bovine animals (BA), the number of sheep and goats (SG), and the number of poultry (P) (Table 1).

Table 1. Description of the variables used in this study

Variables	Units	Descriptions	Data Sources
CO_2	Million tonnes	CO_2 equivalent emissions by agriculture	TURKSTAT (a)
BA	Head	Number of Bovine Animals (cattle and buffaloes)	TURKSTAT (b)
SG	Head	Number of sheep and goats	TURKSTAT (b)
P	Head	Number of poultry (laying hens and broilers)	TURKSTAT (b)

The equation used to determine the effect of the number of animals on climate change was created as in Eq. (1).

$$CO_2 = f\,(BA, SG, P) \qquad (1)$$

The model in Eq (1) was rewritten and converted into the linear-logarithmic form (Eq.2).

$$ln\mathrm{CO}_{2t} = \beta_0 + \beta_1\, ln\mathrm{BA}_t + \beta_2\, ln\mathrm{SG}_t + \beta_3 ln\mathrm{P}_t + \varepsilon_t \qquad (2)$$

where $\ln CO_{2t}$ is the transformation of CO_2 emissions into the logarithmic form and $ln\mathrm{BA}_t$, $ln\mathrm{SG}_t$ and $ln\mathrm{P}_t$ are the logarithmic transformations of the selected independent variables in year t, β_0, β_1, β_2 and β_3 represent the long-run elasticities, and ε_t is the error term.

Time series approach was used as an econometric method in the study. In the research, firstly, logarithms of the series were taken to avoid fluctuations in the time series. Then, unit root tests were performed to test the stationarity of the time series. For this, Augmented Dickey-Fuller (ADF) and Philips-Perron (PP) unit root tests were used. After testing the stationarity, ARDL bounds test approach was used to investigate the existence and direction of the relationship between the series.

Tests such as Engle-Granger (1987) and Johansen (1988) are frequently used in the literature to test the concept of cointegration, which states that there is a stationary combination of at least two series that are not stationary at their levels. In these cointegration tests, there is an assumption that the series of which the cointegration relationship is examined are equally stationary. This prerequisite has become a situation that is not sought with the bounds test approach to cointegration analysis, which has been brought in the literature by Pesaran & Smith (1998) and Pesaran et al. (2001). Advantages of the bounds testing approach are: a) It is possible to apply the bounds test regardless of whether the variables to be used in the model are I(0) or I(1). For this reason, there is no need to determine the stationarity levels of the variables before applying the bounds test. However, since the critical values in the study of Pesaran et al. (2001) are tabulated according to whether the variables are I(0) or I(1), the variables should be tested against the possibility of being I(2). b) Since the unrestricted error correction model is used in the ARDL approach, it has better statistical properties than the Engle-Granger test and gives more reliable results in small samples than the Johansen and Engle-Granger tests (Narayan, 2004). c) it simultaneously provides both short- and long-term estimates.

ARDL bounds test approach consists of 3 stages. While testing whether there is a long-term relationship between the relevant variables in the first stage, long-term and short-term elasticities are obtained in the second and third stages, respectively, under the condition of the existence of a cointegration relationship (Narayan & Smyth 2006).

The ARDL regression analysis model employed can be specified as follows:

$$\Delta \ln(CO_2)_t=\beta_0+\sum_{k=1}^{n}\beta_{1k}\Delta \ln(CO_2)_{t-k}+\sum_{k=0}^{n}\beta_{2k}\Delta \ln BA_{t-k}+\sum_{k=0}^{n}\beta_{3k}\Delta \ln SG_{t-k}+\sum_{k=0}^{n}\beta_{4k}\Delta \ln P_{t-k}+\beta_5\ln(CO_2)_{t-1}+\beta_6\ln BA_{t-1}+\beta_7\ln SG_{t-1}+\beta_8\ln P_{t-1}+\varepsilon_t \quad (3)$$

In this model, Δ refers to the difference processor, β and n refer to the intercept term and the lag lengths, respectively, whereas εt is serially independent random errors with zero mean and constant variance (Eq.3). The optimal lags of the ARDL model are chosen based on the information criteria such as Schwarz information criteria or Akaike information criteria.

The ARDL bound test offers the possibility to test the cointegration between variables, based on F-test on the joint null hypothesis. H_0 hypothesis shows that there is no cointegration between variables while the H_1 alternative hypothesis indicates the existence of co-integration.

H_0: $\beta_5=\beta_6=\beta_7=\beta_8$

H_1: $\beta_5\neq\beta_6\neq\beta_7\neq\beta_8$

The null hypothesis is rejected in the case when the calculated F value is greater than upper critical bound while accepted when it is lower than the lower critical bound regardless of the integrated order I(0) or I(1). After it is understood that the model has a cointegration relationship, long-term and short-term models are formed.

Following equations, the short and long-run coefficients of ARDL model can be computed after the determination of long-term relationship among the variables. The long-term ARDL model used in this study is as follows (Eq.4).

$$\ln(CO_2)_t=\beta_0+\sum_{k=1}^{n}\beta_{1k}\ln(CO_2)_{t-k}+\sum_{k=0}^{n}\beta_{2k}\ln BA_{t-k}+\sum_{k=0}^{n}\beta_{3k}\ln SG_{t-k}+\sum_{k=0}^{n}\beta_{4k}\ln P_{t-k}+\varepsilon_t \quad (4)$$

An error correction model based on ARDL is used to determine short-term relationships between variables.

$$\Delta \ln(CO_2)_t=\beta_0+\sum_{k=1}^{n}\beta_{1k}\Delta \ln(CO_2)_{t-k}+\sum_{k=0}^{n}\beta_{2k}\Delta \ln BA_{t-k}+\sum_{k=0}^{n}\beta_{3k}\Delta \ln SG_{t-k}+\sum_{k=0}^{n}\beta_{4k}\Delta \ln P_{t-k}+\beta_5 ECT_{t-1}+\varepsilon_t \quad (5)$$

The Error Correction Term (ECT) in Eq.(5) shows how quickly disequilibrium between the short-term and long-term values of the dependent variable is eliminated in each period.

3. Results and Discussion

The descriptive statistics for the data used in this study are seen in Table 2. The descriptive statistics show the variables' mean, median, maximum and minimum values and standard deviations for 30 observations.

Table 2. Descriptive statistics of variables

	CO_2	Bovine Animals (BA)	Sheep and Goats (SG)	Poultry (P)
Unit	Million tonnes	Head	Head	Head
Mean	47.804	12 203 437	38 736 919	244 793 042
Median	44.585	11 583 000	38 269 898	245 028 350
Max	68.020	17 688 139	51 530 000	353 561 499
Min	37.610	9 788 102	26 877 793	96 676 000
Std.Dev.	7.9704	2 057 268	7 117 486	70 561 043
Observations	30	30	30	30

The trend of all the variables after the logarithmic transformation was applied is seen in Figure 1. As can be seen from the figure, there is a significant increase in agricultural CO_2 emissions, especially after 2002. In parallel with this, a significant increase was observed in the number of both BA and SG (Figure 1).

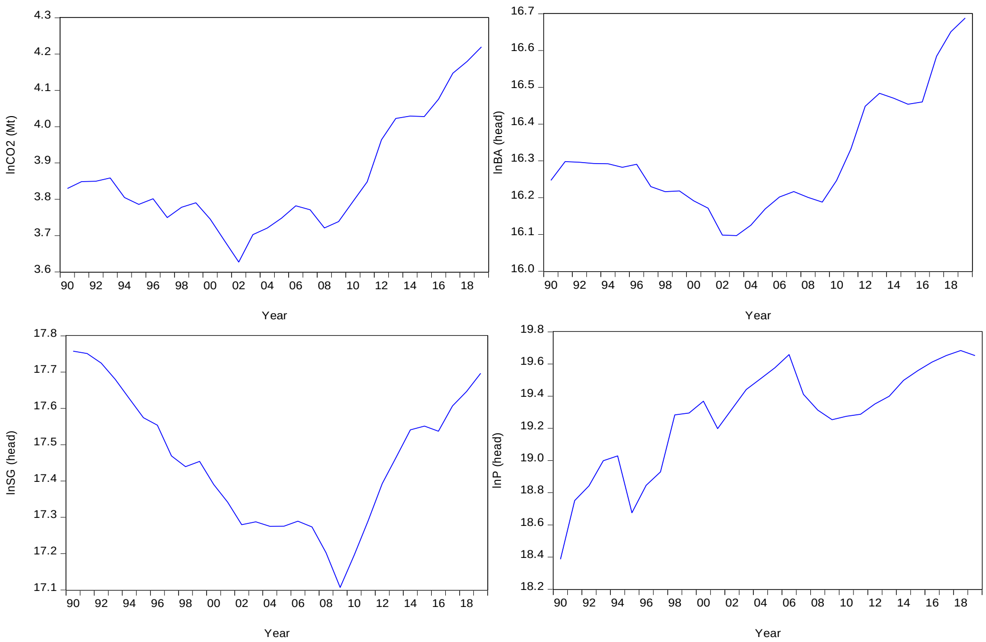

Figure 1- The trend of variables.

In the analyses performed on time series, the non-stationarity of the series leads to obtaining unreliable results among the variables. For this reason, Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) unit root tests, which are the most widely used methods to test the stationarity properties of the series, were used. Table 3 shows the results of the ADF and PP unit root tests.

Table 3. Results of Unit root test

	ADF at Level		ADF at First Difference		PP at Level		PP at First Difference	
	t-stat	*p value*	*t-stat*	*p value*	*t-stat*	*p value*	*t-stat*	*p value*
Intercept								
$lnCO_2$	1.2449	0.9977	-3.3377**	0.0226	1.2449	0.9977	-3.3377**	0.0226
lnBA	-2.6539	0.0979	-0.6859	0.8321	0.8055	0.9924	-2.9723**	0.0499
lnSG	-1.6283	0.4554	-2.5525	0.1146	-1.4328	0.5525	-2.5466	0.1158
lnP	-2.7617	0.0763	-5.4531***	0.0001	-2.8457	0.0644	-8.8426***	0.0000
Trend and Intercept								
$lnCO_2$	-0.3883	0.9832	-4.1437**	0.0154	-0.0898	0.9926	-5.1060***	0.0016
lnBA	-3.1913	0.1117	-4.4720***	0.0077	0.2241	0.9970	-5.7158***	0.0004
lnSG	0.01739	0.9945	-3.7165**	0.0378	-0.0457	0.9934	-3.6192**	0.0462
lnP	-2.6494	0.2634	-5.3547***	0.0009	-3.1850	0.1071	-9.9105***	0.0000

*** Significance at the 1% level, ** Significance at the 5% level.

The results of both the ADF and PP tests show that the null hypothesis of the unit root cannot be rejected at a 5% significance level. In other words, all variables have unit roots in their levels. Based on the unit root test results, all variables become stationary I(1) at their first differences, which means that all the variables are integrated of the I(1) series at 1% and 5% significance levels over the period of 1990–2019 (Table 2). Since the pre-condition of the ARDL model is fulfilled that none of the variables are integrated with I(2), cointegration between variables is examined by using the ARDL bound test.

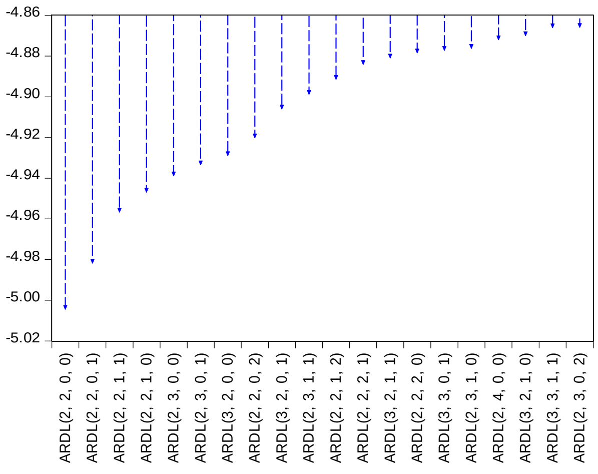

Figure 2. ARDL model selection criterion (AIC)

After unit root testing, which showed all variables are integrated at I(1), the ARDL method of cointegration to estimate the relationship between the variables was employed. The maximum number of lags in the ARDL was set equal to 4 and the optimal lag length was selected using the Akaike information criterion (AIC). Employing the AIC shows the top twenty possible ARDL models (Figure 2). According to Figure 2, the most suitable model was determined as (2, 2, 0, 0) model.

In the ARDL bounds test, it is necessary to determine the F-statistic to determine whether there is a cointegration relationship between the variables. The ARDL bound test proposed by Pesaran et al. (2001) is based on F-test on the joint null hypothesis. The ARDL bounds test cointegration test results are presented in Table 4.

The value of the F-statistic, which tests the long-term relationship between the variables, was found to be 7.112 (Table 4). This value was found to be greater than the critical upper limit values that were taken from both Pesaran et al. (2001)) and Narayan (2005) at the 1% and 5% significance levels. According to the results of the bound test, the null hypothesis of no cointegration association among variables is rejected. This result reveals that there is a cointegration relationship between the variables.

Table 4 - ARDL Bound Test

Test Statistic	Value	k	Sig.	Narayan critical values		Pesaran critical values	
				I(0)	I(1)	I(0)	I(1)
F-statistic	7.112***	3	10%	3.01	4.15	2.72	3.77
			5%	3.71	5.02	3.23	4.35
			1%	5.33	7.06	4.29	5.61

*** Significance at the 1% level.

The long-run and short-run model results of the cointegration relationship are included in Table 5. According to the long-run coefficients of bovine animals (BA), sheep-goat (SG) and poultry (P) have a positive and statistically significant impact on CO_2 emissions (Table 5). 1% increase in the number of BA, SG, and P in Türkiye will increase CO_2 emissions by 0.87, 0.09, and 0.09%, respectively.

In previous studies, positive correlations were found between livestock and CO_2 emissions (Sarkodie and Owusu, 2017; Appiah et al., 2018;Hongdou et al., 2018; Ullah et al., 2018; Doğan and Saçlı, 2019; Chandio et al., 2020 Balogh, 2020; Leitao and Balogh, 2020; Ali et al., 2021).

The results estimated by the ARDL model, which is based on the error correction model to examine the short-term relationship between the variables, are shown in Table 5. The important outcome of the short-run model is the calculation of the Error Correction Term (ECT). The lagged error correction coefficients ECT(-1) are significant in both cases verifying the established co-integrating relationships among the variables. As shown in Table 4, the ECT(-1) is negative and statistically significant at 1%. The results show that the speed of adjustment ECT(-1) value is −1.045. Narayan and Smyth stated that if the error correction coefficient is greater than -1, the system may fluctuate and reach its long-term equilibrium (Narayan and Smyth 2006).

Table 5 - Long-run and short-run coefficient estimates for the selected model ARDL (2,2,0,0)

Long-run model coefficients				
Variable	Coefficient	Std. Error	t-statistic	Prob.
LnBA	0.871727***	0.054622	15.95928	0.0000
LnSG	0.097658**	0.040834	2.391594	0.0267
LnP	0.092251***	0.020231	4.559996	0.0002
Short-run model coefficients				

Variable	Coefficient	Std. Error	t-statistic	Prob.
Δ ($LnCO_2$(-1))	0.249613	0.144984	1.721663	0.1006
Δ (LnBA)	0.921847***	0.100103	9.209008	0.0000
Δ (LnBA(-1))	-0.371527**	0.132545	-2.803028	0.0110
C	-14.46808***	2.530146	-5.718279	0.0000
ECT(-1)	-1.045180***	0.182734	-5.719688	0.0000

*** Significance at the 1% level, ** Significance at the 5% level.

The validity and robustness of the estimated equations are confirmed by employing such relevant diagnostic tests, such as the Jarque–Bera normality test, the Breusch–Godfrey serial correlation LM test, the Ramsey RESET test for model specification, and plots of the cumulative sum (CUSUM) and the cumulative sum of the square of the recursive residuals (CUSUMSQ).

Table 6 shows the diagnostic tests of the ARDL model. The serial correlation of the estimated ARDL model is tested by using the Breusch-Godfrey test. The test reports the p-value of 0.7167, which indicates to accept the null hypothesis of no serial correlation at all conventional levels of significance. The result from the Breusch-Pagan Test for heteroskedasticity has an LM statistic with a p-value as 0.4803 demonstrating that the LM statistic is insignificant at a 5 percent level of significance. Since the null hypothesis of constant variance is not rejected, there is no heteroscedasticity problem. The Jarque–Bera value with a p-value of 0.6891 shows that the residuals are normally distributed. The Ramsey test confirms the correct functional form of the model.

Table 6 - Diagnostic test results of the ARDL model

Tests			
Heteroskedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	0.9679	Prob. F (7,20)	0.4803
Breusch-Godfrey Serial Correlation LM Test			
F-statistic	0.3393	Prob. F (2,18)	0.7167
Jarque-Bera Test of Normality			
Jarque-Bera	0.7447	Prob.	0.6891
Ramsey RESET Test			
F-statistic	2.3095	Prob. F (1,19)	0.1451

The plots of parameter stability tests, namely CUSUM and CUSUMSQ, are given in Figure 3. Since the CUSUM and CUSUMSQ plots are within the 5% critical bound, the estimated parameters do not have structural instability over the period of the study, so they are constant or stable within the sample considered. According to the test results, the ARDL model is accepted as robust, stable, and reliable in its form.

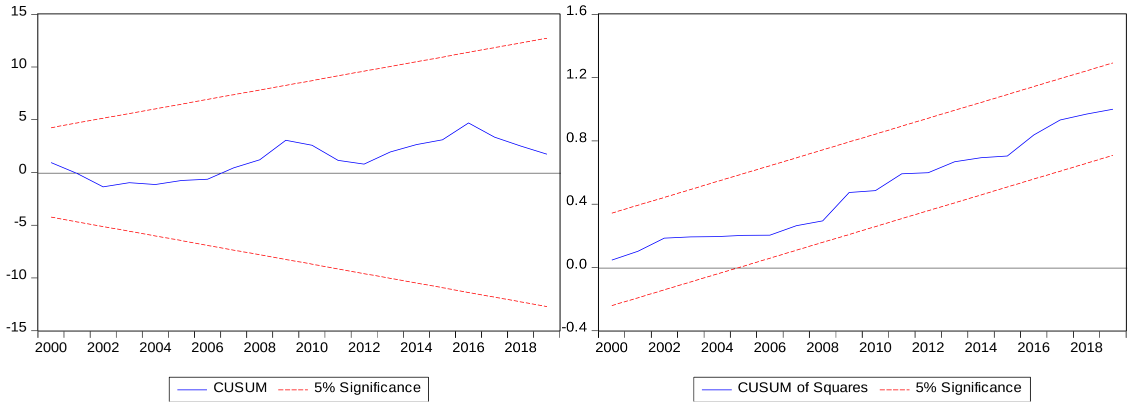

Figure 3.Plots of CUSUM and CUSUMSQ

4. Conclusions

This study aims to explain the relationship between animal stock, which has increased in recent years, and climate change to ensure animal food security in Türkiye. For this purpose, the ARDL bound test method was used with the data covering the period 1990-2019, and long and short-term cointegration were determined. According to the results of the analysis, a positive and statistically significant relationship was found between the number of bovine animals, sheep-goats and poultry and CO_2 emissions. In other words, the increase in the number of animals (especially the number of bovine animals) increases CO_2 emissions.

Several measures and policies are needed to reduce the effects of livestock activities on climate change. Some recommendations regarding these policies and measures are presented below.

Food loss and waste is very important problem in the world and Türkiye. Reducing food loss and waste is seen as an important way to reduce production costs and increase the efficiency of the food system, improve food security and nutrition, and contribute to environmental sustainability. Reducing food loss and waste is important because it will reduce GHG emissions, slow down the destruction of nature through land conversion and pollution, and increase food security. Climate change mitigation efforts must find ways to reduce food losses and waste in Türkiye and around the world. Reducing food losses and waste must be considered as an important part of climate change adaptation strategies. Improving the efficiency of food systems can be identified as an important way of reducing GHG emissions from the food and agriculture sector without compromising food security

Enteric fermentation originating from livestock is the most important source of agricultural GHG emissions with a share of 49%. While the number of animals worldwide is increasing, GHG emissions from animal production will inevitably continue to increase unless improvements are made to enhance nutrition practices. One of the methods to reduce CH_4 emissions in enteric fermentation is to use feeds more efficiently in livestock. Also, emissions from enteric fermentation can be reduced by adding special additives to the feed and long-term management changes. Many studies are conducted to improve animal nutrition, such as feeding animals with sunflower seeds or adding fat to the diet. Such applications seem promising for reducing enteric fermentation.

Improvements in manure management also play an important role in reducing emissions from livestock. Composting, biogas production, and storage of CH_4 can be considered as an important emission reduction strategy when evaluated in terms of animal waste amounts in Türkiye.

Instead of increasing the number of animals, focusing on improvement to increase milk and meat yield per animal will contribute to reducing emissions.

Carbon pricing is considered an effective tool in achieving the Paris Climate Agreement's goals on reducing global climate change. Carbon pricing is based on applying a direct price to GHG emissions. However, considering the importance of the agricultural sector, It is appropriate to offer subsidies that encourage sustainable agricultural techniques instead of punishing farmers who cause GHG emissions using carbon pricing. For this purpose, carbon pricing revenues from other sectors can be used. Policymakers should demand climate change adaptation measures from farmers but must consider local conditions. Policymakers should educate farmers to cope with climate change.

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