



Agricultural Total Factor Productivity in Türkiye: An ARDL Analysis of Macro-Institutional Drivers

Türkiye’de Tarımsal Toplam Faktör Verimliliği: Makro-Kurumsal Unsurların ARDL Yaklaşımıyla Analizi

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Abstract: *This study examines the determinants of agricultural total factor productivity (TFP) in Türkiye over the period 1991–2022 using the ARDL approach. The analysis incorporates agricultural credit, agricultural CO₂ emissions, human capital (average years of schooling), urbanization, and agricultural value added as explanatory variables. The Bounds test confirms the existence of a cointegration relationship among the variables. The long-run ARDL model results show that agricultural credit and urbanization have negative effects on TFP, while human capital and agricultural value added contribute positively. These signs are also confirmed by the short-run ARDL model. The empirical results indicate that agricultural CO₂ emissions are insignificant in the long run but exert a negative short-run effect, reflecting temporary stress and inefficiencies. Overall, the study provides important policy insights, emphasizing the need for financial reforms, human capital development, rural revitalization, value-chain strengthening, and climate-smart practices to sustain agricultural productivity growth.*

Keywords: *Agricultural productivity, Agricultural credit, Human capital, ARDL, Türkiye*

Öz: *Bu çalışma, 1991–2022 dönemi için Türkiye’de tarımsal toplam faktör verimliliğinin (TFP) belirleyicilerini ARDL yaklaşımıyla incelemektedir. Analizde tarım kredisi, tarımsal CO₂ emisyonları, insan sermayesi (ortalama eğitim süresi), kentleşme ve tarımsal katma değer açıklayıcı değişkenler olarak kullanılmıştır. Bounds testi, değişkenler arasında uzun dönemli bir eşbütünlük ilişkisinin varlığını doğrulamaktadır. Uzun dönem ARDL model sonuçları, tarım kredisi ve kentleşmenin TFP üzerinde olumsuz etki yaptığını, insan sermayesi ve tarımsal katma değer ise olumlu katkı sağladığını göstermektedir. Söz konusu etkiler, kısa dönem ARDL modelinde de doğrulanmıştır. Ampirik sonuçlar, tarımsal CO₂ emisyonlarının uzun dönemde anlamsız olduğunu, ancak kısa dönemde geçici stres*

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ve verimsizlikleri yansıtarak olumsuz etki yaptığını göstermektedir. Genel olarak, çalışma tarımsal verimlilik artışının sürdürülebilirliğini sağlamak için finansal reformlar, insan sermayesinin geliştirilmesi, kırsal kalkınmanın güçlendirilmesi, değer zincirlerinin iyileştirilmesi ve iklim dostu uygulamaların teşvik edilmesi gerekliliğini vurgulayan önemli politika içgörülerini sunmaktadır.

Anahtar kelimeler: *Tarımsal verimlilik, Tarım kredisi, Beşerî sermaye, ARDL, Türkiye*

Introduction

Agricultural production adds not just a dimension of economic growth but also a crucial aspect of social welfare, rural resilience, and environmental sustainability. As in many developing countries, the agricultural sector of Türkiye plays a significant role in employment and rural development. However, during the past years, this sector has faced multiple risks resulting from issues like climate change, increasing input costs, rural–urban migrations, a sluggish structural transformation, and lacking adaptive policy measures (TEPGE, 2024). In particular and irrespective of the rising production costs, the waning real efficacy of support policies against inflation has negatively impacted production patterns, productivity horizons, as well as producer behavior.

Türkiye's agricultural sector has also experienced significant structural reform since the 2000s through reform initiatives; yet many of the reforms failed both to improve producer incentives and guarantee the sustainability of productivity. In particular, the Agriculture Law of 2006 requires that the budget spent on agriculture should at least account for 1% of the GDP; yet the target has always failed and reached only 0.22% as of 2024 (Bobat, 2024). Within this context, governmental support insufficiency, payment lags, and failure to respond promptly to market changes created pressures leading producers to make suboptimal decision aspect and therefore lowered agricultural productivity (Merdan, 2024).

As well as these structural issues within agriculture, new issues of decision making for production have arisen due to climate change and environmental pressures. Drought, insufficient rainfall, input-price volatility, and lack of technological shift bring the economic (Mercan & Özçelik, 2024) and social risks especially for the producers in strategic products like wheat as well. In contrast, agricultural insurance systems are not sufficiently widespread, and risk management tools are inadequate for producers with low levels of education (TARSİM, 2023). These multi-layered vulnerabilities in the sector threaten not only production but also the long-term sustainability of agricultural productivity.

The European Green Deal aims to reorganize the agricultural system toward higher environmental performance, energy efficiency, and circular production. In this context, Cerit and Olhan (2025) emphasize that candidate countries such as Türkiye need to improve their agricultural productivity and resource-use efficiency. Yet, the contribution of Türkiye to these policy processes is unfortunately rather insignificant due to a lack of tangible, focused, and trackable policy instruments. Market reports also show that self-sufficiency rates are declining for many products (e.g., sunflower: 51%, rice: 74%), dependence on imports is increasing, and structural interventions are not coming in time (TEPGE, 2024).

In this sense, evaluations based on qualitative criteria, not only in terms of production quantity but also in terms of total factor productivity, have gained importance for Turkish agriculture. TFP, which indicates efficiency of the inputs, i.e., labor, capital, land, and other aggregate variables used in production process of agriculture is the most important issue especially for sustainable development policies. It is important to simultaneously examine multiple, multidimensional drivers of agricultural productivity, if for no other reason than that the relevant factors are interdependent and this analysis can offer useful insights for understanding and solving these complex issues both in academic circles and in policy making.

This study empirically examines the major drivers of agricultural total factor productivity utilizing time series data from Türkiye during the period of 1991 until 2022. The developed model takes a number of independent variables namely the proportion of agricultural loans out of total loans, agricultural carbon dioxide emissions, average years of schooling (LHDI), the urban population growth rate, and the share of the agricultural sector of gross domestic product. Using analysis with the aid of the ARDL approach, both the short-run and long-run associations are established with a view to assessing the major policy implications regarding productivity. The aim of this work is to illuminate the intricate process involved with agricultural productivity from Türkiye and provide concrete suggestions with a view to assisting policymakers, particularly regarding rural financing, environmental friendliness as well as human capital formation.

Literature Review

The agriculture sector occupies a key place with regard to economic development, food security, as well as rural development while simultaneously being an issue of debate for resource utilization and production efficiency. Recent literature on Türkiye discusses the complicated dynamics of transformation at the sectoral level of agriculture with an emphasis on the term of total factor productivity. In such a case, the available body of scholarly work that addresses financial, technological, environmental, as well as demographic determinants of agricultural productivity assumes that the nature of the sector should be studied not only from the standpoint of production but also from the efficiency of input utilization.

A considerable amount of the initial research on agricultural productivity concentrated on examining variations in productivity performance over time. Within this framework, Kaya and Erdoğan Aktan (2011) assessed changes in Total Factor Productivity through the Malmquist productivity index methodology, utilizing data from 81 provinces in Türkiye covering the years 2000 to 2009. Their findings indicated that technological advancement constituted the primary driver of productivity growth, which averaged 23.3%, whereas technical efficiency experienced a decline of 6%. Likewise, a comparative examination conducted by Avcı and Kaya (2008) pointed out that Türkiye's TFP levels were below the average found among transition economies, attributing this disparity primarily to an absence of technical change and technological deficiencies. Both investigations underscore the necessity for structural reforms aimed at promoting the utilization of technology and enhancing producer education to safeguard the sustainability of productivity growth.

The examination of regional Total Factor Productivity variations is notably sparse within the Turkish academic literature. In an effort to address this shortfall, Tekiner-Moğulkoç and Şişman (2022) conducted an analysis of TFP changes utilizing the Malmquist index methodology. Their study encompassed 26 regions classified at the NUTS2 level for the timeframe spanning from 2006 to 2015, revealing a mean annual decrease of 2% in productivity across Türkiye. This reduction was predominantly linked to a technological regression of 2%, whereas improvements in technical efficiency were recorded at a modest 1%. The findings indicate that disparities in regional access to technology significantly influence productivity outcomes.

Research examining the economic and demographic factors related to productivity is particularly crucial within scholarly literature. In a paper exploring the case of BRICS-T countries, Aydınbaş (2024) examined the effects of urbanization, human capital stock, agricultural value-added employment metrics on Total Factor Productivity; results showed two-way causality between TFP and human capital stock as well as unilateral causality from urbanization towards TFP. Moreover, Yücel and Çalışkan (2021) carried out a study that specifically looked at Türkiye, finding that an increment of 1% of mechanization corresponds with a reduction of 0.56% of the employment rate of agriculture in the longer term but corresponds positively to employment increment concerning increased productivity within the short term. This case demonstrates that the impact of technological development on employment could change over time and that rural labor policies need to be established with consideration of such changing dynamics.

Research investigating the correlation between agricultural productivity and international trade examines the implications of global integration within the sector on productivity levels. Within this framework, a study by Otgun, Fulginiti, and Perrin (2024) revealed that an uptick in exports enhances total factor productivity, whereas a rise in imports diminishes productivity. Additionally, it was observed that, on a regional scale, the Marmara and Central Anatolia regions exhibit low productivity levels, in contrast to the Aegean and Black Sea regions, which demonstrate high productivity levels. These results suggest that foreign trade policies ought to be evaluated in conjunction with regional production capacities.

In their analysis of environmental factors' impact on farm productivity, Ürkmez, Sevim, and Çatık (2024) identified a nonlinear, structurally disturbed relationship between agricultural CO₂ emissions and value addition in agriculture; they reported that CO₂ emissions positively affect productivity while at the same time reporting that productivity negatively affects environmental quality. This two-way interaction highlights the need for policymakers to handle the balance between environmental sustainability and productivity extremely cautiously.

Uslu and Apaydın (2021), in analyzing the impact of agricultural support policies on productivity, found from a province-level study spanning the years 2002 to 2020 that nominal support had negative effects on production as well as on the use of land. When allowed for price variation in terms of exchange rate and purchasing power, however, it revealed a significant increase in productivity. This indicates that policy restructuring needs to shift focus from volume per se to efficiency. By a similar logic, Uzun (2009) concludes that the productivity of Türkiye's agriculture

falls short of that of the EU average and believes that such a problem could be met by structural rather than populist policies.

Upon comprehensive evaluation of these studies, it becomes apparent that the determinants of agricultural productivity encompass a broader spectrum than merely production techniques. These determinants span various domains, including support mechanisms, trade policies, urbanization, human capital, technological transformation, and environmental sustainability. The existing literature concerning total factor productivity typically concentrates on aspects such as production techniques, regional disparities, or support policies. Nevertheless, a considerable number of these investigations either emphasize unidimensional variable sets or are often limited to short-term evaluations. In this regard, the present study seeks to address this identified gap in the literature by utilizing time series data pertaining to Türkiye from 1991 to 2022 to explore the correlation between agricultural total factor productivity and multidimensional variables, which include agricultural loans, CO₂ emissions, average education duration, urbanization rates, and agricultural value added. This study presents a distinctive contribution by examining the economic, social, and environmental facets of productivity within a unified framework; it also aspires to provide guidance for policymakers towards more comprehensive and sustainable intervention strategies.

Data and Methodology

This paper investigates the key determinants of agricultural total factor productivity in Türkiye. In the empirical analysis, the study utilizes the ARDL model for the period 1991–2022. The model employed in this study is presented in Equation (1).

$$LTFP_t = \alpha_0 + \beta_1 LCRD_t + \beta_2 LCO_2_t + \beta_3 LHDI_t + \beta_4 LURB + \beta_5 LVA + \varepsilon_t \quad (1)$$

In Equation (1), TFP signifies the agricultural total factor productivity; CRD indicates the ratio of agricultural loans to total loans; CO₂ denotes carbon dioxide emissions from agriculture; HDI refers to Human Development Index (mean years of schooling), URB is the urban population growth; and VA denotes the share of the agricultural sector in gross domestic product. The β coefficients represent the long-run elasticities of total factor productivity with respect to the corresponding independent variable. All variables are transformed into natural logarithms, and L stands for the natural logarithm.

The dependent variable used in this study—agricultural total factor productivity—is obtained directly from the United States Department of Agriculture, Economic Research Service (USDA-ERS), based on a standardized 2015=100 index series. The TFP measure is not recalculated by the authors; rather, it is taken exactly as provided by the USDA-ERS to ensure methodological consistency and cross-country comparability. According to the USDA-ERS documentation, the TFP index is constructed as the ratio of a total agricultural output index to a total input index, both aggregated using the Tornqvist-Theil method. The output index represents the constant-price (2015-based) gross production of crops, livestock, and aquaculture. The total input index combines four major factor categories: land, reflecting agricultural land use; labor, adjusted for demographic and skill characteristics; capital, including machinery, equipment, structures, and livestock capital; and

intermediate (material) inputs, such as fertilizers, feed, pesticides, seeds, and energy. Each of these input categories is weighted by its respective cost share, enabling the TFP index to capture the contribution of production inputs in a theoretically grounded manner.

Because the USDA-ERS TFP index internally incorporates the effects of land, labor, capital, and material inputs through this comprehensive growth-accounting framework, these production factors are not included as separate regressors in the empirical model. Instead, the present study focuses on examining how macro-institutional and structural variables—such as agricultural credit, human capital, urbanization, and environmental pressures—are associated with productivity once primary inputs have already been embedded within the TFP measure. The index series used in this study relies on the latest update available as of October 2024, ensuring a reliable, internationally consistent, and methodologically transparent measure of long-term productivity trends in Türkiye’s agricultural sector.

CRD is collected from the database of the Banks Association of Türkiye. VA, CO₂, and URB are sourced from the World Bank, while HDI is gathered from UNDP. Descriptive statistics of the variables are presented in Table 2.

Table 1

Descriptive Statistics

	LTFP	LCRD	LCO ₂	LHDI	LURB	LVA
Mean	4.53	1.66	0.68	1.85	0.74	2.20
Median	4.56	1.29	0.75	1.81	0.74	2.14
Maximum	4.81	2.93	1.20	2.20	1.12	2.82
Minimum	4.31	0.97	0.02	1.51	0.04	1.71
Std. Dev.	0.13	0.69	0.28	0.23	0.19	0.34
Skewness	0.09	0.76	-0.51	0.06	-1.50	0.47
Kurtosis	1.94	1.93	2.65	1.63	7.22	1.95
Jarque-Bera	1.53	4.64	1.52	2.50	35.64	2.63
Observations	32	32	32	32	32	32

The descriptive statistics in Table 1 show reasonable variability across all variables, with no extreme outliers. The values fall within expected ranges, indicating that the dataset is suitable for the ARDL analysis.

Table 2

Correlation Matrix and VIF Scores

	LTFP	LCRD	LCO ₂	LHDI	LURB	LVA	VIF
LTFP	1.00	-0.81	0.76	0.85	-0.59	-0.83	-
LCRD	-0.81	1.00	-0.71	-0.67	0.62	0.87	7.79
LCO ₂	0.76	-0.71	1.00	0.75	-0.52	-0.78	5.48
LHDI	0.85	-0.67	0.75	1.00	-0.55	-0.84	8.37
LURB	-0.59	0.62	-0.52	-0.55	1.00	0.64	1.78
LVA	-0.83	0.87	-0.78	-0.84	0.64	1.00	9.93

The correlation coefficients and VIF values presented in Table 2 indicate that although there is a certain level of multicollinearity among the variables in the model, this does not compromise the model’s structural validity. The high correlations

between LCRD–LVA and LHDI–LVA, along with the VIF value of 9.93 calculated for LVA, indicate that these variables tend to move together. However, the fact that all VIF values remain below the threshold of 10 reveals that there is no serious multicollinearity problem within the limits accepted in the literature. Similarly, the VIF values observed for the LCRD (7.79) and LHDI (8.37) variables indicate moderate multicollinearity, but do not create a distortion that would undermine the reliability of the model coefficients. On the other hand, the low correlations of the LURB variable and its very low VIF value of 1.78 confirm that it poses no risk in terms of multicollinearity. Overall, the results show that although there is a possibility of multicollinearity in the model, it remains within acceptable limits and does not negatively affect the interpretability or statistical robustness of the obtained ARDL estimates.

In the study, the cointegration analysis is applied by using ARDL Bound test. The Unrestricted Error Correction Model (UECM) specification used for the Bounds test is illustrated in Equation (2).

$$\begin{aligned} \Delta LTFP_t = & a_0 + a_{1t} + \sum_{i=1}^m a_{2i} \Delta LTFP_{t-i} + \sum_{i=0}^m a_{3i} \Delta LCRD_{t-i} + \sum_{i=0}^m a_{4i} \Delta LCO2_{t-i} + \\ & \sum_{i=0}^m a_{5i} \Delta LHDI_{t-i} + \sum_{i=0}^m a_{6i} \Delta LURB_{t-i} + \sum_{i=0}^m a_{7i} \Delta LVA_{t-i} + a_8 LTFP_{t-1} + a_9 LCRD_{t-1} + \\ & a_{10} LCO2_{t-1} + a_{11} LHDI_{t-1} + a_{12} LVA_{t-1} + \varepsilon_t \end{aligned} \quad (2)$$

The Bounds test applies the null hypothesis of no long-run association among the variables, formulated for this study as $H_0: \alpha_8 = \alpha_9 = \alpha_{10} = \alpha_{11} = \alpha_{12} = 0$. This hypothesis is tested by comparing the estimated F-statistic with the critical bounds proposed by Pesaran et al. (2001). If the statistic exceeds the upper bound, the null is rejected, whereas if it falls below the lower bound, the null cannot be rejected.

After establishing cointegration, the analysis proceeds with the ARDL model to explore the long-run and short-run linkages among the variables. Equations (3) and (4) present the respective specifications of the long- and short-run models.

$$\begin{aligned} LTFP_t = & a_0 + \sum_{i=1}^p a_{1i} LTFP_{t-i} + \sum_{i=0}^q a_{2i} LCRD_{t-i} + \sum_{i=0}^r a_{3i} LCO2_{t-i} \\ & + \sum_{i=0}^s a_{4i} LHDI_{t-i} + \sum_{i=0}^s a_{5i} LURB_{t-i} + \sum_{i=0}^s a_{6i} LVA_{t-i} + \varepsilon_t \end{aligned} \quad (3)$$

$$\begin{aligned} \Delta LTFP_t = & a_0 + a_1 ECT_{t-1} + \sum_{i=1}^m a_{2i} \Delta LTFP_{t-i} + \sum_{i=0}^n a_{3i} \Delta LCRD_{t-i} + \sum_{i=0}^n a_{4i} \Delta LCO2_{t-i} + \sum_{i=0}^n a_{5i} \Delta LHDI_{t-i} \\ & + \sum_{i=0}^n a_{6i} \Delta LURB_{t-i} + \sum_{i=0}^n a_{7i} \Delta LVA_{t-i} \\ & + \varepsilon \end{aligned} \quad (4)$$

Equation (4) includes the error correction term (ECT), which indicates how quickly the variables converge to the long-run equilibrium. A negative and significant coefficient of ECT is required to confirm convergence.

Empirical Results

As a preliminary step of the ARDL approach, it is necessary to verify the order of integration of the variables, since the model is not applicable when any of the series are integrated of order two (I(2)) (Pesaran et al., 2001; McNown et al., 2018).

Accordingly, the study applies the Augmented Dickey-Fuller (ADF) and Ng-Peron unit root tests to examine the stationarity properties of the variables.

Table 3*Unit Root Test Results*

	ADF Test	Ng-Perron Test			
		MZa	MZt	MSB	MPT
LTFP	-3.054	-12.066	-2.334	0.193	8.18
LCRD	-1.035	-3.595	-1.195	0.332	23.02
LCO ₂	-1.992	-12.699	-2.42	0.191	7.707
LHDI	-2.208	-11.969	-2.4	0.201	7.854
LURB	-2.653	-13.552	-2.597	0.192	6.759
LVA	-2.047	-8.401	-1.914	0.228	11.256
ΔLTFP	-7.640***	-13.028**	-2.468**	0.189**	2.197**
ΔLCRD	-5.477***	-14.372***	-2.657***	0.185***	1.793***
ΔLCO ₂	-6.286***	-44.605***	-4.721***	0.106***	0.553***
ΔLHDI	-3.562**	-12.141**	-2.379**	0.196**	2.340**
ΔLURB	-4.123***	-13.273**	-2.563**	0.193**	1.895**
ΔLVA	-5.188***	-14.998***	-2.591***	0.173***	2.171**

, and * denotes 5%, and 1% significant level, respectively.

In the ADF test, the null hypothesis is that the series contain a unit root. The results in Table 3 show that the null hypothesis cannot be rejected for any of the variables. The ADF test results indicate that all series become stationary after first-differentiating. In the Ng-Perron framework, the null hypothesis assumes a unit root for the MZa and MZt statistics, and stationarity for the MSB and MPT statistics. The results reveal that, for all series, the null hypothesis cannot be rejected in the case of the MZa and MZt statistics, whereas it is rejected for the MSB and MPT statistics.

In sum, the Ng-Perron results corroborate the ADF results, confirming that all series are integrated of order one (I(1)).

After confirming that the stationarity properties of all series are suitable for the application of the ARDL model, the bounds test developed by Pesaran et al. (2001) is employed to examine the cointegration relationship among the variables.

Table 4*Bound Test Results*

<i>k</i>	<i>F statistics</i>	<i>Significance level</i>	<i>Critical Values</i>	
			<i>Lower Bound</i>	<i>Upper Bound</i>
5	6.788	1%	3.06	4.15
		5%	2.39	3.38

k denotes the number of explanatory variables in Equation (2). The critical values are obtained from Table CII(ii) in Pesaran et al. (2001, p. 300).

Table 4 indicates that the calculated F-statistic exceeds the upper bound of the critical values. Therefore, the null hypothesis of the bounds test is rejected, confirming

the existence of a long-run relationship between LTFP and the explanatory variables.

After establishing cointegration among the series, the study proceeds to analyze both the long-run and short-run dynamics within the ARDL framework. The estimation results of the ARDL (2, 1, 2, 0, 2, 1) model are reported in Table 4. In the ARDL model, the optimal lag structure was selected using the Akaike Information Criterion (AIC).

Table 5

ARDL (2, 1, 2, 0, 2, 1) Model Results

<i>Long-run Estimation</i>			
Variables	Coefficient	T-statistics	Prob.
LCRD	-0.073	-2.907	0.010
LCO ₂	0.039	0.249	0.806
LHDI	0.839	10.549	0.000
LURB	-0.369	-5.022	0.000
LVA	0.464	3.654	0.002
C	2.328	5.606	0.000
<i>Short-run Estimation</i>			
Variables	Coefficient	T-statistics	Prob.
D(LTFP(-1))	0.246	1.898	0.076
D(LCRD)	-0.115	-5.499	0.000
D(LCO ₂)	-0.132	-4.178	0.001
D(LCO ₂ (-1))	-0.098	-3.575	0.003
D(LURB)	-0.051	-2.028	0.060
D(LURB(-1))	0.143	4.460	0.000
D(LVA)	0.274	4.835	0.000
ECT (-1)	-0.894	-8.083	0.000
Diagnostic Tests	Test Stat.	Prob.	
LM test (Breusch-Godfrey)	1.075	0.316	
Heteroscedasticity test (ARCH)	0.130	0.710	
Jarque-Bera test	1.611	0.448	
Ramsey Reset Test	0.521	0.463	

The diagnostic test results in Table 5 show that the ARDL model does not suffer from issues of serial correlation, heteroskedasticity, non-normality, or misspecification, as indicated by the LM, ARCH, Jarque–Bera, and Ramsey RESET tests. Besides, the stability of the models is confirmed by the CUSUM and CUSUMQ tests shown in Figure 1.

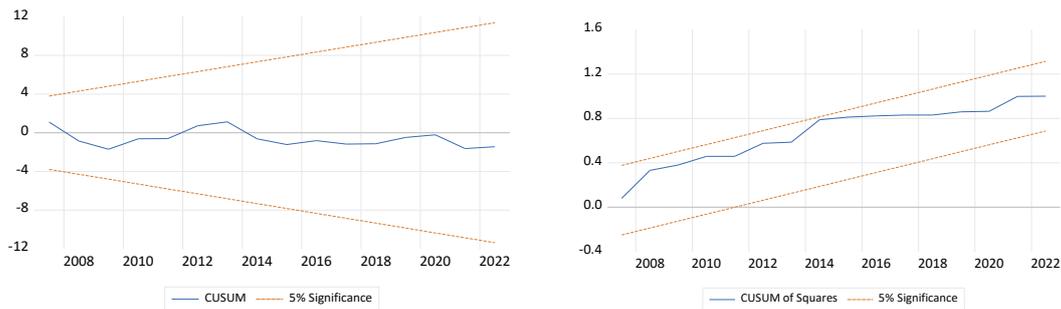
The long-run ARDL estimation results indicate that the coefficients of LCRD, LHDI, LURB, and LVA are statistically significant at the 1% level. The coefficient of LCO₂ is found to be insignificant. Specifically, the coefficient of LCRD implies that a 1% increase in agricultural loans results in a 0.07% decrease in agricultural total factor productivity. The coefficient of LHDI is found to have a strong and

significant impact. The results indicate that a 1% increase in human capital raises agricultural total factor productivity by approximately 0.84%. The results of the long-run elasticities indicate that a 1% increase in LURB leads to a 0.37% decrease in agricultural total factor productivity. Finally, the coefficient of LVA suggests that a 1% increase in LVA raises agricultural total factor productivity by 0.46%. The findings of the short-run ARDL model demonstrate that the first lag value of agricultural total factor productivity has a positive and statistically significant effect on its current level. According to this, improvements in agricultural total factor productivity in the previous period enhanced productivity in the current period. In the short-run, LCRD, LCO₂, and LURB have negative and statistically significant impacts on agricultural total factor productivity. In contrast, LVA positively affects total factor productivity, as in the long-run.

The coefficient of the error correction term (ECT(-1)) is estimated as -0.894 and is statistically significant. This indicates a strong adjustment mechanism, meaning that approximately 89% of the short-run disequilibrium is corrected within one period, and the system rapidly converges to its long-run equilibrium.

Figure 1

CUSUM and CUSUM of Squares Test Results



Discussion and conclusion

Identifying the determinants of agricultural total factor productivity is particularly crucial for Türkiye, where the agricultural sector still plays a significant role in food security, employment, and rural development. Understanding the long-run and short-run drivers of productivity helps to design effective strategies for sustaining growth in the sector, especially in the face of challenges such as climate change, rural-urban migration, and structural transformation. This study aims to investigate the determinants of agricultural total factor productivity in Türkiye over 1991–2022 using an ARDL framework. To this end, the analysis incorporates agricultural credit, agricultural carbon dioxide emissions, average years of schooling as a proxy for human capital, urbanization, and agricultural GDP as explanatory variables.

In the empirical analysis, the results of the Bounds test confirm the existence of a cointegration relationship between total factor productivity and its covariates. The long-run ARDL estimates reveal that agricultural credit exerts a negative impact on agricultural total factor productivity. This result is consistent with Uslu and Apaydın (2021), who reported that nominal support policies had adverse effects on productivity, and with the evidence provided by Şeyranlioğlu (2025). This finding can be attributed to the use of agricultural credit primarily for short-term cash

flow rather than productivity-enhancing investments, and from banks' collateral-based lending policies that may create adverse selection problems. The findings reveal that urbanization has a negative impact on productivity. This finding is in line with the results of Hu et al. (2025). The adverse impact of urbanization may stem from labor and knowledge losses caused by rural out-migration and from productivity declines due to potential land fragmentation associated with migration. This process can weaken scale economies and hinder sustainable productivity growth in agricultural production. The long-run results indicate that human capital has a positive impact on productivity. Similar evidence has been reported by Eruygur et al. (2016), Kabiru and Arshad (2019), and Ninh (2021). The long-run positive effect of human capital on agricultural productivity indicates that improvements in education support the diffusion of modern practices and more efficient resource use in agriculture. This finding highlights human capital as a structural driver of sustained productivity growth in the sector. Similarly, the study captures the positive influence of agricultural value added on agricultural total factor productivity. An increase in agricultural value added indicates a strengthening contribution of the agricultural sector to the economy. This may be associated with improvements in productivity, the wider adoption of technological practices, and a shift of farmers toward higher-value products. The observed effects of the explanatory variables are also evident in the short run. The findings indicate that agricultural CO₂ emissions have no significant effects on TFP in the long run, while exerting a negative impact in the short run. This can be explained by the fact that sudden increases in emissions reflect stress and inefficiencies in production; in the long term, however, adaptation and offset mechanisms may neutralize this relationship.

The study has several important policy recommendations to address the agricultural productivity. First, agricultural credit policies should be redesigned to channel funds toward long-term, productivity-enhancing investments such as mechanization, irrigation efficiency, and precision agriculture. Establishing monitoring mechanisms to ensure that credit is not diverted to short-term cash flow management could improve the impact of financial support on productivity. Second, strengthening human capital through education, vocational training, and agricultural extension services is crucial. Policies that foster knowledge transfer and innovation adoption can enhance the farmers' capacity to make efficient production decisions and to respond effectively to climate-related challenges. Third, mitigating the adverse consequences of urbanization requires comprehensive rural development policies. Preventing excessive rural out-migration, encouraging youth participation in agriculture, and promoting land consolidation would help mitigate productivity losses from labor shortages and land fragmentation. The positive effect of agricultural value added on productivity underscores the need for policies that enhance agriculture's contribution to GDP. Promoting value-added production through improved processing, stronger cooperatives, higher quality standards, and better access to digital markets can support this goal. In order to reduce the negative impact of CO₂ emissions, agriculture should promote precision input use, encourage the adoption of climate-smart practices (such as conservation tillage, drip irrigation, and drought-resistant seeds), and develop carbon footprint monitoring systems that enable farmers to track and manage their emissions.

This study has certain limitations. Although country-level time series data provide useful macro-level insights, they do not allow a detailed examination of differences in production processes. Future research may explore technology diffusion mechanisms, such as the adoption of modern inputs, digital tools, or climate-smart practices. In addition, the limited availability of long-term national data—for example, on agricultural machinery and equipment, which are published only from 2003 onwards—restricts the inclusion of important determinants such as mechanization in the current ARDL framework. To address this limitation, future studies may adopt a panel data approach using regional or cross-country datasets, which would allow the integration of technological variables and provide a deeper understanding of spatial heterogeneity in productivity dynamics. Furthermore, incorporating variables such as the share of agricultural exports or price indicators, including the Agricultural PPI and price volatility, could offer additional insights into how price and competitiveness dynamics influence productivity.

References

- Avcı, M. A., & Kaya, A. A. (2008). The analysis of efficiency and total factor productivity in agricultural sectors of Türkiye and transition economies (1992-2004). *Ege Academic Review*, 8(2), 843–860. <https://dergipark.org.tr/en/pub/eab/article/472518>
- Aydınbaş, G. (2024). Tarımsal verimlilik ile ilişkili faktörlerin tespiti: BRICS-T ülkeleri örneği. *Türk Tarım ve Doğa Bilimleri Dergisi*, 11(2), 524–535. <https://doi.org/10.30910/turkjans.1401633>
- Bobat, A. (2024). Introduction. In A. Bobat (Ed.), *Tarım Ekonomisinde Yeni Yaklaşımlar* (pp. 3–4). BİDGE Yayınları.
- Cerit, H., & Olhan, E. (2025). Türkiye tarım sektörü yeşil dönüşüm süreci: Avrupa yeşil mutabakatı'nın etkileri ve uyum politikaları. *Turkish Journal of Agriculture-Food Science and Technology*, 13(6), 1605–1614. <https://doi.org/10.24925/turjaf.v13i6.1605-1614.7814>
- Eruygur, O., Kıymaz, T., & Küçüker, M. C. (2016). Türk tarımında rekabet edebilirlik ve toplam faktör verimliliği. *Ekonomik Yaklaşım*, 27(100), 237–279. <https://doi.org/10.5455/ey.35960>
- Hu, G., Li, X., Liu, X., Wang, S., Zhang, X., Shi, X., Bai, X., & Hubacek, K. (2025). Mitigating the ripple effects of urbanization on farmland productivity and ecological security through inclusive urbanization strategies. *npj Urban Sustainability*, 5(1), 12. <https://doi.org/10.1038/s42949-025-00199-8>
- Kabiru, S. A., & Arshad, R. (2019). The effect of education on agricultural productivity: Implication for rural development. *Journal of Management and Economic Studies*, 1(6), 28–35. <https://doi.org/10.26677/TR1010.2019.152>
- Kaya, P., & Erdoğan Aktan, H. (2011). Türk tarım sektörü verimliliğinin parametrik olmayan bir yöntemle analizi. *Uluslararası Alanya İşletme Fakültesi Dergisi*, 3(1), 261–282. <https://dergipark.org.tr/tr/pub/uaifd/article/231843>
- McNown, R., Sam, C. Y., & Goh, S. K. (2018). Bootstrapping the autoregressive distributed lag test for cointegration. *Applied Economics*, 50(13), 1509–1521. <https://doi.org/10.1080/00036846.2017.1366643>

- Mercan, A., & Özçelik, A. (2024). Tarımsal girdi desteklerinin buğday üretim maliyetindeki önemi, In A. Bobat (Ed.), *Tarım Ekonomisinde Yeni Yaklaşımlar* (pp. 5–21). BİDGE Yayınları.
- Merdan, K. (2024). Türkiye'nin tarım sektörü: Tarımının dünü, bugünü ve yarını. *Bingöl Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, 8(1), 47–70. <https://doi.org/10.33399/biibfad.1337246>
- Ninh, L. K. (2021). Economic role of education in agriculture: Evidence from rural Vietnam. *Journal of Economics and Development*, 23(1), 47–58. <https://doi.org/10.1108/JED-05-2020-0052>
- Otgun, H., Fulginiti, L., & Perrin, R. (2024, July). The impact of trade openness on regional agricultural productivity in Türkiye. *Paper presented at the Agricultural & Applied Economics Association (AAEA) Annual Meeting*, New Orleans, LA.
- Pesaran, M. Hashem, Yongcheol Shin, and Richard J. Smith. 2001. Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, 16, 289–326. <https://doi.org/10.1002/jae.616>
- Şeyranlıoğlu, O. (2025). The impact of agricultural support, credit, and raw material trade on agricultural value added in Türkiye. *Ege Üniversitesi Ziraat Fakültesi Dergisi*, 62(3), 313–330. <https://doi.org/10.20289/zfdergi.1509516>
- TARSİM. (2023). *2022 yılı faaliyet raporu*. https://www.tarsim.gov.tr/staticweb/krm-web/dergi/faaliyet-raporlari/2022_1.pdf
- Tekiner-Moğulkoç, H., & Şişman, Z. (2022). Using malmquist TFP index for evaluating agricultural productivity: Agriculture of Türkiye NUTS2 regions. *Sigma Journal of Engineering and Natural Sciences*, 40(3), 513–528. <https://doi.org/10.14744/sigma.2022.00055>
- TEPGE. (2024). *2024 Tarım ürünleri piyasa raporları*. Tarımsal Ekonomi ve Politika Geliştirme Enstitüsü. <https://arastirma.tarimorman.gov.tr/tepge/Menu/27/Tarim-Urunleri-Piyasalari>
- Ürkmez, İ., Sevim, A., & Çatık, A. N. (2024). Türkiye'de tarım sektörü ve karbondioksit emisyonu arasındaki ilişki: Doğrusal olmayan bir kanıt. *Tekirdağ Ziraat Fakültesi Dergisi*, 21(1), 94–110. <https://doi.org/10.33462/jotaf.1239615>
- Uslu, H., & Apaydın, F. (2021). Türkiye'de tarımsal verimlilik ve alan bazlı desteklemeler üzerine ampirik bir uygulama. *Hitit Sosyal Bilimler Dergisi*, 14(2), 477–499. <https://doi.org/10.17218/hititsbd.1002014>
- Uzun, A. M. (2009). Tarımsal verimlilik ve Türkiye'deki durum: Tarımsal verimliliğin artırılmasına dönük tedbirler üzerine bir inceleme. *Sosyal Bilimler Araştırmaları Dergisi*, 2, 24–40. <https://dergipark.org.tr/tr/pub/gopsbad/article/616477>
- Yücel, M. H., & Çalışkan, Z. (2021). Tarımda verimlilik ve makineleşmenin tarımsal istihdam üzerindeki etkisi: Türkiye örneği. *Ekonomik Yaklaşım*, 31(117), 525–546. <https://doi.org/10.5455/ey.17303>