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Anatomy of agricultural export performance: Sectoral evidence from Türkiye

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Abstract

Purpose: This study aims to investigate the determinants of agricultural export performance across eight sub-sectors in Türkiye. The main objective is to identify the sector-specific effects of macroeconomic factors such as exchange rates, income levels of importing countries, and agricultural productivity.

Design/Methodology/Approach: Using panel data from 2012 to 2022, Fixed Effects (FE) and Instrumental Variables (IV, 2SLS) are employed as the main estimation techniques. In addition, Generalized Method of Moments (GMM) estimators were tested as a robustness check; however, since the results were not consistent with econometric assumptions, they are not reported. The dependent variable is the sectoral export value, while REER, GDP, and TFP are included as key explanatory variables.

Findings: The effect of the exchange rate on exports is significant and negative in most sectors. The GDP variable is found to be positive and significant across all sectors. The TFP variable is significant only in the tobacco sector. The results indicate that Türkiye holds comparative advantages in certain sectors.

Research Limitations/Implications: In line with the conceptual framework adopted in this study, only agricultural total factor productivity (TFP) is included to represent production capacity, while other production-related variables are deliberately excluded from the scope of analysis.

Originality/Value: The study provides novel empirical insights into sectoral heterogeneity by examining agricultural export performance through the lens of exchange rate competitiveness and demand-side factors at the product level.

Keywords: Agricultural exports, exchange rate, external demand, panel data, productivity.

Tarım ihracatında performansın anatomisi: Türkiye üzerine sektörel bulgular

Özet

Amaç: Bu çalışma, Türkiye'nin sekiz tarımsal alt sektörüne ait ihracat performansını etkileyen belirleyicileri sektörel düzeyde analiz etmeyi amaçlamaktadır. Çalışmanın temel hedefi, döviz kuru, alıcı ülke geliri ve tarımsal verimlilik gibi makro değişkenlerin sektörel ihracat üzerindeki etkilerini ortaya koymaktır.

Tasarım/Metodoloji/Yaklaşım: –2022 dönemine ait panel veri kullanılarak sabit etkiler ve IV (2SLS) tahmin yöntemleri temel analiz yöntemleri olarak uygulanmıştır. Ayrıca GMM tahmincileri ek bir sağlamlık kontrolü amacıyla denenmiş, ancak sonuçlar ekonometrik varsayımlarla tutarlı bulunmadığından raporlanmamıştır. Bağımlı değişken olarak ihracat değeri, bağımsız değişkenler olarak reel efektif döviz kuru (REER), alıcı ülkelerin GSYH'si (GDP) ve tarımsal toplam faktör verimliliği (TFP) değişkenleri kullanılmıştır.

Bulgular: Döviz kurunun ihracat üzerindeki etkisi çoğu sektörde anlamlı ve negatiftir. GDP değişkeni tüm sektörlerde pozitif ve anlamlı bulunmuştur. TFP değişkeni yalnızca tütün sektöründe anlamlıdır. Sonuçlar, Türkiye'nin bazı sektörlerde karşılaştırmalı üstünlüğe sahip olduğunu göstermektedir.

Araştırma Sınırlamaları/Etkileri: Bu çalışmada odaklanılan kavramsal çerçeve doğrultusunda, üretim kapasitesini temsilen yalnızca tarımsal toplam faktör verimliliği (TFP) değişkeni modele dâhil edilmiştir; diğer üretim faktörleri ise araştırma kapsamı dışında bırakılmıştır.

Özgünlük/Değer: Çalışma, ürün bazlı sektörel ayrım yaparak, döviz kuru ve dış talep kanalları üzerinden ihracat performansına dair yeni ve detaylı ampirik bulgular sunmaktadır.

Anahtar kelimeler: Tarımsal ihracat, döviz kuru, dış talep, panel veri, verimlilik.

INTRODUCTION

Global agricultural trade has been profoundly shaped by recent economic and political shocks. The COVID-19 pandemic, the Russia–Ukraine conflict, and recurring climate-related disruptions have exposed the fragility of international supply chains and intensified concerns over global food security (FAO, 2023). Rising input costs and extreme weather conditions, together with growing population pressures, have amplified volatility in food prices, making agricultural exports increasingly important for both economic resilience and policy design (WB & IMF, 2011; Yang, 2022). In this context, agriculture is no longer viewed solely as a sector for food provision but as a strategic field that directly affects employment, trade balances, and macroeconomic stability worldwide.

For developing economies such as Türkiye, agricultural exports hold particular importance. The sector not only contributes to foreign exchange earnings but also sustains rural employment and provides essential linkages to industry through value chains (Verter & Bečvárová, 2016). Despite its declining share in GDP over time, agriculture remains a key driver of export revenues and regional development. At the same time, Türkiye faces growing exposure to exchange rate volatility, shifting demand conditions in foreign markets, and structural productivity constraints that jointly determine export competitiveness. Understanding how these factors influence agricultural export performance is therefore critical for both academic analysis and policy formulation.

The literature has extensively examined the role of exchange rates and income growth in shaping trade performance. Earlier studies often relied on aggregate trade data, which obscure sectoral heterogeneity and limit insights into price and quantity dynamics (Grant & Boys, 2012; Berman et al., 2012). While evidence generally suggests that currency depreciation enhances competitiveness, the magnitude and persistence of this effect remain contested, particularly in agriculture where goods are perishable and margins are thin (Amiti et al., 2014; Wang & Barrett, 2007). Moreover, the impact of agricultural productivity-especially in importing countries-on bilateral trade flows has received relatively little empirical attention. As a result, the interaction between exchange rate dynamics, demand conditions, and productivity remains insufficiently understood at the subsector level.

This study addresses these gaps by analyzing Türkiye's agricultural export performance across eight subsectors between 2012 and 2022. Panel data econometric methods are employed; Fixed Effects (FE) and Instrumental Variables (IV, 2SLS) are used as the main estimation techniques, and the Generalized Method of Moments (GMM) is additionally tested as a robustness check. However, since the GMM results did not yield econometrically consistent estimates, they are not reported, and the primary focus remains on FE and IV estimations. By disaggregating exports into subsectoral categories, the study offers novel evidence on how external demand and macroeconomic conditions affect trade in different product groups. The findings aim to contribute to the literature by clarifying the sector-specific determinants of export performance and to provide policymakers with insights for designing strategies that enhance resilience and competitiveness in Türkiye's agricultural trade.

LITERATURE

The literature on agricultural trade has traditionally emphasized the decisive role of exchange rate dynamics and the income levels of destination countries in shaping export performance. Exchange rate fluctuations directly affect price competitiveness, and their effects are particularly pronounced in agriculture, where thin margins and perishability amplify vulnerability (Cho et al., 2002; Wang & Barrett, 2007). Berman et al. (2012) show that currency changes significantly influence exporters' behavior, while Amiti et al. (2014) highlight the disproportionate impact of exchange rate volatility on cost structures in low-margin sectors. These findings underline the need to integrate exchange rate considerations into broader trade and sectoral strategies.

Another strand of research focuses on the demand side. Higher income levels in importing countries are consistently associated with stronger demand for agricultural goods (El-Shagi, Sawyer & Tochkov, 2022). In line with Engel's law, food demand in high-income economies is more stable and diversified, while demand in lower-income countries remains volatile and highly sensitive to income shocks (Headey, 2011). Consequently, the GDP of partner countries is often used as a proxy for external demand conditions in empirical models of agricultural exports.

In addition to prices and income, productivity has emerged as a potential determinant of trade flows. Fuglie (2018) argues that agricultural total factor productivity (TFP) captures improvements in efficiency that can enhance self-sufficiency and reduce import dependence. However, empirical evidence linking importing-country TFP to bilateral trade remains scarce. Most studies either examine aggregate productivity effects on global trade or neglect heterogeneity across products. This gap provides scope for examining how foreign productivity affects Türkiye's exports at the subsector level.

Beyond these three key factors, several complementary frameworks have enriched the analysis of agricultural trade. The exchange rate pass-through (ERPT) literature demonstrates that in agriculture, cost shocks are quickly transmitted to export prices due to the limited ability of producers to absorb costs (Chen & Juvenal, 2016). Studies on pricing-to-market (Krugman, 1987; Knetter, 1989) emphasize that exporters adapt prices differently across destination markets, depending on demand elasticity and market structure. Similarly, Melitz's (2003) heterogeneous firms model suggests that productivity disparities shape firms' ability to survive currency shocks, with larger and more efficient exporters showing greater resilience.

Finally, product-specific studies indicate that the structural characteristics of agriculture-such as homogeneity, perishability, and reliance on natural conditions-make exports more sensitive to external shocks than manufactured goods (Piesse & Thirtle, 2009). At the same time, agricultural exports have broader welfare implications, influencing rural development, employment, and food security (Barrett et al., 2001). These findings highlight the importance of analyzing export determinants at a disaggregated level.

Against this backdrop, our study contributes to the literature in two ways. First, it jointly evaluates exchange rates, GDP, and agricultural TFP of importing countries as determinants of Türkiye's agricultural exports. Second, it employs a sectoral panel dataset across eight subsectors, allowing us to capture heterogeneity that is typically obscured in aggregate studies.

DATA SET AND VARIABLES

In this study, a panel dataset was constructed to analyze the determinants of export performance across eight different agricultural subsectors in Türkiye. The dependent variable is defined as the agricultural exports from Türkiye to selected partner countries, disaggregated by subsector. The independent variables include: the agricultural total factor productivity (TFP) of importing countries, their real gross domestic product (GDP), and Türkiye's real effective exchange rate index (REERTR). All variables were transformed into logarithmic form to ensure consistency in estimation and interpretation.

The dependent variable, exp (exports), was derived by the authors using the "Annual Consolidated Sectoral Exports by Country" statistics published on the official website of the Turkish Exporters Assembly (TİM). Accordingly, the analysis covers the period 2012–2022 and includes the following eight agricultural subsectors: Hazelnuts and Products, Cereals, Pulses, Oilseeds and Products, Dried Fruits and Products, Processed Fruits and Vegetables, Aquatic and Animal Products, Tobacco, Fresh Fruits and Vegetables, Olives and Olive Oil.

Among the independent variables, TFP represents the total factor productivity in agriculture for the importing countries. This variable was sourced from the "International Agricultural Productivity" dataset published by the Economic Research Service (ERS) of the United States Department of Agriculture (USDA). TFP reflects the change over time in the ratio between agricultural output and inputs (land, labor, capital, and materials). Input shares were calculated using national and regional cost data, following the methodology described in Fuglie (2015). Theoretically, an increase in an importing country's agricultural TFP may reduce its demand for imports from Türkiye by enhancing its domestic production capacity. However, this effect may vary by product type.

The REERTR variable is Türkiye's consumer price index (CPI)-based real effective exchange rate index, obtained from the Electronic Data Delivery System (EDDS) of the Central Bank of the Republic of Türkiye (CBRT). A real depreciation of the Turkish lira lowers the relative price of Turkish export goods in foreign markets, which is expected to positively affect export performance.

The final independent variable, GDP, represents the real gross domestic product of the importing countries, as retrieved from the World Bank's data portal. Since GDP is indicative of income levels in the importing country, a higher GDP is expected to be associated with greater demand for Turkish agricultural exports.

Table 1. Variables, definitions, data Sources, and logarithmic transformation

Variable	Definition	Source	Log
exp	Türkiye's exports to selected countries in eight agricultural subsectors ($)	Turkish Exporters Assembly (TİM)	Yes
tfp	Agricultural total factor productivity index of importing countries (2015=100)	USDA-ERS, International Agricultural Productivity	Yes
reertr	Türkiye's CPI-based real effective exchange rate index	Central Bank of the Republic of Türkiye (CBRT), EDDS	Yes
gdp	Real gross domestic product of importing countries (GDP)	World Bank	Yes

All variables cover the period from 2012 to 2022 on an annual basis. All variables were transformed into logarithmic form for the analysis. This transformation facilitates the interpretation of linear relationships between variables and helps to reduce heteroskedasticity issues. Thus, the resulting coefficients allow for elasticity interpretation.

ECONOMETRIC METHOD

Fixed effects, random effects, and the hausman test

In panel data analysis, both fixed effects (FE) and random effects (RE) models are widely used to manage heterogeneity by accounting for both temporal and cross-sectional dimensions. The fixed effects model directly incorporates the unobserved heterogeneity specific to each unit (e.g., country, firm, or sector) that does not vary over time by including it as a fixed term in the equation. In this case, the basic model is expressed as follows:

$$y_{it} = \alpha_i + \beta x_{it} + \varepsilon_{it} \quad 1$$

Here, α_i represents the individual fixed effects estimated separately for each observation unit; x_{it} denotes the independent variables, ε_{it} represents the error term (Baltagi, 2005). The fixed effects model controls for time-invariant differences across observation units through these fixed terms. In contrast, in the random effects model, α_i is treated not as a fixed parameter but as a random variable and is considered a part of the error term. In this case, the model is written as follows:

$$y_{it} = \beta x_{it} + (\mu_i + \varepsilon_{it}) = \beta x_{it} + \mu_{it} \quad 2$$

Here, μ_i denotes the unit-specific random effects, while ε_{it} represents the classical error term. The key assumption in the random effects model is that there is no correlation between μ_i and x_{it}. This assumption allows the RE model to offer more degrees of freedom; however, if this assumption does not hold, the estimates become inconsistent (Wooldridge, 2010). Therefore, to determine whether the fixed effects or the random effects model is more appropriate, the Hausman test (Hausman, 1978) is applied. The Hausman test evaluates the null hypothesis (H_0) that "the random effects model is consistent." If the test statistic is significant ($p < 0.05$), the key assumption of the RE model is violated, and the fixed effects model becomes the more reliable alternative.

Panel data diagnostic tests

In panel data analysis, it is essential to test the underlying model assumptions to ensure the reliability and validity of the estimated models. Three primary diagnostic tests are commonly applied:

Cross-Sectional Dependence Test (Pesaran CD Test); this test is used to determine whether the error terms across units in the panel are correlated. If there is cross-sectional dependence, classical assumptions are violated, and the standard error estimates may be misleading. The CD test, proposed by Pesaran (2004), is based on the average of pairwise correlations of the residuals across all cross-sectional units in the panel. Heteroskedasticity Test (Modified Wald Test); this test assesses whether the error variances are homogenous across units in panel data models. If variances differ, heteroskedasticity is present, and standard error estimates become unreliable. The Modified Wald test is particularly used in fixed effects models to detect group-wise heteroskedasticity. Autocorrelation Test (Baltagi-Wu LBI Alternative); This test examines whether the error terms are correlated over time within each cross-sectional unit in panel data models. The presence of autocorrelation implies inefficient estimators and biased standard errors. The test, proposed by Baltagi and Wu (1999), is designed specifically for detecting autocorrelation in the structure of panel data and serves as an alternative to classical tests.

Advanced standard error corrections: Clustered and Driscoll-Kraay

In panel data analyses, issues such as autocorrelation, heteroskedasticity, and cross-sectional dependence in the error terms can render classical standard error estimates invalid. This may severely distort the statistical inferences regarding the significance of coefficient estimates. To address such issues, Clustered and Driscoll-Kraay standard error corrections have been widely adopted in applied econometric analyses.

Clustered standard errors are especially suitable when there is correlation among error terms within panel groups (e.g., countries, firms, or sectors). In this method, the error structure is allowed to vary freely within each group, while assuming that errors are independent across groups. This approach accounts for both within-group autocorrelation and heteroskedasticity. Mathematically, the clustered variance-covariance matrix under the fixed effects model is expressed as follows:

$$\hat{V}^{cluster} = (X'X)^{-1}(\sum_{g=1}^{G} X'\hat{u}_g\hat{u}'_g X_g)\,(X'X)^{-1}) \qquad 3$$

In the equation above, g denotes the cluster (e.g., country) index, $X_{(g)}$ represents the matrix of observations for cluster g, and $u_{(g)}$ is the vector of residuals corresponding to that cluster. This method should be applied with caution, particularly when the number of observations is large but the number of clusters is limited; it is important to note that with a small number of clusters, standard errors may exhibit a downward bias (Cameron and Miller, 2015).

The standard error correction method developed by Driscoll and Kraay (1998) offers an approach that accounts for heteroskedasticity, as well as serial correlation across time and cross-sectional dependence at the group level. This method is especially suitable for panel datasets with a long time dimension and a relatively small number of cross-sectional units. The estimation of standard errors in this framework follows a structure similar to the heteroskedasticity-robust Newey-West estimator, and can be formally expressed as follows:

$$\hat{V}_{DK} = (X'X)^{-1}(\sum_{S=-L}^{L} k(s,L)\hat{\Gamma}_s)\,(X'X)^{-1}) \qquad 4$$

In the equation above, $\hat{\Gamma}_s$ denotes the estimated covariance of residuals at lag s, $k(s, L)$represents a weighting function, and L indicates the maximum lag length. The Driscoll-Kraay method is particularly useful in contexts where ignoring cross-sectional dependence may lead to misleading inferences. It offers reliable variance estimates and is therefore widely used in macro-panel analyses (Hoechle, 2007).

Both methods enable valid inference in situations where classical standard error estimates are inadequate. While the clustered standard error correction is preferred when within-group correlation is a concern, the Driscoll-Kraay correction is more appropriate in the presence of more complex error structures, including both cross-sectional and serial dependence. Ensuring the correct estimation of standard errors is essential not only for statistical significance but also for making economically sound interpretations of model results.

Endogeneity problem and testing

In econometric models, the presence of correlation between some of the independent variables and the error term is referred to as the endogeneity problem. Endogeneity leads to biased and inconsistent parameter estimates, thereby undermining the reliability and validity of the model. To detect and correct for this issue, a variety of endogeneity tests have been developed. Among the most commonly used are the Baum-Schaffer-Stillman test and the Durbin-Wu-Hausman (DWH) test.

The Baum, Schaffer, and Stillman (2007) test is widely employed, particularly in econometric software such as Stata, and is specifically designed to directly test whether independent variables are endogenous. The logic of the test involves estimating the potentially endogenous variable using instrumental variables (IVs), and then examining whether the predicted values are correlated with the error term in the original regression model.

The Durbin (1954), Wu (1973), and Hausman (1978) test-commonly known as the DWH test-is a classical and widely used method for testing the endogeneity of one or more explanatory variables. The test compares the results obtained from two different estimation methods: typically Ordinary Least Squares (OLS) and Instrumental Variables (IV) estimation. If the explanatory variables are exogenous, both OLS and IV estimators are consistent, and the difference between them is statistically insignificant. However, if the variables are endogenous, OLS estimates become inconsistent, while IV estimates remain consistent; hence, a significant difference between the two sets of estimates indicates the presence of endogeneity.

Estimation with instrumental variables (IV): Application of 2SLS

The endogeneity problem, frequently encountered in economic analyses, leads to biased and inconsistent estimates of regression coefficients. In such cases, the classical Ordinary Least Squares (OLS) method becomes invalid, as one of its core assumptions-zero correlation between the explanatory variables and the error term-is violated (Wooldridge, 2010). To address this issue, the Instrumental Variables (IV) approach has been developed.

The IV method involves replacing endogenous variables with instruments, which are variables that are correlated with the endogenous regressors but uncorrelated with the error term. The most widely used implementation of this approach is the Two-Stage Least Squares (2SLS) estimator, which estimates the model in two steps. The main strength of this method lies in its ability to provide consistent estimates of the structural parameters as long as the instrument is valid, i.e., not correlated with the error term. However, it is equally crucial that the instrument is strong, meaning that it has a high correlation with the endogenous regressor. The use of weak instruments may lead to severely biased estimates (Bound, Jaeger, and Baker, 1995).

The IV–2SLS method has a prominent place in the econometric literature, particularly in the context of structural models, where it is employed to identify the effects of policy variables and to uncover causal relationships (Angrist and Pischke, 2009; Stock and Watson, 2015).

Although the IV approach was originally developed to address endogeneity, it may still be appropriate under certain structural conditions even when all explanatory variables are exogenous. In the panel data model used in this study, diagnostic tests reveal statistically significant heteroskedasticity, autocorrelation, and cross-sectional dependence. These structural distortions violate the assumptions underlying classical fixed effects and random effects estimators, thereby undermining the reliability of standard error estimates and hindering the correct interpretation of statistical significance.

Although robust standard error corrections-such as Driscoll-Kraay or clustered standard errors-can mitigate these problems to some extent, they are limited in scope. Specifically, these methods adjust only for the variance structure of the error term, without addressing potential weaknesses in the estimation of structural coefficients. For this reason, the Instrumental Variables (IV) method is employed in this study even in the absence of significant endogeneity, as it offers a moment-based estimation framework that improves the efficiency of structural parameter estimates and provides a more robust alternative in the presence of misspecified error structures.

FINDINGS

The results presented in Table 2 reveal that there are significant structural differences across subsectors, and model selection has been shaped sensitively in accordance with this heterogeneity. According to the Hausman test, the fixed effects (FE) model is preferred in six sectors, while the random effects (RE) model is found to be more appropriate in only two sectors. This indicates that the unobserved fixed effects at the sectoral level are significantly correlated with the independent variables, making the FE model a more reliable estimator. Notably, the real effective exchange rate (REER) variable has a significant and negative coefficient in most sectors, suggesting that currency depreciation has an enhancing effect on exports. On the other hand, the total factor productivity (TFP) variable appears to be statistically insignificant in many sectors, implying that the production structure of importing countries has a limited impact on sector-specific exports. In this context, choosing the appropriate model based on the unique structure of each sector is crucial for ensuring the validity of empirical results.

Table 2. Results of fixed and random effects models

Sektör	Model	TFP	REER	GDP	Constant	Hausman χ²	Hausman p
Grain-Legumes-Oil Seeds	FE	-0.170 [0.140] (0.225)	-0.431 [0.027] (0.000***)	0.345 [0.090] (0.000***)	2.390 [1.084] (0.028**)	17.83	0.0005***
Hazelnuts and Products	FE	0.249 [0.303] (0.411)	-0.131 [0.055] (0.018**)	0.202 [0.192] (0.293)	1.144 [2.405] (0.634)	24.72	0.0000***
Dried Fruit Products	FE	0.397 [0.295] (0.179)	-0.153 [0.054] (0.005***)	0.644 [0.175] (0.000***)	-4.101 [2.215] (0.064*)	20.06	0.0002***
Fruit and Vegetable Products	RE	-0.157 [0.244] (0.520)	-0.241 [0.043] (0.000***)	0.799 [0.069] (0.000***)	-4.437 [0.977] (0.000***)	5.65	0.1297
Tobacco	RE	1.263 [0.478] (0.008***)	0.059 [0.089] (0.505)	0.232 [0.116] (0.045**)	-1.936 [1.782] (0.277)	4.74	0.1918
Olives and Olive Oil	FE	-0.321 [0.383] (0.402)	-0.426 [0.070] (0.000***)	0.943 [0.222] (0.000***)	-5.609 [2.799] (0.045**)	16.36	0.0010***
Fresh Fruits and Vegetables	FE	-0.057 [0.485] (0.907)	-0.311 [0.089] (0.000***)	1.377 [0.285] (0.000***)	-10.855 [3.587] (0.003***)	20.04	0.0002***
Aquatic and Animal Products	FE	-0.334 [0.344] (0.333)	-0.897 [0.065] (0.000***)	0.808 [0.208] (0.000***)	-0.980 [2.604] (0.707)	15.25	0.0016***

In the sectors of Cereals, Hazelnuts, Dried Fruits, Fruit-Vegetable Products, Olives, Fresh Fruits, and Aquatic and Animal Products, the Pesaran CD test results are statistically significant (p<0.01). This indicates that common factors and external shocks link the error terms across these sectors. Cross-sectional dependence poses a risk of underestimating error variances in model estimations and necessitates standard error corrections. In contrast, the Tobacco sector did not show significant cross-sectional dependence. The results of the heteroskedasticity test are highly significant across all sectors, revealing that error variances are not homogeneous between cross-sections, thereby indicating the presence of heteroskedasticity. This condition undermines the reliability of classical standard error estimates. Autocorrelation was also found to be significant in most sectors, suggesting that error terms are dependent over time. The presence of autocorrelation may lead to bias in standard error calculations and requires the use of adjusted estimation methods. Except for the Tobacco sector and partially the Hazelnut sector, autocorrelation is strong in the other sectors.

Table 3. Panel data diagnostic tests results

Subsector	Pesaran CD	Modified Wald	Baltagi-Wu Autocorrelation
Grains, Pulses, and Oil Seeds	CD = 14.170 (0.000)***	χ²(142) = 40323.94 (0.000)***	F(3,1269) = 60.98 (0.000)***
Hazelnuts and Products	CD = 20.677 (0.000)***	χ²(77) = 52013.41 (0.000)***	F(3,684) = 3.94 (0.0084)***
Dried Fruits and Products	CD = 6.224 (0.000)***	χ²(93) = 271705.79 (0.000)***	F(3,821) = 5.15 (0.001)***
Olives and Olive Oil	CD = 8.523 (0.0000)***	χ²(86) = 95608.79 (0.000)***	F(3,738) = 18.55 (0.000)***
Fresh Fruits and Vegetables	CD = 7.243 (0.0000)***	χ²(91) = 677436.22 (0.000)***	F(3,775) = 7.41 (0.000)***
Seafood and Animal Products	CD = 10.213 (0.000)***	χ²(97) = 28718.48 (0.000)***	F(3,845) = 33.27 (0.000)***
Sector	**Pesaran CD**	**Breusch-Pagan LM**	**Wooldridge Autocorrelation**
Fruit and Vegetable Products	CD = 10.998 (0.000)***	χ² = 4364.32 (0.000)***	t = –9.38 (0.000)***
Tobacco	CD = 1.529 (0.126)	χ² = 1370.94 (0.000)***	t = –6.46 (0.000)***

These diagnostic test results reveal three major violations of classical panel data model assumptions: cross-sectional dependence, heteroskedasticity, and autocorrelation. Therefore, to ensure the validity of the findings, it is necessary to use advanced estimation techniques such as Clustered or Driscoll-Kraay standard error corrections.

According to the results presented in Table 4, based on the fixed effects model, the estimated effects of the real effective exchange rate (REER) and GDP on agricultural exports are found to be consistent and statistically significant across estimations using both clustered standard errors and Driscoll-Kraay corrections. The REER variable exhibits a negative and often highly significant (at the 1% level) coefficient across all sectors, indicating that a real depreciation of the Turkish Lira tends to enhance export performance, which is consistent with standard trade theory (Edwards, 1989; Bahmani-Oskooee and Ratha, 2004).

On the other hand, the GDP variable is positive and highly significant in nearly all sectors, suggesting that Turkish agricultural exports are largely responsive to the income levels of importing countries. As these economies grow, their demand for Turkish agricultural products increases accordingly, reflecting typical income elasticity patterns in agricultural trade (Engel, 1857/1895; Fousekis and Grigoroudis, 2020).

In contrast, the total factor productivity (TFP) variable is statistically significant in only a few sectors and generally found to be ineffective. This result implies that, especially in agricultural sectors where Türkiye benefits from climatic and geographical advantages, the production efficiency of importing countries has a limited effect on Turkish exports, highlighting Türkiye's absolute or comparative advantage in specific sub-sectors of agricultural production (Ricardo, 1817/2004; Balassa, 1965). The only exception is tobacco, where higher local productivity in importing countries can directly substitute imports due to its labor-intensive and standardized production structure. This pattern suggests that, unlike other products highly dependent on ecological and quality-specific factors, tobacco demand is more sensitive to foreign productivity gains.

Table 4. Clustered and Driscoll-Kraay standard errors test results

Subsector	TFP (Clustered)	TFP (Driscoll-Kraay)	REER (Clustered	REER (Driscoll-Kraay)	GDP (Clustered	GDP (Driscoll-Kraay)
Grains, Legumes, Oilseeds and Products	–0.169 (*p*=0.225)	–0.170 (*p*=0.393)	–0.431 (*p*=0.000)***	–0.431 (*p*=0.000)***	0.345 (*p*=0.000) ***	0.345 (*p*=0.003)***
Hazelnuts and Products	0.249 (*p*=0.411)	0.249 (*p*=0.587)	–0.131 (*p*=0.018) **	–0.131 (*p*=0.159)	0.202 (*p*=0.293)	0.202 (*p*=0.314)
Dried Fruits and Products	0.397 (*p*=0.179)	0.397 (*p*=0.017)**	–0.153 (*p*=0.005)***	–0.153 (*p*=0.000)***	0.644 (*p*=0.000)***	0.644 (*p*=0.046)**
Fruits and Vegetables	–0.190 (*p*=0.439)	–0.190 (*p*=0.343)	–0.249 (*p*=0.000)***	–0.249 (*p*=0.018)**	0.758 (*p*=0.000)***	0.758 (*p*=0.003)***
Tobacco	1.166 (*p*=0.016)**	1.166 (*p*=0.000)***	–0.002 (*p*=0.984)	–0.002 (*p*=0.977)	–0.201 (*p*=0.538)	–0.201 (*p*=0.292)
Olives and Olive Oil	–0.321 (*p*=0.402)	–0.321 (*p*=0.172)	–0.426 (*p*=0.000)***	–0.426 (*p*=0.008)***	0.943 (*p*=0.000)***	0.943 (*p*=0.008)***
Fresh Fruits and Vegetables	–0.057 (*p*=0.907)	–0.057 (*p*=0.928)	–0.311 (*p*=0.000)***	–0.311 (*p*=0.001)***	1.377 (*p*=0.000)***	1.377 (*p*=0.008)***
Seafood and Animal Products	–0.334 (*p*=0.333)	–0.334 (*p*=0.494)	–0.897 (*p*=0.000)***	–0.897 (*p*=0.000)***	0.808 (*p*=0.000)***	0.808 (*p*=0.000)***

An examination of the Baum-Schaffer-Stillman and Durbin-Wu-Hausman test results presented in Table 5 reveals that the p-values across all sectors are relatively high and well above the conventional significance threshold (typically 0.05). This indicates that the independent variables are not endogenous, meaning that they are not correlated with the error term in the model.

Accordingly, both tests consistently demonstrate the absence of endogeneity across all sectors, thereby supporting the conclusion that the explanatory variables used in the model are exogenous. This result implies that the coefficient estimates are consistent and reliable, and that standard estimation methods such as Ordinary Least Squares (OLS) can be validly applied in this context (Baum, Schaffer, and Stillman, 2007; Wooldridge, 2010).

Table 5. Endogenous test results

Subsector	Wu-Hausman F	Prob. (F)	Durbin-Wu-Hausman Chi²	Prob. (Chi²)	Decision
Grains, Pulses, and Oil Seeds	0.02645	0.97390	0.05309	0.97380	Exogenous
Hazelnuts and Products	0.00582	0.99419	0.01173	0.99415	Exogenous
Dried Fruits and Products	0.09095	0.91307	0.18296	0.91258	Exogenous
Fruit and Vegetable Products	0.36762	0.69245	0.73811	0.69139	Exogenous
Tobacco	1.55866	0.21120	3.13106	0.20898	Exogenous
Olives and Olive Oil	0.73702	0.47883	1.48139	0.47678	Exogenous
Fresh Fruits and Vegetables	1.08492	0.33835	2.17855	0.33646	Exogenous
Seafood and Animal Products	0.03345	0.96711	0.06728	0.96692	Exogenous

According to the IV estimation results presented in Table 6, the effects of TFP (Total Factor Productivity), REER (Real Effective Exchange Rate), and GDP (Gross Domestic Product) on agricultural exports vary across

Türkiye's eight agricultural sub-sectors. These estimations were obtained using the Two-Stage Least Squares (IV–2SLS) method to address potential endogeneity issues. The validity and strength of the instrumental variables used in the model are assessed through the SW F-statistics (for TFP and REER) and the Cragg-Donald F-statistics / Sargan p-values reported in the table.

First, the Sanderson-Windmeijer (SW) F-statistics, which evaluate the strength of the instruments, are notably high across all sectors. In the literature, SW F-statistics greater than 10 generally indicate strong instruments; the values observed here-such as 339.14 and 291.36 in the Cereals-Legumes-Oilseeds sector-demonstrate the presence of very strong instruments. Similarly, Cragg-Donald F-statistics range between 94.99 and 214.55 across sectors, exceeding the critical thresholds proposed by Stock and Yogo (2005), indicating that the weak instrument problem is not present.

The Sargan test p-values, which test for overidentifying restrictions, are above 0.05 in all sectors, suggesting that the instruments are valid and that the overidentifying restrictions cannot be rejected. Collectively, these diagnostics confirm that the IV estimates are both statistically reliable and consistent.

The REER variable yields negative and statistically significant coefficients in 7 out of 8 sectors, indicating that a real depreciation of the Turkish Lira enhances exports. This effect is particularly pronounced in the Aquatic and Animal Products sector (-0.897) and the Cereals-Legumes-Oilseeds sector (-0.431), both in magnitude and statistical significance. These results imply that the exchange rate channel plays a strong role in boosting exports for price-sensitive agricultural products.

The GDP variable (representing the total GDP of importing countries) is positive and statistically significant in most sub-sectors. Notably, high coefficients are observed in Fresh Fruit (1.377) and Olives and Olive Oil (0.943), suggesting that economic growth in destination countries directly supports export performance in these sectors. This also implies that these sub-sectors may exhibit high demand elasticity.

In contrast, the TFP variable is statistically significant only in the Tobacco sector (1.166, p = 0.016), while remaining insignificant in all other sub-sectors. This finding indicates that improvements in the production capacity of importing countries do not substantially influence their decision to import from Türkiye. In the context of agricultural trade, this suggests that Türkiye enjoys absolute or comparative advantages in certain products; thus, even when foreign productivity increases, demand for Turkish agricultural products persists. The tobacco exception can be explained by its labor-intensive and standardized production structure, which allows efficiency gains in importing countries to directly reduce import demand-unlike products such as nuts or olives, where ecological and quality-specific factors dominate.

Table 6. IV (2SLS) Estimation results

Subsector	Coefficient (p) Values	SW F (TFP - REER)	Cragg-Donald F / Sargan p
Grains, Pulses, and Oil Seeds	TFP: -0.169 (0.225) REER: -0.431 (0.000)*** GDP: 0.345 (0.000)***	339.14 – 291.36	214.55 / 0.8762
Hazelnuts and Products	TFP: 0.249 (0.411) REER: -0.131 (0.018)** GDP: 0.202 (0.293)	130.30 – 161.80	96.67 / 0.8498
Dried Fruits and Products	TFP: 0.397 (0.179) REER: -0.153 (0.005)*** GDP: 0.644 (0.000)***	189.33 – 189.45	141.26 / 0.4771
Fruit and Vegetable Products	TFP: -0.190 (0.439) REER: -0.249 (0.000)*** GDP: 0.758 (0.000)***	300.55 – 265.76	194.85 / 0.2819
Tobacco	TFP: 1.166 (0.016)** REER: -0.002 (0.984) GDP: -0.201 (0.538)	131.85 – 127.46	94.99 / 0.7650
Olives and Olive Oil	TFP: -0.321 (0.402) REER: -0.426 (0.000)*** GDP: 0.943 (0.000)***	178.21 – 185.95	133.18 / 0.1098
Fresh Fruits and Vegetables	TFP: -0.057 (0.907) REER: -0.311 (0.000)*** GDP: 1.377 (0.000)***	174.49 – 201.36	130.64 / 0.7518
Seafood and Animal Products	TFP: -0.334 (0.333) REER: -0.897 (0.000)*** GDP: 0.808 (0.000)***	246.46 – 213.67	153.30 / 0.7294

Taken together, these findings demonstrate that the applied IV estimation technique is robust, both in terms of instrument strength and model validity. From an econometric standpoint, the sub-sectoral results reveal that the determinants of export performance differ by product group, and that exchange rate movements and economic growth in target markets play critical roles in shaping foreign demand. The insignificance of TFP in most sectors further suggests that the production capacities of importing countries are not a binding constraint on Türkiye's agricultural exports-underscoring Türkiye's strong competitive position in several strategic product categories.

RESULTS AND DISCUSSION

Exchange rate policies in Türkiye have long been a contentious issue, particularly in export sectors such as agriculture that are relatively less dependent on imported inputs. One of the most commonly voiced concerns among exporters is that during periods when the Turkish Lira (TRY) is overvalued, competitiveness in foreign markets declines, costs rise, and pricing flexibility is lost. Consequently, it is frequently argued that the real exchange rate should be lower; otherwise, export volumes may decrease. However, the findings of this study suggest that this assumption should be critically reassessed both in terms of the magnitude and sustainability of its effects.

Indeed, models developed using panel data covering eight agricultural sub-sectors in Türkiye between 2012 and 2024 reveal that a 10% real depreciation of the Turkish Lira results in an export increase of only 1% to 9%. This indicates that the impact of exchange rate changes on foreign demand is limited and that price elasticity of demand in many sectors is low. In 2024, Türkiye's total exports amounted to approximately USD 226 billion, while agricultural exports reached around USD 28 billion. Assuming an average export response of 5% to a 10% depreciation, the resulting increase would translate into an additional USD 1.4 billion in agricultural export revenue. However, this increase does not contribute to a structural transformation in export earnings. Given rising production costs, the unsustainability of price-based competition, and the fragility of external demand conditions, this increase is unlikely to provide a meaningful or lasting economic benefit.

Evaluated within the framework of the Marshall-Lerner condition, these findings further demonstrate that in cases where export demand is insufficiently price-sensitive, exchange rate devaluations fail to yield the expected improvements in the trade balance. In summary, even in the sectors with the highest responsiveness, export gains remain marginal. More importantly, these gains are neither sustainable nor uniform across sectors, and therefore cannot serve as the sole basis for export policy.

While this finding is noteworthy on its own, the study's more striking result is the absence of a statistically significant relationship between the agricultural total factor productivity (TFP) levels of importing countries and their import volumes from Türkiye. In other words, increases in agricultural productivity in countries importing Turkish agricultural goods do not appear to influence their propensity to source these goods from Türkiye. This suggests that Türkiye enjoys structural competitive advantages-such as climatic and logistical benefits and product uniqueness-in several agricultural domains. However, these advantages are not uniform across all sectors, and product-specific strengths necessitate differentiated export strategies.

To explore why TFP appears statistically insignificant, the study focuses on two main product groups and examines the implications of this finding in terms of sectoral vulnerability, market diversification, and value-chain dynamics. The first group includes cereals-legumes-oilseeds, fresh fruits and vegetables, processed fruits and vegetables, and aquatic and animal products. The main importers of these products tend to be countries with limited production capacity, poor infrastructure, and unfavorable climatic conditions for agriculture. For example, Iraq-Türkiye's top importer of cereals and animal products-relies on rainfall for over 60% of its agricultural production, has insufficient irrigation systems, low feed production, and weak logistics infrastructure (FAO, 2021). Similarly, Russia lacks the natural conditions necessary for self-sufficient fruit and vegetable production and is heavily import-dependent according to FAO data. The study finds no significant correlation between rising TFP levels in these countries and their import volumes from Türkiye, underscoring the persistence of demand despite domestic productivity improvements.

However, these structural advantages also entail significant vulnerabilities. Export volumes in these product groups are heavily concentrated in a few countries. For instance, Iraq and Russia dominate Türkiye's export markets for cereals and fresh produce, respectively. Any GDP-driven demand contraction, political instability, or diplomatic dispute in these countries could drastically reduce Türkiye's export revenues. In lower-income or economically volatile countries, demand for agricultural products with high income elasticity is especially sensitive to such shocks. For example, despite Iraq's agricultural imports exceeding USD 3 billion in 2024, a drop in its GDP could result in hundreds of millions of dollars in export losses for Türkiye. This dynamic can also be analyzed through Engel's Law, as changes in income disproportionately affect the demand for non-essential food products. Therefore, relying solely on current comparative advantages is insufficient, and market diversification emerges not as a strategic option but as a necessity.

The second product group-comprising hazelnuts and their derivatives, dried fruits, and olives/olive oil-also shows no statistically significant correlation between importing countries' TFP and Turkish export volumes. However, these sectors hold significantly greater income potential. Türkiye's competitive advantage in these products stems not only from production capacity but also from agro-climatic conditions. Hazelnuts, for instance, are cultivated in only a few countries worldwide, with Türkiye accounting for 60-70% of global production (FAOStat, 2023). Even high-TFP countries like Germany and Italy cannot produce hazelnuts efficiently due to climate constraints. As a result, they import hazelnuts from Türkiye but use them in industrial applications such as chocolate, snacks, and spreads before re-exporting them.

A similar dynamic exists in the olive oil sector. While Spain and Italy are also major producers, they import Turkish olive oil, repackage it under their own brands, and export it globally (IOC, 2023). Dried fruits such as figs, apricots, and raisins require high sunlight, low humidity, and long ripening periods-conditions not found in major importing countries like Germany and the UK. As a result, these countries remain consistent net importers according to FAO and ITC data (ITC TradeMap, 2023). Moreover, these products are frequently processed into high-value-added forms after importation.

Despite these advantages, Türkiye remains primarily a raw material supplier in global value chains. The value added is mostly captured by countries that market the final product. Hence, although Türkiye demonstrates strong production dominance in these products, this has not translated into sustainable income growth. Consequently, the study finds no statistical relationship between importing countries' TFP and Turkish export volumes in these sectors either.

The key takeaway from these findings is that Türkiye must shift away from relying on currency depreciation as a primary competitive strategy. Instead, structural policies that convert sectoral advantages into lasting export income must be prioritized. Two main policy recommendations emerge:

Market Diversification: The study clearly demonstrates that certain agricultural products are overly reliant on a small number of importing countries, and that GDP is a critical determinant of export volumes. While the current market composition may offer short-term advantages, it poses long-term risks. Türkiye must target alternative markets with high-income levels and growth potential to ensure export sustainability.

Value-Added Production and Branding: For products such as hazelnuts, olive oil, and dried fruits-which have high processing potential and value-added capacity-Türkiye must transition from being a commodity supplier to a branded producer. This requires not only investment in production infrastructure but also coordinated development in branding, packaging, marketing, and trade strategies. The goal should not merely be to increase export volumes, but to maximize unit export revenues.

In conclusion, this study demonstrates that external variables such as exchange rate fluctuations, productivity, and income levels affect Türkiye's agricultural export performance in different ways across sub-sectors. A tailored policy approach for each product group is essential. Türkiye can achieve sustainable export success by complementing its absolute advantages with strategic product positioning and market intelligence. This necessitates a comprehensive transformation toward "high value-added agricultural export", which must involve producers, the food industry, packaging firms, brand managers, and logistics providers in a multi-stakeholder strategy. Through such a transformation, Türkiye can move beyond the role of a raw material supplier to become a key actor in the global agricultural supply chain.

Contribution Rate of Researchers Declaration Summary

The authors declare that they have contributed equally to the article and have not plagiarized.

Conflict of Interest Declaration

The authors of the article declare that there is no conflict of interest between them.

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