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Trade Incentives and Destination-Market Dynamics in Türkiye's Cherry Exports: Evidence from Gravity Modelling and Machine Learning

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Abstract

Although Türkiye is among the leading producers of cherries worldwide, its export performance does not fully reflect its production potential. This gap points to the importance of understanding how trade incentives, destination-market demand, and trade costs shape export outcomes in high-value horticultural products. This study investigates the determinants of Türkiye's fresh cherry exports during 2015–2023 by combining a gravity trade model with machine learning approaches. The empirical framework incorporates export support mechanisms, macroeconomic indicators of partner countries, import demand, and geographical distance between Türkiye and its trading partners. It was found out that trade incentives have a positive effect on cherry exports; showing support mechanisms can strengthen Türkiye's competitiveness in international markets. The findings also reveal that rising import demand in destination countries stimulates exports, while geographical distance and adverse changes in importer income conditions limit export performance. These results suggest that maintaining export incentives alone may not be sufficient; rather, support policies should be adjusted according to market-specific demand conditions, income dynamics, and trade-cost factors. By integrating policy variables with destination-market characteristics, this study provides empirical evidence for designing more effective export support strategies for Türkiye's cherry sector.

Keywords: cherry; export; gradient boosting; machine learning; random forest; tariff supports

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1. Introduction

Cherries, being one of the significant fresh crops and exportable fruits of Türkiye, have been produced in the Aegean and Northern Mediterranean regions of the country. Global demand for Turkish cherries, including "Prunus cerasus", is momentous and Türkiye ranks first in the world in production since the beginning of the 1990s. The recorded production dates to 1961, according to the FAOSTAT database. The quantity of production in tonnes and the area of production in hectares are shown in Figure 1. The quantity of production rose by more than 14 times from 48 to 736 thousand tonnes per year on lands that rose by 6 times from 10,857 to 79,862 hectares (1961–2023). These figures indicate rising cherry

yields despite the declining amount of land under production and this trend continued in the last decade as well.

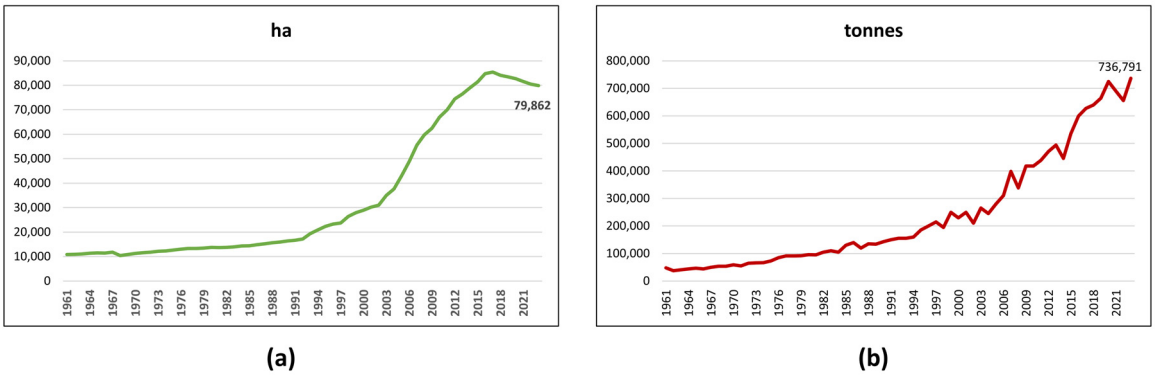


Figure 1. (**a**) Turkish cherry production area in hectares (1961–2023); (**b**) Turkish cherry production in tonnes (1961–2023)—(FAOSTAT, retrieved: January 2026).

Despite being the main producer, Türkiye is the third exporter, after the USA and Chile, due to the inexistence or inefficiency of marketing policies and supporting schemes [1]. Competitiveness indicators such as relative trade balance and export openness infer that Chile, Argentina, Iran, Poland, Spain, Türkiye, the USA, and New Zealand are the most competitive players. The USA and Türkiye together account for 43% of exports in the Northern Hemisphere and Chile leads the Southern Hemisphere with 7% of global exports [2]. Europe alone is dominated by Türkiye (45%), Italy (20%), and Spain (10%) [1].

It can be noted that Türkiye's share in the world market has been critically declining in the last two decades from 14% to 6% [3]. Also, inefficiency of organization among producers results in them having no say in sales price determination or accepting lower prices from buyers [4,5]. Türkiye has a strong comparative advantage in cherry exports globally, but this advantage has been gradually eroding due to price competition, exporter difficulties in supplying consistent quality, and tariff and non-tariff barriers [3]. Türkiye's annual cherry exports averaged around USD 124 million, the EU has been a significant market, and Russia has become an important partner over the last decade. Türkiye keeps a comparative advantage in cherry exports although this advantage has been declining in recent years, motivating a need to develop new markets. Türkiye experienced an average annual export growth of 18.4% between 2001 and 2020, yet its share of the world cherry market dropped from 14% to 5.9% because of low unit export value. Chile, in particular, dominated the global market with a 72.5% share in 2020 [6]. China has emerged as a "game changer" in cherry trade in Asia, and Turkish exporters must get prepared strategically for this shift [7].

Turkish cherry exports are expected to rise imminently due to changing production and supporting schemes. However, the variation in the climatic conditions and macroeconomic indicators may suggest the reverse [8,9]. So, the effectiveness of available supports needs to be reviewed to evaluate the sustainability of production and trade. The public authorities are re-funding Turkish cherry exporters, if the country they are in a trade relationship imposes trade barriers as tariffs or quotas. Additionally, there have been supports to major exporters. These supported sector actors primarily maintain trade relationships with market actors in the EU member states that are the main trade partners of Türkiye. Therefore, the impact of changes in these supports on Turkish export revenues are worth analysing to consider potential future policies.

Previous research on Turkish cherries has focused on time-series-based assessments; recent analyses have projected rising production and market dominance for Türkiye. Recent research forecasted a 27% rise in production from 2020 to 2025 [9]. In this study, cherry

supplies are expected to increase from 696.35 to 887.61 tonnes within a time-series framework. Another recent time-series forecast inferred that total global production will increase to 3.08 million tonnes in 2028 and Türkiye will contribute 26% of these supplies, followed by Chile with 18% and the USA with 11% [10]. It was considered that these time-based evaluations can be strengthened to develop policy proposals not only for Türkiye, but for countries that have similar productive and supportive structures. Therefore, it was intended to analyse Turkish cherry trade from a time and trade-destination perspective. So, this study aims to assess the impact of support mechanisms and external factors associated with trade destinations and annual variation on Türkiye's cherry exports to prospect and propose future policy tools.

2. Materials and Methods

There are many approaches and tools used to measure marketing and trade policies, some of them focus on time-based validation, irrespective of trade destination. On the other hand, many research studies also include a destination-based variation, and panel data analysis to incorporate both spatial and temporal dimensions in a single equation. The spatial dimension is a set of cross-sectional units, while the temporal dimension refers to the observations of a set of variables characterizing these cross-sectional units over a specific time period [11]. This multidimensional structure allows for the examination of individual heterogeneity and dynamic changes over time within the same model [12].

This methodological approach is referred to as gravity trade analysis and is mostly used to analyse the variations in time and destination with a bi-dimensional focus. The gravity trade model is being used to explain the relationship, relying on the effects of the distance between cross-sections. The model was developed in relation to Newton's Law of Gravitation and is based on the idea that commodity trade between partners that are close to each other is higher in volume and value. In other words, trade flow is inversely related to proximity measures, while the macroeconomic development level, as can be exemplified by income or per capita income, has positive effects on trade due to Tinbergen's proposition in 1962 [13].

Structural gravity models have taken place in the trade literature for different purposes with theoretical and applied aspects since 1979. The research suggested an insertion of quantified supportive actions and production and/or transaction costs in the estimation process [14]. There have been challenges in the implementation of the gravity model since its introduction, especially in addressing economic problems. Also, the inclusion of border existence and the distance between countries are accepted as being determinative in assessments of commodity trade [14,15]. The researchers inferred that the amount of trade can be resistant to distance variation, and policy tools might be more effective in explaining the relationships.

Earlier studies that use a gravity model approach contributed to trade policy development. A study prepared a full guideline for structural and dynamic gravity estimation of trade with utilisation of WTO data [15]. They concluded that general and partial equilibrium analyses would contribute to the trade literature and measure the impacts of policy tools. Yotov's contemporary research findings supported the idea that the model can be used for domestic trade flows as well, especially taking the production costs into consideration [16,17]. The studies focused on the impacts of determinants as price indices and further reliance on time and distance in parametric and non-parametric settings [17,18]. The latest research started to focus on the integration of machine learning approaches into gravity model analyses for international trade. A study inferred that the gravity model is still a preferred approach to undermine effects like tariffs or financial tools on trade [15]. Another study of Heid and his friends proposed the inclusion of intra-national

trade operations into time- and destination-based estimations of trade flows in 2021 [19]. This approach suggested using data relying on supporting tools within the countries as well as the supportive actions imposed by the exporters. In other words, not only should the impacts of tools used by importers be considered, but the backing actions provided to traders and/or producers in the exporting country should be considered as a determinant as well. Therefore, the measurement of bi-dimensional variations can still provide better insights for policy making when an assessment of commodity trade is considered.

The ability of panel data to control for the effects of unobserved variables reduces biased estimations [20–22]. The method reveals behavioural patterns that are not apparent in a single cross-section or time-series analysis and provides better inferences. It also offers a suitable framework for modelling individual responses over time [23]. Repeated observations help to reduce measurement errors in this analysis [22,23]. The base of the model is as follows.

$$y_{it} = \alpha_i + \beta_i \sum x_{it} + u_{it}$$

Here, y_{it}, standing for the dependent variable in a general panel framework, is explained by a combination of x_{it} explanatory variables for i number of cross-sections and t periods. The effects of time (t) and cross-sections (i) are measured via disaggregating the error terms (u_{it}) [24,25]. Relying on the theoretical and practical research, a product-specific panel gravity model was used in this study to estimate the cherry exports of Türkiye.

Recently, estimating non-linear relationships or explaining inflated data in economic analyses has become widespread in economics [26]. Due to non-linearity and multicollinearity situations that would lead to inefficient inferences, specific algorithms based on Machine Learning (ML) methodologies are being implemented in various fields [27,28]. The global trade of some specific crops and meat products as wheat, rice, and beef was estimated for different countries [24]. It was proposed that machine learning estimations of trade with the inclusion of tariff and trade barriers can be used for future policy proposals. Machine learning algorithms were utilized in this study using Python 3.12.7 Anaconda v24.9.2 libraries. In finding factor effects, ranking methodologies can be used in the scope of ML mechanisms. The comparable methodologies introduced for this research are Random Forest Importance (RF) and Gradient Boosting (GB). The Random Forest approach is used to integrate decision trees or factor trees to develop an interpretable ranking, as introduced by Breiman [29]. These RF algorithms have been used in regression comparison and the estimation of factorial orders in planning or policy making for the future. With training and forecasting, RF contributes to the interpretation of macroeconomic factors' effects on both cross-sectional and time-series data [26]. The second ordering model, Gradient Boosting (GB) was introduced by Friedman [28]. GB focuses on reducing the loss of explanatory variation via minimisation of the estimation errors and can be used to purify models that do not fit pre-defined methodologies. For this study, a Light Gradient Boosting Machine was used to rank the factors in the concerned bi-dimensional dataset [29,30].

Accordingly, fixed and random estimations of trade relationships in the panel framework were followed with RF and GB approaches to determine the categorical relationship for the cherry export amount of Türkiye in tonnes (y_{it}) for 9 major importer countries between 2015 and 2023. The dependent variable is the amount of Turkish cherry exports. It was estimated against income levels and the US Dollar exchange rate of the partner country. The explanatory variables were selected, relying on the nature of a commodity trade analysis. The value of export supports in US Dollars is an additional independent variable, which differentiates the current study from supporting inferences. Additionally, it was intended to detect the effectiveness of significant variables. The ranking method is expected to provide inputs to policy proposals not only for cherries but also for relevant

horticultural products. Therefore, the research intended to detect these impacts and their effective power signed by the rank.

The methodological integration of the research can be summarized and demonstrated in Figure 2 as below with reference to the previous work of de Melo and friends [31].

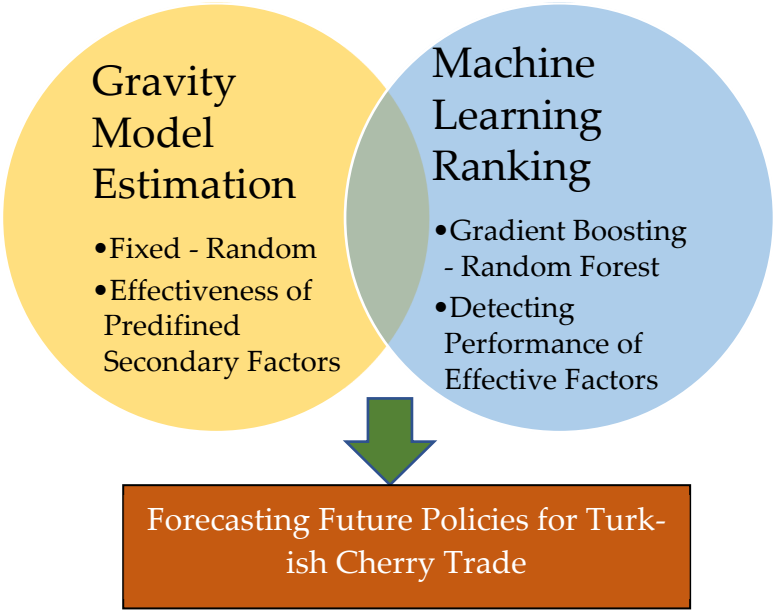


Figure 2. Methodological flow of the research.

With this research, the impacts of macroeconomic indicators and supportive instruments were measured to understand the evolution of Turkish cherry trade. The proximity between Türkiye and its trade partners was inserted into the model as a km distance for the fixed effects estimation and evaluated after disaggregation of the error terms. Therefore, depending on the accuracy of the estimation, the inference on distance was adjusted in addition to the macro variables. The estimated equation included the following explanatory variables that infer secondary information for exports (Table 1).

Table 1. Explanatory variables and dimensions of the research.

Variable	Description	Years (t): 2015–2023
GDP_{it}	Gross Domestic Product of country i at year t (current USD)	**Countries involved (i)**
EXC_{it}	Local currency of country i for year t in USD	Germany
$EXP1000_{it}$	Value of cherry exports and re-exports of country i at year t (current USD)	Poland Russian Federation Iraq Italy Norway Bulgaria Denmark The Netherlands
$IM1000_{it}$	Value of cherry imports of country i at year t (current USD)	
$EUCE_{it}$	Eliminated tariffs by the EU member states (current USD)	
RT_{it}	Return of tariffs to Turkish exporters (current USD)	

The full model can be specified as follows:

$$EXP_{Turkey,t} = \alpha_i + \beta_1 \times GDP_{it} + \beta_2 \times EXC_{it} + \beta_3 \times EXC_{it} + \beta_4 \times EXP1000_{it} + \beta_5 \times IM1000_{it} + \beta_6 \times EUCE_{it} + \beta_7 \times RT_{Turkey,t}$$

The hypothesized research expects a positive relationship between Turkish cherry trade with income level, re-exports of the partner country, and supportive tools such as

eliminated tariffs and returns on tariffs issued by Türkiye. The negative expectations on the other hand include the import value of the partner country and distance as an a priori expectation of gravity modelling. The experimental data were retrieved from open secondary databases such as the FAOSTAT, EUROSTAT, TURKSTAT, and central banks or financial databases of the partner countries to estimate quantities exported in 1.000 tonnes. The selection of annual range and country was related to data availability including the trade volume and financial data of countries that pose significant partnerships for the Turkish market. Accordingly, this research, by relying on the estimation of trade revenues as announced by official datasets, aims to undermine and evaluate the effects of aggregate trade relationship determinants.

Initially, data characteristics need to be evaluated using fundamental tests. In the literature, the Hausman test is defined as an efficiency test. This test is used to choose between the fixed and the random effects model for linear panel modelling [32]. The hypothesis of the Hausman test suggests an estimation of the model with random effects and the rejection of the hypothesis infers preference towards fixed effects modelling [22,23]. Multicollinearity among the independent variables can be detected with Spearman's correlation coefficient and the Variance Inflation Factor (VIF) test. The homogeneity test developed by Pesaran and Yamagata [33,34] measures the variability of coefficients across cross-sections. Following this data evaluation, the appropriate estimation method can be selected [20,35,36]. Autocorrelation is analysed through tests proposed by different researchers [23,37,38], including the Durbin–Watson (D-W) test. Therefore, the appropriate testing and confirmation tools were used to determine the methodological setup of this research.

3. Results

3.1. Descriptive Evaluation

The analysis focused on trade flows to nine countries between 2015 and 2023. During this period, Germany and the Russian Federation ranked first and second in amounts imported from Türkiye. The exports to Germany were approximately 179,000 tonnes in 2015 and rose to 317,000 tonnes in 2023. The figures for the Russian Federation were 203,000 to 168,000 tonnes. The results mean a change in the order of main importers. The re-export of cherries has been one of the main inducers of rising cherry sales to the Russian Federation. However, cherries are considered a main consumer good in Germany. The Russian Federation appears as a re-exporter, mainly to Central Asia and China, due to its proximity to these regions. The cherries imported by the Russian Federation are mostly from Türkiye and Iran originally [39,40]. Additionally, at the beginning of the 2020s, it was seen that China, Hong Kong, and South Korea had become important partners for Türkiye, with rising demand and the elimination of trade-related sanctions in 2017 [3]. However, the annual data available for these countries are not in the time scope of the analysis (2015–2023) and they were not included in the current research.

The relationship between the proximity of countries and their imports from Türkiye can briefly be evaluated hereafter. In an unexpected but explainable way, the distance and tonnes of exports were found to be positively correlated with a coefficient of 0,4. The furthest country, the Russian Federation, appears as the first or second importer within the given period, which reverses the expected relationship. When Russia is excluded, the correlation coefficient becomes negative, at -0.14. With the exclusion of Germany, the correlation turns out to be -0.59. Looking from the time-variation aspect, the correlation figures appeared to be -0.13 for 2015 and -0.08 for 2023 for the complete dataset. Therefore, the awaited explanation of the trade relationship seemed to be less related to the distance in fixed terms.

The lowest support levels were observed in 2022, confirming the decline in Turkish cherry production and external cherry sales. However, the aggregate rise in the value of supports was 82% for the EU refunds and 48% for tariff supports within the analysis period. Changing trade in favour of Germany has been a significant indicator of the accelerated rise in EU trade refunding [6]. It is important to note that the quantity of exports and revenue receipts from Poland and the Netherlands also rose significantly within the given period. The fluctuation in these financial supports is demonstrated in Figure 3.

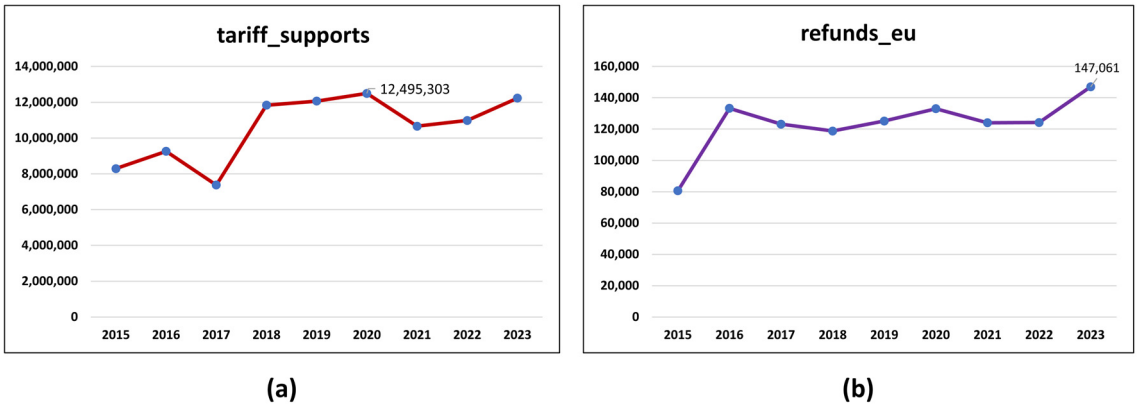


Figure 3. (**a**) Tariff refunds to exporters (2015–2023). (**b**) Refunds for the EU exports—TURKSAT and EUROSTAT.

The tariff refunds provided to exporters varied between 8.3 million and 12.4 million US Dollars (USD), and the refunds provided for the exports to the EU fluctuated between USD 80 thousand and USD 147 thousand between 2015 and 2023. It was expected that tariff refunds and trade acceleration funds would affect Turkish cherry exports positively.

The estimation of the hypothesized trade relationship included the disaggregating effects of macroeconomic indicators and situational factors as well as the proximity between trade partners using multiple gravity-based analytical methods. Accordingly, the results are shown and discussed below.

3.2. Analysis of Trade

The trade equilibrium was first estimated using 20% training with a fixed effects methodology, as suggested by the Hausman test findings. It was found out that the GDP of import partners and their revenues gained from cherry exports in Dollars negatively affected Turkish exports. Even though some countries import cherries for re-exporting purposes, they make significant payments on imports. This level of expenditure was expected to have a positive impact on Turkish exports. When the average of 9 years for the nine countries was checked, it was seen that the average revenues for re-exporting cherries they imported ($EXP1000_{it}$) was USD 9.15 million, while their average payment for imports from Türkiye was ($IM1000_{it}$) USD 43.12 million. So, the negative impact of their imports seemed to affect Turkish exports by around four times that of their exports. Yet, the significant impact of currency exchange was also negative. Considering the imports and exchange rate relationship with partners, the sign appeared as expected.

Hereafter, specific trade policy tools are evaluated. The elimination of custom duties for exports to an EU counterpart and the return of custom tariff payments made to exporter enterprises positively affected the aggregate exports. While the direction of impact was as expected, the explanatory power of the model (R^2) was 0.98 and the F-statistic was 3958.9 (0.00), indicating a complete inference that eliminates the necessity of interpretation. The Haussmann test also confirmed the use of fixed effects in the exchange of random effects with a 113.39 (0.00) value. However, the heteroscedasticity test results of the Breusch–Pagan

Statistic as 16.19 (0.00) indicated non-normal variance of the estimation. The Jarque–Bera (J-B) statistic of 116.73 with a below 0.05 *p*-value also indicated a non-linear distribution of estimation errors. In addition, the D-W statistic below two appeared as a sign of a positive correlation relying on non-linearity. Therefore, this initial inference, aside being politically interpretable, needed to be revised. For this reason, the data were first normalized using a logarithmic transformation. Meanwhile, the variance inflation factors were checked and demonstrated (Table 2). There was an exact correlation (0.99) between the tariff refunds and tonnes exported. The national income of the partner country was considered as an essential factor, and the Variance Inflation Factor (VIF) score was neglected [22]. However, it was understood that the tariff refunds contributed to the variance in the estimated quantity more than expected.

Table 2. Results for linearity testing on level and variance inflation.

Linearity		Variance Inflation	
R^2	98%	**GDP_{it}**	20.23
F-statistic	3958.9 (0.00)	**EXC_{it}**	2.91
Hausman	113.39 (0.00)	**$EXP1000_{it}$**	3.61
Breusch–Pagan	16.19 (0.00)	**$IM1000_{it}$**	10.12
Jarque–Bera statistic	116.73 (5.37×10^{-26})	**$EUCE_{it}$ (tariff-EU)**	3.65
Durbin–Watson	1.05	**RT_{it} (tariff-refund)**	26.74

The reformed model was estimated after eliminating the refunds. The variance inflation factor for import payments of the partner country was reduced to below 10 (9.08) and kept in the model. The fixed effects estimation of transformed data provided the same overall significance statistics. Prior to estimating the final fixed-effects specification, the potential endogeneity of the Türkiye's tariff refund variable (RT) was evaluated. The assessment did not reveal evidence of substantial endogeneity, and a tariff refund was considered an exogenous explanatory variable. Additionally, the tariff refund policies in Türkiye are determined through national export support regulations and implemented according to predetermined eligibility criteria rather than contemporaneous export performance [41–43].

The parameters that affect trade were calculated (Table 3). The existing tariff supports appeared as stimulating factors, and rising import demand was also a stimulator for further production and trade for Turkish cherry exporters. The incremental reducing effect of the income of the importer country might be correlated to changing imported fruit preferences. Simultaneously, it can be noted that cherry production within the EU has also been rising in the recent decade. This is also reflected in the rising exports of main producers such as Spain, Greece, and Austria and a 2.5% rise was recorded from 2023 to 2024 [44]. Accordingly, even if the price of Turkish cherries appears more appealing, the higher GDP would lead to rising intra-EU trade.

Table 3. Fixed effects estimates for Turkish cherry supplies.

Parameters with Positive Effect	Parameters with Negative Effect
The value of re-exports of partner country in 1000 Dollars (0.02)	The exchange rate depreciation of the importing country (−0.001)
Elimination of customs by the EU (0.09)	The GDP (−0.44)
Tariff supports of Türkiye (0.92)	The value of imports of partner country in 1000 Dollars (−0.02)

The variation related to importing countries appeared as ineffective. In other words, changing the distance did not alter the export amount or the order of countries. The positive correlation between tonnes of exports and distance was recognised with a 0.4 positive coefficient in the above descriptive section. This positive correlation is reflected clearly with the ranking of the Russian Federation, which is the furthest trade partner. The country is ranked second for the amount and value of Turkish exports. At the same time, the lowest cherry trade is with Bulgaria, the closest partner. Therefore, the aggregate cherry exports had appeared to be free from situational/location-related factors. When factors related to time variation were considered, it was well seen that supplies reduced in 2017, 2018, 2020, and 2023 within the concerned sample period, as demonstrated (Figure 4).

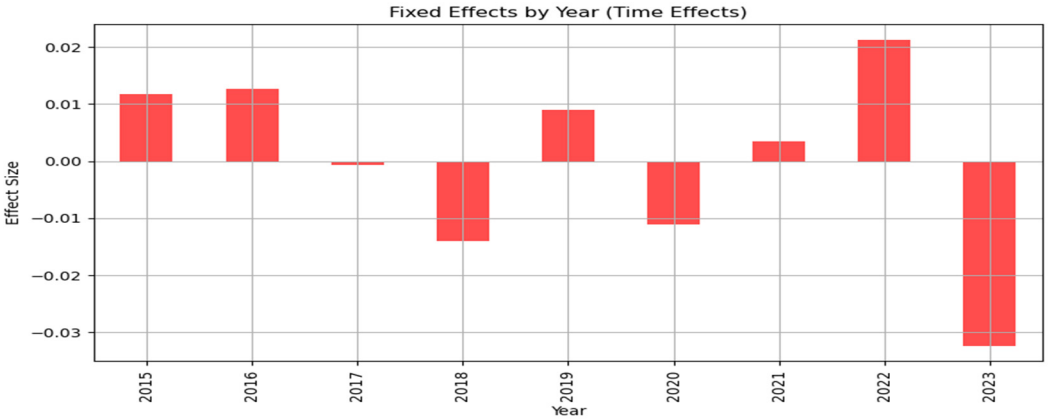


Figure 4. Time effects on exports due to Fixed Panel results.

The declining demand over time can be attributed to several reasons, including the sudden depreciation of the Turkish Lira, which led to rising expenditures on mainly imported chemical inputs. Despite rising production from 600 to 627 thousand tonnes in the 2017–2018 period, the aggregate exports declined from 91 to 84 thousand tonnes according to records from the Strategy Development Unit of the Ministry of Agriculture and Forestry [45]. The same public report also indicated the impact of currency depreciation. Simultaneously, global competitors in the cherry market, Chile and the USA, strengthened their position in the market. The further fluctuation in the exchange rate, rising costs, and adverse weather conditions accelerated the reduction specifically in 2023 [9]. The forecasts showed lower production and trade for Türkiye in the following years especially due to rising competition [46,47]. The changing production and export contribution can also be attached to negative impact of GDP on Türkiye's position in the market.

Following the panel data estimation under the training methodology, specific training tools were used to detect the effective factors from a contemporary perspective. Departing from the non-linearity of panel factors, Random Forest (RF) and Gradient Boosting (GB) models were crosschecked to detect and confirm the effectiveness of factors under the panel framework. The negativity or ineffectiveness of factors is considered less in the presentation of the outcomes. However, negative correlations imply a reducing income effect of the importers. This income variable ranks second in RF and third in the GB estimation, as demonstrated in (Table 4).

Table 4. Factors effective in the production of cherries, using machine learning methodologies.

Estimators	Random Forest Importance	Gradient Boosting
Import value in Dollars	0.56	0.47
Export value in Dollars	0.04	0.09
GDP of importer	0.19	0.14
Exchange rate of the importer	0.11	0.09
Elimination of customs by the EU (EUCE)	0.09	0.21

With machine learning methodologies, the importance and ranking of the effects can be detected by training and evaluating the data and the direction of effects can be attached to the parameter estimates discussed above. The difference between RF and GB lies in the inclusion of a non-factorial constant effect in the first one. The current results indicate that there is no out of dataset factor that can be considered effective on Turkish exports. Import payments made by the concerned partners appeared as the most effective factor with a share of more than 50%, as estimated (Figure 5).

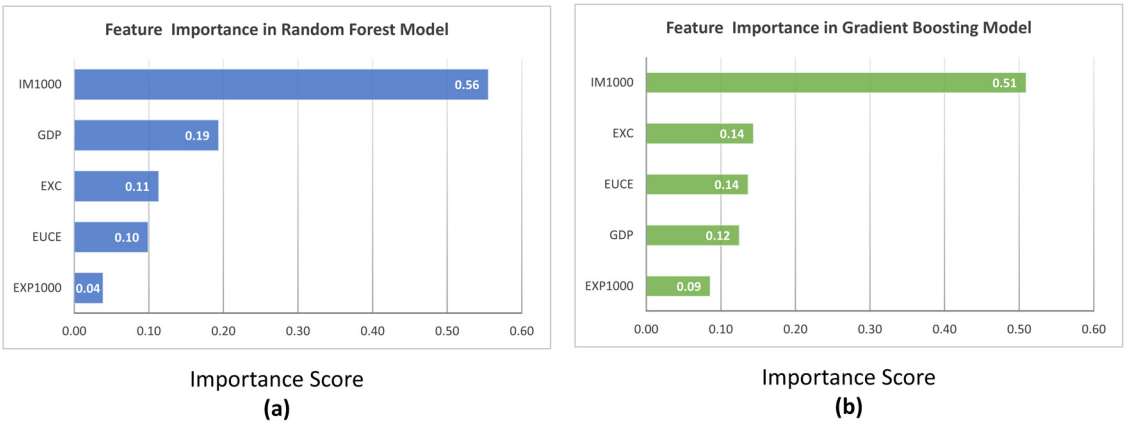


Figure 5. Effective factors in the cherry trade of Türkiye: (**a**) Random Forest Importance, and (**b**) Gradient Boosting.

The predominance of import demand for cherries is visible. Even if the partner countries recorded exports or re-exports of imported cherries, the existing trend of payments for imports from Türkiye is still the most effective factor. Yet, following this factor, the RF methodology ranked GDP of the importer as second, while the exchange rate is visible for the GB. With the reduction in the average income of importers, their cherry demand decreases and affects Turkish exports by around 20%. However, the GB referred to the EU membership as the second factor. There is a fact for the sample that not all the countries are members of the EU. Therefore, for the Russian Federation, Norway, and Iraq, the ranking can be redistributed. For these countries, the effect of import demand rises above 60%. The importer's GDP appeared to be effective with 21% within the RF framework. The GDP and exchange rates were almost equally important for the GB framework. If we turn back to the initial findings of the fixed effects estimation of the cherry trade, we understand that return-on tariffs appeared to have an effect on potential rises in Turkish exports such that a USD 1 rise in refunds leads to an almost 2000 tonnes rise in the quantity exported. Additionally, the elimination of customs duties by the European partners and the re-export potential of the partners have lower but positive impacts. The most effective negative factor is the rising income level. With rising per capita GDP in the partner, the average demand is reduced by around 1500 tonnes. The reduction due to importers' payments in 1000 Dollars also caused an incremental reduction in the quantity exported by Türkiye. In addition to

these, the machine learning ordering results showed a complementary ordering scheme for the effective factors.

Departing from these findings, two important inferences require further discussion. Relying on the varying refunds provided due to import restrictions imposed by partners and variations in the importers' income, the cherry export policies need to be explained and forecasted. However, time variation was closely related to the changing production in Türkiye and macroeconomic indicators. The indicative inference proves the positive impacts of the tariff refunds on the exporters and support for exports to European Union members. Therefore, there is a necessity to continue supporting producers and exporters for the sustainability of the cherry market. The key emphasis here is on limiting disruptions to free trade.

4. Discussion and Conclusions

Türkiye has been a significant exporter of sweet and sour cherries. The country is the first producer, and the crop is branded as a "Turkish Cherry" due to its traditional characteristics, the climatic conditions in Türkiye, and manageable prices and costs. Türkiye ranks the third in exports after the USA and Chile. However, it can be noted that the country is the major exporter in the Eurasia. Declining production is also a fact for Türkiye, especially due to the rising production costs attached, and the lack of bargaining power of producer organisations. Additionally, the rising power of China is visible with more than 1,6 million tonnes of supplies [48]. While China's rising demand has been met by re-exports from the Russian Federation, Turkish exports to this country began to accelerate in 2017.

This study reconnects with the gravity model logic stating that there is a positive correlation between bilateral trade volumes and the size of the economies of trading partners as well as a negative relation for trade distances. Variable importance ranking disclosed that the imports quantity in destination countries (a measure of their "gravitational power") was the key variable that explains the export performance of Turkish cherries. This validates theoretical expectations concerning the greater relative importance of the factors of demand-pull (related to the market attractiveness of destinations) compared to those of supply-push (such as export incentives) [49,50]. Thus, the results suggest that while trade policy tools can have a positive impact on export flows, their effectiveness cannot exceed the ceiling set by destination markets. Trade distance has a special significance for perishable products like fresh cherries. As compared to the exports of non-perishable goods, cherry (perishable) exports take place for a narrow period of time, usually 6 to 8 weeks [51]. Because of the time constraint of exports, in the case of cherries, the cost of transporting fresh fruits poses more challenges related to temperature control and phytosanitary clearance at ports. This makes clear why even well-established markets show the negative influence of trade distance [14].

As per the regression results, the relative inefficacy of proximity could be influenced by institutions and pre-existing trade relations, rather than just proximity alone. In these situations, the geographic distance will lose its traditional discouragement factor. This indicates that the coefficient of distance reflects distance's deterrent effect in the context of the quantity of trade, and the markets without institutional foundations will experience significantly greater geographic barriers [52]. Thus, entering in a new market will require investment in trade facilitation infrastructure in addition to incentives.

Driven by these changing situations, the variation in the export supplies of Türkiye was estimated to understand the effects of time variation, the destinations of exports, and the effectiveness of policy tools. The estimation results initially indicated the ineffectiveness of proximity between trade partners, which was mostly attributed to the distance to major importers such as the Russian Federation and Germany. The exchange rate depreciation of partner countries has the expected negative effect on Turkish exports. In other words,

partner countries demand less when they lose their purchasing power. However, even if the importers lose their income or exchange rate advantages, the Turkish currency depreciation within the analysis period reversed this process and the exports rose. There are two sides to see in the positive impact of Turkish Lira depreciation that must be considered carefully. The depreciation of the Turkish Lira reduces the price of Turkish cherries in foreign markets, thereby stimulating exports. However, it also raises the cost of imported production inputs, including agricultural chemicals, biological pest control products, cold storage materials, harvesting machinery, and other essential inputs [53]. These cost pressures have a structural basis related to similar exchange rate considerations such as the visible benefits from the export of cherries. So, a policy framework which depends on exchange rate competitiveness to handle export volumes, does not account for the structural difficulties of production itself.

When the impacts of the factors were ranked, the supports provided for trade with EU members appeared as important, following the volume of cherries imported by the trade partners. There may be an expectation of extending trade contracts with the European countries. This effect and expectation coincide with the higher demand from Germany, Poland, and the Netherlands. In particular, the German market has been expanding with a specific interest in organic and certified varieties. Cherry producers have been supported for supplies in addition to trade. The financial supports provided for the establishment of cherry gardens and the modification of cherry varieties due to the varying external and internal demands. These supports include the production of organic cherries and meeting Good Agricultural Practices (GAPs) standards issued by the World Trade Organisation [54]. However, the rising costs, especially the costs of imported chemical/biological inputs, seemed to distract producers in recent years. So, these supports also need to be maintained and altered for sustainability of the market position of Turkish cherries. While our study model assumes all exported cherries to be of a homogenous type, empirical evidence suggests that there may be a significant differentiation between the organic/GAPs-certified cherries and the conventional product. Given Germany's clear bias in favour of the former type of product, as mentioned before, one can speculate that factors influencing the competitiveness of cherry exports are different, depending on the product category, i.e., certified versus conventional. The strategy followed by the EU for the ongoing changes in the Maximum Residue Limit regulations and the Farm-to-Fork policy, suggest that the certified products' role will become more prominent over time [55], thus making aggregate model coefficients increasingly irrelevant to the structure of the real-world market [56].

Our research observed the key factors of Türkiye's fresh cherry exports between 2015 and 2023, finding the gap between the country's leading production capacity and its share in world export markets. By combining a gravity trade model with a machine learning concept, this study revealed that the strongest driver of Turkish cherry export performance is import demand in the destination countries, which outshine all policy instruments in explanatory power. This study found that geographical distance proved less restrictive than expected owing to well-established institutional trade relationships with key partners. Our research findings convey a clear policy message. Although export incentives remain necessary, they are not sufficient alone. Future support strategies should be designed and adjusted according to the destination country-market demand conditions. Income dynamics and structural weaknesses on the supply side, particularly fragmentation of the producer organizations and rising input costs should also be given more attention.

Some previous research focusing on fresh crop trade confirms this interpretation of effective factors. Quantitative and qualitative comparison research showed that the quality of the crop, logistic conditions, and costs have been gaining more importance in fostering trade [57]. A review on the impacts of CAP supports on the Italian fresh product

market also inferred the low stimulation power of financial supports [58]. This research also engaged the necessity of rising competitive power through quality and structural enterprise-level supports.

The necessity to empower producers and traders with knowledge about production, logistic, and trade costs is there, but this empowerment is not directly attached to financial supports. Some quantitative research in India confirms this interpretation as well. The Indian horticulture sector is also very important as domestic demand is completely met by domestic production, and the sector is being supported financially by the government. Governmental supports provided to the production and marketing of horticultural products were evaluated in 2025 [59] through an examination of successful enterprises in India. This shows that supported infrastructure investments and an extension to farmers and supports to producer-marketing organisations are needed to empower the sector. The time-series comparison for Indian horticultural production and exports revealed that while production can be induced by financial supports, exports need more investments in logistics and storage [60].

Considering the current global competition, the scale of financial supports cannot determine Türkiye's long-term export performance alone. The strategic and selective allocation of the resources across markets, product standards, and a more resilient production base are also rather important.

This inference is not only valid for Türkiye, it is effective in other relevant countries. Market actors require more supportive actions on infrastructure, knowledge, and organisation. There are active production and trade unions in Türkiye. The unions of fruit producers and fresh fruit and vegetable exporters guide their members through applications to official support schemes and finding trade partners. However, membership to the organizations is limited and hard for small scale operators [55]. The producers mostly lack information on the roles and support, and this situation is also valid for many producer–trader countries.

The governments and state organisations shall focus more on non-financial instruments, and they need to be ready for national and international macroeconomic fluctuations. Even though the current research is restricted by time and trade destination, the expected and partially unexpected findings may call for repetition of this bi-dimensional research and extension of its scope. Assessments of the financial and different supporting instruments for Türkiye and other countries within different settings would produce more forecasts for the close future and would lead preparation for national and international changes. The recent digital supports appear to be effective and marketing stimulation due to the international demand for green and labelled products and changing quality expectations may help the producers to cope with the changing environmental conditions as well as economic conditions [61]. Macro challenges detected as fluctuations of the importers' demand and currency exchange appear as effective for our bi-dimensional analysis. Therefore, the policy makers need to take extension activities and entrepreneurial supports more seriously not only for cherries and not only for Türkiye but for all the economies where agriculture has a significant contribution.

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a.eu/eurostat, accessed on 16 June 2026), TURKSTAT (https://www.tuik.gov.tr, accessed on 16 June 2026). Additionally, GDP and exchange rate data of partner countries was withdrawn from national datasets.

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