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Trade Competitiveness and Market Dynamics of U.S. Eggplant Production

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ABSTRACT

This study provides a comprehensive economic assessment of supply, demand, and trade competitiveness in the U.S. eggplant (*Solanum melongena* L.) sector, using annual import and export data from 2000 to 2022. Although eggplant is a regionally important specialty crop in the United States, domestic production remains limited relative to rising consumer demand driven by demographic diversification and shifting dietary preferences. Using descriptive statistics, compound annual growth rates, correlation analysis, log-linear elasticity models, and multiple trade competitiveness indicators, this research examines long-term trends in trade quantity, value, and pricing; evaluates the responsiveness of trade flows to price changes; and analyzes the structural factors underlying persistent import dependence. Results show that both import and export quantities and values have increased steadily, with import volumes averaging nearly four times those of exports. Strong positive correlations among trade variables indicate a high degree of integration with global markets. Elasticity estimates reveal atypical positive price responsiveness in both imports and exports, indicating supply-driven price dynamics, limited substitutability, and quality-differentiated export behavior. Competitiveness indicators, particularly the consistently negative Trade Balance Index, high Import Dependency Ratio, and low Self-Sufficiency Ratio, confirm that the U.S. eggplant market is structurally reliant on foreign supply, despite the premium pricing of U.S. exports. The findings align with comparative advantage theory, market integration frameworks, and product differentiation models, showing that trade patterns are shaped by deep-rooted economic conditions rather than short-term fluctuations. This study highlights the need for strategies to enhance domestic production capacity, improve supply chain resilience, and strengthen competitive positioning in global fresh vegetable markets.

INTRODUCTION

Eggplant (*Solanum melongena* L.) is an economically significant solanaceous vegetable widely cultivated across tropical, subtropical, and warm temperate regions (Chen & Li, 1997; Mat Sulaiman *et al.*, 2020). Globally, it ranks as the fifth most important crop in the Solanaceae family, after tomato, potato, chili, and tobacco, underscoring its agricultural and commercial importance (Chapman, 2019). Major global producers include China, India, Egypt, and Turkey, which collectively account for most of the world's eggplant output due to their favorable agro-climatic conditions and established production systems (FAOSTAT, 2023). Beyond its agricultural value, eggplant is also recognized for its nutritional profile, providing potassium, calcium, phosphorus, iron, and B-complex vitamins, which contribute to its growing dietary and market demand (Oladosu *et al.*, 2021).

In the United States, eggplant is classified as a specialty vegetable crop with production concentrated in a limited number of states. The South Atlantic States, New Jersey, and California grow considerable quantities of eggplant for shipment within the United States (Lawande & Chavan, 1998). Georgia, Florida, California, New Jersey, and New York are the primary production zones, reflecting the crop's sensitivity to frost, preference for warm temperatures, and susceptibility to heat stress

(Díaz-Pérez & Eaton, 2015). The economic contribution of eggplant cultivation, though modest relative to other vegetable crops, is nonetheless regionally important. U.S. production was valued at \$42.5 million in 2001, and by 2012, Georgia alone reported farm-gate values nearing \$17 million, illustrating the crop's sustained economic role within specific horticultural sectors (Díaz-Pérez & Eaton, 2015). Production studies have also documented yield improvements linked to advances in variety development, nutrient management, and soil optimization. For example, New Jersey reports average yields of approximately 18,500 kg/ha, attributed in part to enhanced cultivation practices and the performance of newer hybrids (Paterson, 2019; Taher *et al.*, 2017).

Despite stable domestic production, U.S. eggplant consumption has expanded alongside demographic diversification, the growth of multicultural cuisines, and increasing consumer interest in plant-based and nutrient-dense foods. This rise in demand has outpaced domestic supply capacity, making the United States a structurally import-dependent market for eggplant. Imports primarily come from countries with comparative advantages in labor availability, climatic suitability, and year-round production, particularly in the Americas. The crop's biological and agronomic characteristics, especially its heat requirements and high labor input, further reinforce

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the competitive edge of foreign suppliers relative to the United States, a pattern consistent with established trade and factor-endowment theories.

Although eggplant plays a distinct role in U.S. specialty crop markets, scholarly research on its economic and trade dimensions remains limited. Existing literature predominantly examines horticultural production practices (Batabyal *et al.*, 2017; Costa *et al.*, 2013; Hamdy *et al.*, 2002), varietal performance (AKPAN *et al.*, 2016; Alam *et al.*, 2021; Lyu *et al.*, 2024; Onyeausi *et al.*, 2025), and physiological responses to environmental conditions (Concellón *et al.*, 2007; Kirnak *et al.*, 2001; Martins *et al.*, 2012; Savvas *et al.*, 2008). Comprehensive assessments of market behavior, price dynamics, and trade competitiveness are relatively scarce. In particular, very few studies have investigated long-term import and export trends, supply-demand interactions, or the structural factors shaping the United States' position in international eggplant markets. As consumer demand continues to grow and global supply chains evolve, understanding these economic dynamics is increasingly critical for guiding domestic production strategies, informing trade policy, and supporting industry development.

The present study addresses this gap by providing a detailed economic analysis of U.S. eggplant supply, demand, and trade performance. By integrating descriptive trend analysis, elasticity estimation, and trade competitiveness indicators, the study offers a comprehensive examination of long-term patterns in U.S. eggplant trade. It situates them within broader agricultural and economic contexts. This work aims to enhance understanding of the economic forces shaping the U.S. eggplant sector and to support evidence-based decision-making among growers, policymakers, and industry stakeholders.

MATERIALS AND METHODS

This study employed a combination of descriptive, econometric, and trade competitiveness analyses to examine long-term trends, price responsiveness, and structural competitiveness in the U.S. eggplant trade. The methodology integrates time-series statistical techniques, elasticity modeling, and internationally recognized competitiveness indicators, using U.S. annual import and export data from 2000 to 2022, obtained from the FAOSTAT database.

Data Sources and Variables

The dataset included annual values and quantities for the following:

- Export value (USD 1,000)
- Export quantity (tons)
- Import value (USD 1,000)
- Import quantity (tons)

From these, the following variables were constructed

$$\bullet \text{ Import Unit Value} = \frac{\text{Import Value}}{\text{Import Quantity}} \quad (1)$$

$$\bullet \text{ Export Unit Value} = \frac{\text{Export Value}}{\text{Export Quantity}} \quad (2)$$

These measures follow the standard international price index methodology (International Monetary Fund, 2009). Natural logarithms for elasticity modeling:

To estimate price responsiveness, all key variables were transformed to natural logarithms, including import quantity, export quantity, import unit value, and export unit value. This log transformation allows for elasticity interpretation and stabilizes variance in time-series data (Gujarati & Porter, 2009).

$$\ln(\text{IMPQ}_t), \ln(\text{EXPQ}_t), \ln(\text{IMPP}_t), \ln(\text{EXPP}_t)$$

Where,

$\ln(\text{IMPQ}_t)$ = log of import quantity

$\ln(\text{EXPQ}_t)$ = log of export quantity

$\ln(\text{IMPP}_t)$ = log of import price

$\ln(\text{EXPP}_t)$ = log of export price

In addition, year-over-year percentage changes were calculated for all variables, and several trade competitiveness indicators were constructed, including the Trade Balance Index (TBI), import dependency, export–import ratio, self-sufficiency ratio, and price competitiveness ratio. All computations were carried out in R version 4.5.1.

Descriptive Statistics and Trend Analysis

Descriptive statistics (mean, range, and standard deviation) summarized the central tendency and dispersion of import and export variables. Time-series plots were used to analyze long-term trends in quantities, values, and unit prices.

The year-over-year percentage change was computed using:

Where:

$$\% \Delta X_t = \frac{X_t - X_{t-1}}{X_{t-1}} \times 100 \quad (3)$$

$\% \Delta X_t$ = Year-over-year percentage change in the variable X during year t

X_t = Value of the variable in the current year t

$X_{(t-1)}$ = Value of the same variable in the previous year (t-1)

t = Observation for the current year

t-1 = Observation for the previous year

This approach helps visualize volatility and co-movement across all variables over time. Heatmaps were also generated to visualize co-movement and variability among key variables.

Compound Annual Growth Rate (CAGR)

CAGR was used to measure long-term growth in import and export values, quantities, and unit prices and to assess long-term growth trends (Fernando, 2026). It was calculated using:

Where:

$$\text{CAGR} = \left(\frac{X_{\text{end}}}{X_{\text{begin}}} \right)^{\frac{1}{n}} - 1 \quad (4)$$

- X_{begin} = variable value in the first year

- X_{end} = variable value in the final year
- n = number of years in the study period

CAGR results were categorized as stagnation, slow, moderate, or rapid growth.

Correlation Analysis

Pearson correlation coefficients were computed to assess the relationships among trade quantities, values, and unit values:

$$r_{XY} = \frac{\sum (X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum (X_i - \bar{X})^2 \sum (Y_i - \bar{Y})^2}} \quad (5)$$

The statistical significance of correlations was assessed using t-tests under the null hypothesis ($H_0: R=0$) of no association (Gujarati & Porter, 2009). A correlation matrix and a heatmap were produced to illustrate interactions among variables visually.

Price Elasticity of Import and Export Demand

To estimate how eggplant trade quantities respond to price changes, log-linear regression models were used (Gujarati & Porter, 2009). This specification provides direct elasticity estimates.

$$\ln(IMPQ_t) = \alpha + \beta_1 \ln(IMPP_t) + \epsilon_t \quad (6)$$

Similarly, the export demand elasticity model is specified as:

$$\ln(EXPQ_t) = \alpha + \beta_1 \ln(EXPP_t) + \epsilon_t \quad (7)$$

where,

$\ln(IMPQ_t)$ is the natural log of the import quantity,
 $\ln(EXPQ_t)$ is the natural log of the export quantity,
 $\ln(IMPP_t)$ is the natural log of the import unit price,
 $\ln(EXPP_t)$ is the natural log of the export unit price and
 β_1 represents the price elasticity of demand.

In log-log models:

β_1 = elasticity

Thus, a 1% change in price results in $\beta_1\%$ change in quantity demanded.

Model diagnostics included residual analysis, the Durbin-Watson test for autocorrelation, Augmented Dickey-Fuller (ADF) unit root tests for stationarity, and estimation of 95% confidence intervals for the elasticity coefficients.

Trade Competitiveness Indicators

Multiple indicators were computed to assess the overall competitiveness of the U.S. eggplant sector.

The Trade Balance Index (TBI) was calculated as:

where X_t = export value and M_t = import value.

$$TBI_t = \frac{X_t - M_t}{X_t + M_t} \quad (8)$$

TBI ranges from -1 (complete import dependence) to +1 (strong export orientation) (Lafay, 1992)

Similarly, the absolute trade balance was defined as the difference between exports and imports (Lafay, 1992).

$$Trade\ Balance_t = X_t - M_t \quad (9)$$

The Import Dependency Ratio (IDR) was computed as:

$$IDR_t = \frac{M_t}{X_t + M_t} \quad (10)$$

It indicates the share of domestic consumption met by imports (Food and Agriculture Organization, 2001)

The Export-Import Ratio measures the relative magnitude of exports

$$EIR_t = \frac{X_t}{M_t} \quad (11)$$

While the Self-Sufficiency Ratio (SSR) is defined as:

$$SSR_t = \frac{Q_t^X}{Q_t^X + Q_t^M} \quad (12)$$

where Q_t^X = export quantity and Q_t^M = import quantity, respectively (Food and Agriculture Organization, 2001).

Finally, the Price Competitiveness Ratio (PCR) was calculated as:

$$PCR_t = \frac{Export\ Unit\ Value_t}{Import\ Unit\ Value_t} \quad (13)$$

Values greater than one indicate that exports command higher prices than imports, which reflects competitive positioning in international markets (United Nations Conference on Trade and Development, 2005).

Visualization and Model Validation

To validate robustness and aid interpretation of structural patterns in the US eggplant trade, several visualization techniques were employed, including time-series plots, heatmaps of percentage changes and correlations, fitted-versus-actual plots for regression models, and faceted line graphs of trade competitiveness indicators. These tools helped identify structural patterns and ensured robustness in the analysis.

RESULTS AND DISCUSSION

Trend Analysis

Import and export quantities and values

Between 2002 and 2022, the U.S. eggplant trade increased markedly in both physical volume and monetary value. The average import quantity was approximately 61,506 tons per year (Figure 1), whereas the average export quantity was only 16,302 tons (Figure 2), indicating that imports were roughly 3.8 times larger than exports on a volume basis. In value terms, average imports reached about 62,352 thousand USD (Figure 3), compared with 18,937 thousand USD for exports (Figure 4), so import values were approximately 3.3 times higher than export values. Both import and export values show a clear

upward trend, with steeper increases after 2010, especially after 2019. Value growth exceeds quantity growth, suggesting that rising prices and/or quality upgrades contributed significantly to the expansion of trade. Annual percentage changes show substantial year-to-year variability. Export values experienced their largest decline

in 2005 (about -25%), followed by a sharp rebound in 2006 (about +61%). Import values grew fastest in 2003 (around +52%), while the sharpest decline occurred in 2013 (about -15%). On average, export values increased by about 7.9% per year, and import values by about 7.3% per year, indicating robust nominal expansion of trade

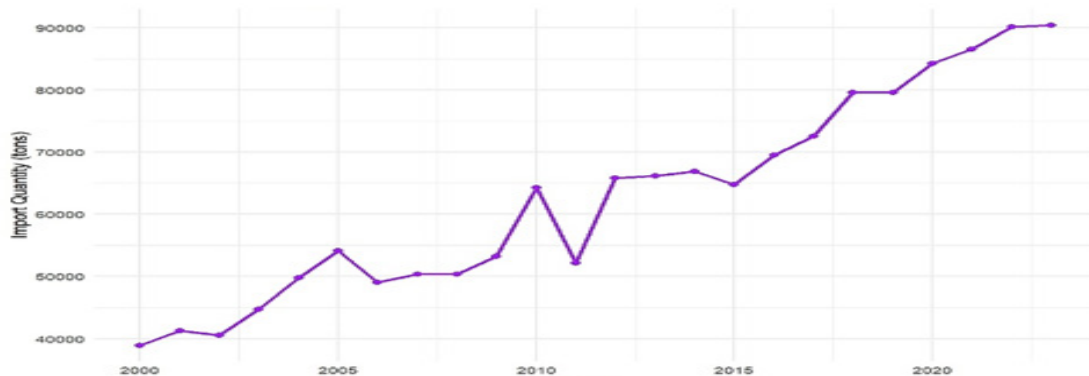


Figure 1: Import Quantity from 2002 to 2022



Figure 2: Export Quantity over time 2002 to 2022



Figure 3: Import value 2002 to 2022



Figure 4: Export value 2002 to 2022

Unit value (price) trends

Import and export unit values (USD/ton) also rose over time. The mean import unit value from 2000 to 2022 was about 1.01 USD/ton, while the mean export unit value was higher at around 1.13 USD/ton, indicating that U.S. eggplant exports tend to consist of higher-priced products than imports. Unit values show pronounced spikes and dips. Import unit value rose most strongly in 2003 (about +36%), whereas the largest decline occurred

in 2011 (around -30%). Export unit value also peaked in 2003 (about +18%), with its largest drop in 2008 (around -11%). From 2020 onward, both import and export unit values increased again, consistent with broader post-pandemic price pressures. Overall, the time-series plots show smooth upward trajectories in quantities and values, with no abrupt structural breaks, but with noticeable volatility in some years, especially 2003, 2005-2006, 2008-2009, and 2020-2022 (Figure 5).

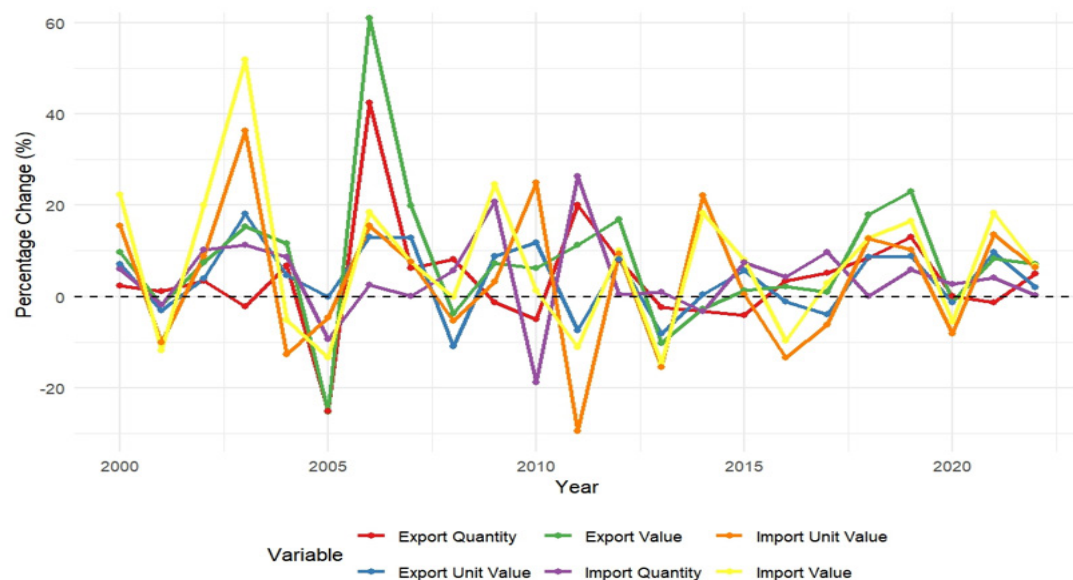


Figure 5: Percentage changes in trade variables (2001-2022)

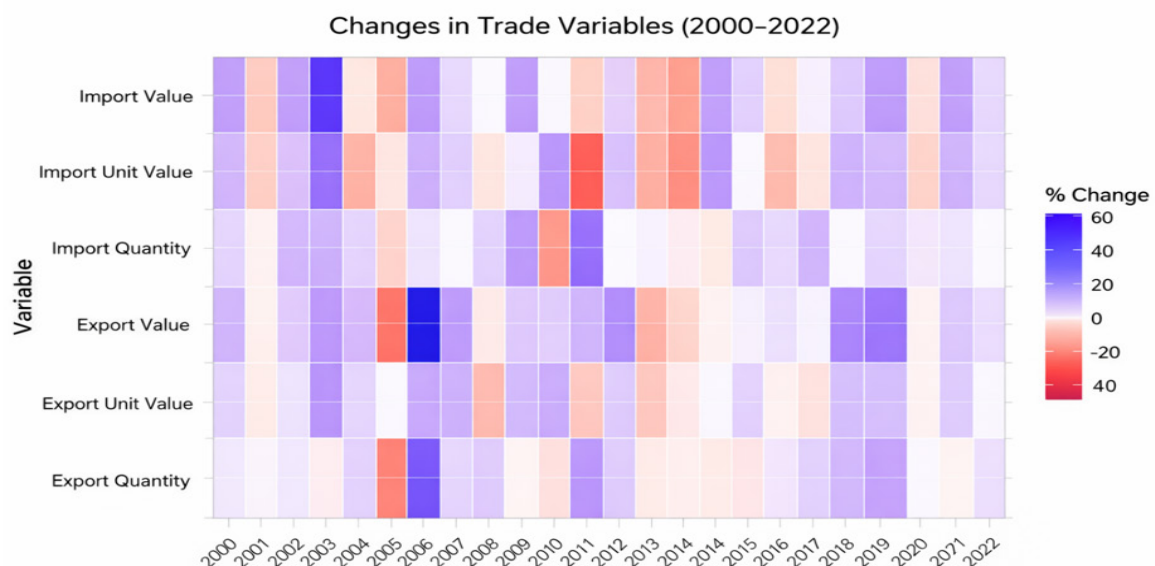


Figure 6: Heatmap of percentage changes in trade variables

Outlier and Missing Value Detection

Visual inspection of time-series plots and boxplots for all numeric variables did not identify any extreme or implausible outliers. All observations fall within reasonable ranges and exhibit consistent temporal

patterns (Figure 7). A completeness check confirmed that the dataset is fully balanced, with no missing values across any of the variables used in the analysis. This allows the use of standard time-series and correlation techniques without the need for imputation or listwise deletion.

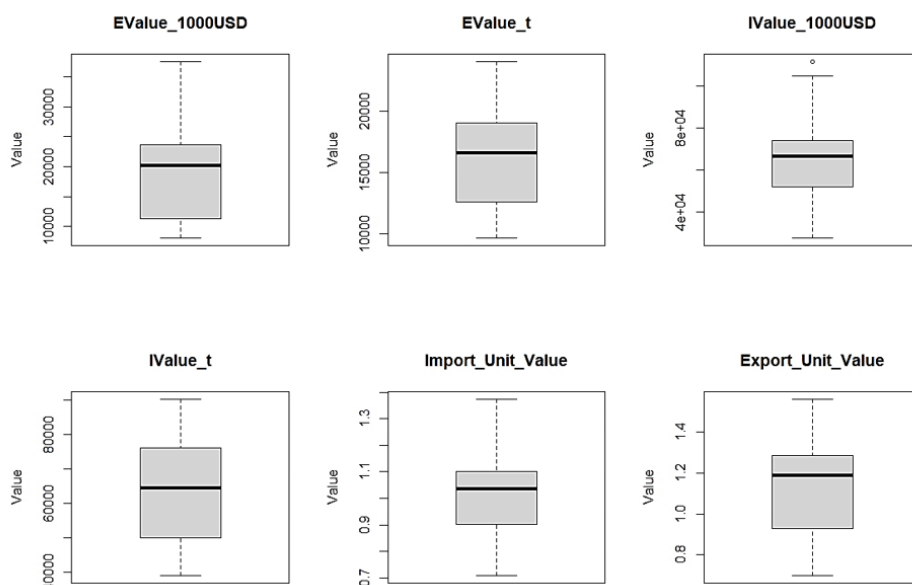


Figure 7: Outliers visualization in trade variables

Descriptive and Statistical Analysis

Measures of central tendency and dispersion

Descriptive statistics for the core eggplant trade variables from 2000 to 2022 show clear differences in the scale and variability of U.S. imports and exports. Export values averaged 19,713 thousand USD ($SD \approx 8,803$), ranging from a low of 8,056 thousand USD in 2000 to a high of 37,581 thousand USD in 2023 (not included in analysis but present in the dataset). Export quantities exhibited a similar pattern, averaging 16,627 tons ($SD \approx 4,225$), with the smallest volume recorded in 2006 at 9,652 tons and the largest in 2023 at 24,090 tons. In contrast, import values were substantially higher, averaging 64,404 thousand USD ($SD \approx 22,029$), increasing from 27,553 thousand USD in 2000 to more than 111,000 thousand USD in 2023. Import quantities followed the same trend, averaging 62,710 tons ($SD \approx 16,274$), rising from 38,918 tons in 2000 to over 90,176 tons in 2022. Regarding prices, import unit values averaged 1.01 USD/ton, ranging from 0.71-1.37 USD/ton, while export unit values averaged 1.13 USD/

ton, ranging from 0.70-1.56 USD/ton. These descriptive patterns strongly corroborate graphical evidence that the United States is structurally a net importer of eggplants. The trade balance remains negative in every year of the series, with an average deficit of approximately -43.4 million USD, reflecting the persistent reliance on foreign supply to meet U.S. market demand.

Compound Annual Growth Rate (CAGR)

The CAGR was calculated for the period 2000-2022 (22 years) using the beginning and ending values for each variable. The results are displayed in Table 1. Quantities grew at around 3-4% per year, whereas values rose at 6-7% per year. This suggests that the nominal expansion of trade has been driven not only by volume increases but also by rising prices and potential shifts toward higher-value products. Export unit values grew faster than import unit values, suggesting a gradual upgrading of U.S. export quality or an improvement in export price premia over time.

Table 1: Compound Annual Growth Rate of U.S. eggplant.

Variable	Year 2000 Value	Year 2022 Value	CAGR (%)	Interpretation
Import quantity (tons)	38,917.53	90,175.83	3.89	Moderate growth
Export quantity (tons)	11,534.79	22,945.95	3.18	Moderate growth
Import value (1,000 USD)	27,553	104,604	6.25	Rapid growth
Export value (1,000 USD)	8,056	35,112	6.92	Rapid growth
Import unit value (USD/ton)	0.708	1.160	2.27	Slow-moderate growth
Export unit value (USD/ton)	0.698	1.530	3.63	Moderate growth

Correlation analysis

Figure 8 shows correlation analysis for the period 2000-2022, which reveals strong co-movements among U.S. eggplant trade variables. Import quantity and import

value exhibit a strong positive correlation ($r = 0.928$, $R^2 \approx 0.862$), indicating that years with higher import volumes are consistently associated with significantly higher import expenditures. A similarly strong relationship is

observed between export quantity and export value, with a very high correlation ($r = 0.982$, $R^2 \approx 0.965$), suggesting that export revenues are closely tied to export volumes and that export prices remain relatively stable over time. Import and export unit values also move together, as evidenced by a positive correlation of $r = 0.705$ ($R^2 \approx 0.497$), which reflects shared underlying price drivers such as production costs, global supply shocks, or transportation expenses—consistent with integrated or

interconnected markets. Additionally, import and export quantities are strongly correlated ($r = 0.944$, $R^2 \approx 0.892$), suggesting that both flows respond to similar demand and supply conditions in the U.S. and neighboring markets. All correlation coefficients are statistically significant at the 5% level, with p-values ranging from approximately 1.7×10^{-10} to below 2×10^{-16} , confirming that these relationships are highly robust and unlikely to be explained by random variation.

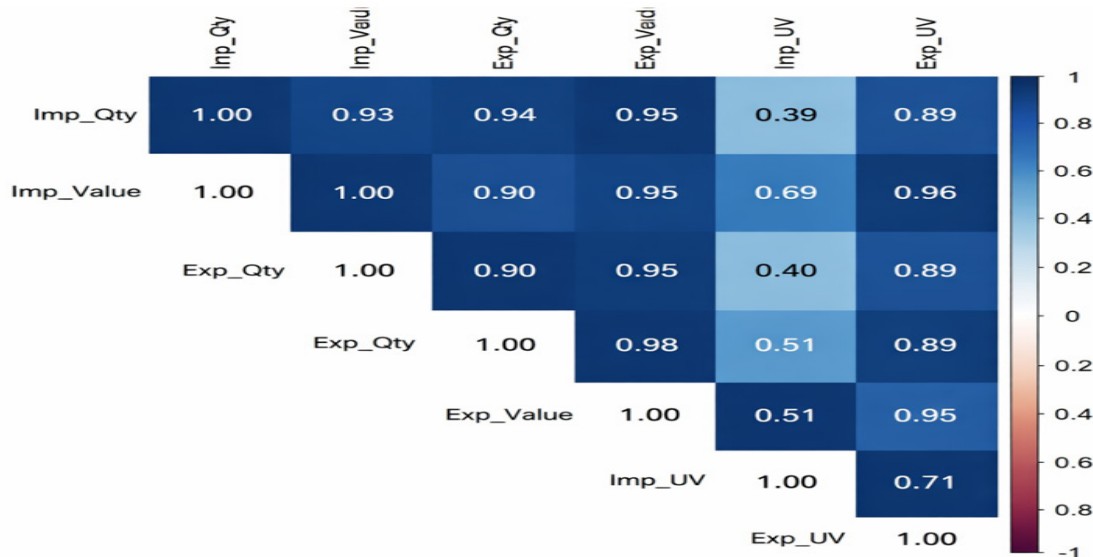


Figure 8: Correlation matrix of trade variables

Price Elasticity of Import and Export Demand

The results of the price elasticity model, estimated using log-log regressions, show how U.S. eggplant import and export quantities respond to changes in their respective prices (Figures 9 and 10). The import demand model indicates an elasticity coefficient of 0.79, which is statistically significant at the 5% level. This indicates that a 1% increase in import price is associated with a 0.79% increase in import quantity. Although theoretically unexpected, because import demand is typically price-elastic and negative, this positive elasticity suggests a Giffen-like response, meaning that higher prices

coincide with higher import volumes. This anomaly may reflect structural market factors such as strong domestic dependence on foreign supply, low substitutability between imported and domestic eggplants, or rising prices driven by demand surges rather than supply shortages. The model's R^2 value of 0.23 suggests modest explanatory power, and the Durbin-Watson test results indicate autocorrelation in the residuals, suggesting that market adjustments are influenced by time-dependent factors beyond price alone.

The export demand model exhibits different behavior, with an elasticity coefficient of 0.95, which is also

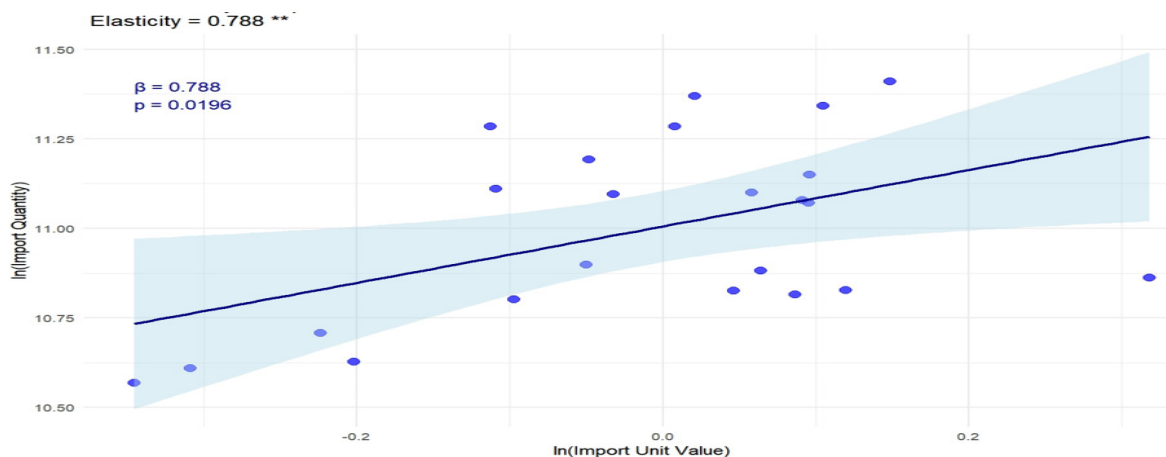


Figure 9: Price elasticity of Import Demand

statistically significant at the 5% level. Here, a 1% increase in export price corresponds to a 0.95% increase in export quantity, suggesting that U.S. exports behave more like normal differentiated goods. This positive responsiveness may indicate a role for quality improvements, branding advantages, or market power in export destinations. The model demonstrates strong explanatory power (R^2 of 0.76), and the Durbin–Watson statistic again suggests some autocorrelation in residuals, consistent with the presence of persistent time trends in export

data. The 95% confidence intervals for the elasticity estimates further support these findings: import elasticity ranges from 0.14 to 1.44, while export elasticity ranges from 0.71 to 1.20, confirming robust and statistically meaningful parameter estimates. Together, these results demonstrate that U.S. eggplant trade exhibits atypical price responsiveness: imports behave anomalously, while exports reflect positive, market-driven responses to price changes.

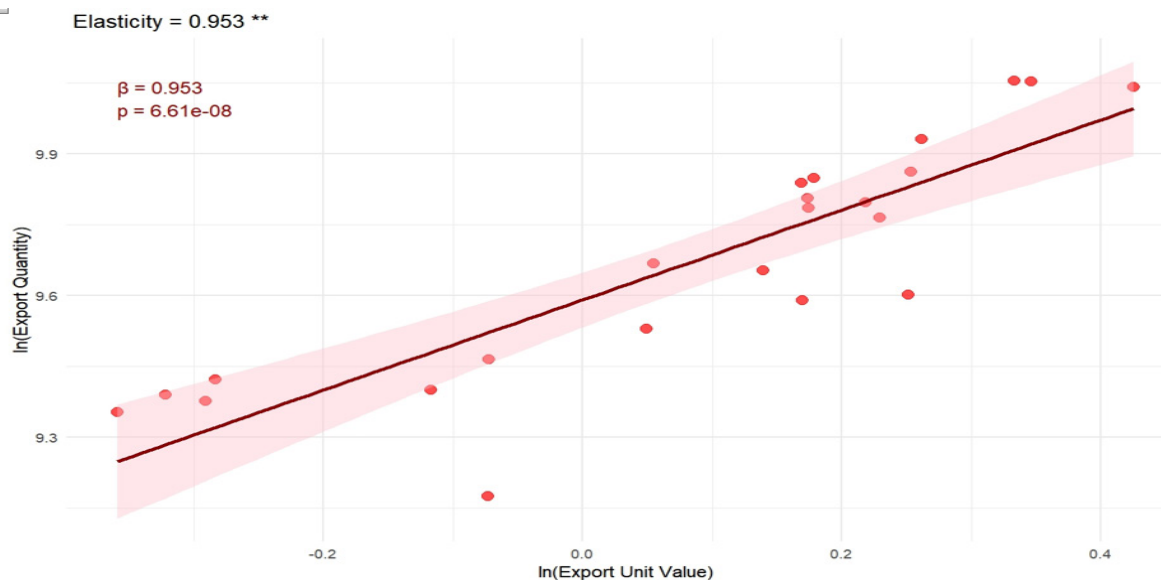


Figure 10: Price Elasticity of Export Demand

Trade Competitiveness Indicators

Several indicators were computed to assess the competitiveness of the U.S. eggplant trade, including the Trade Balance Index (Figures 11 and 12), Import Dependency Ratio, Export-Import Ratio, Self-Sufficiency

Ratio, and Price Competitiveness Ratio. Across the entire study period, the TBI remains negative, averaging -0.546, reaffirming that the United States is structurally a net importer of eggplants.

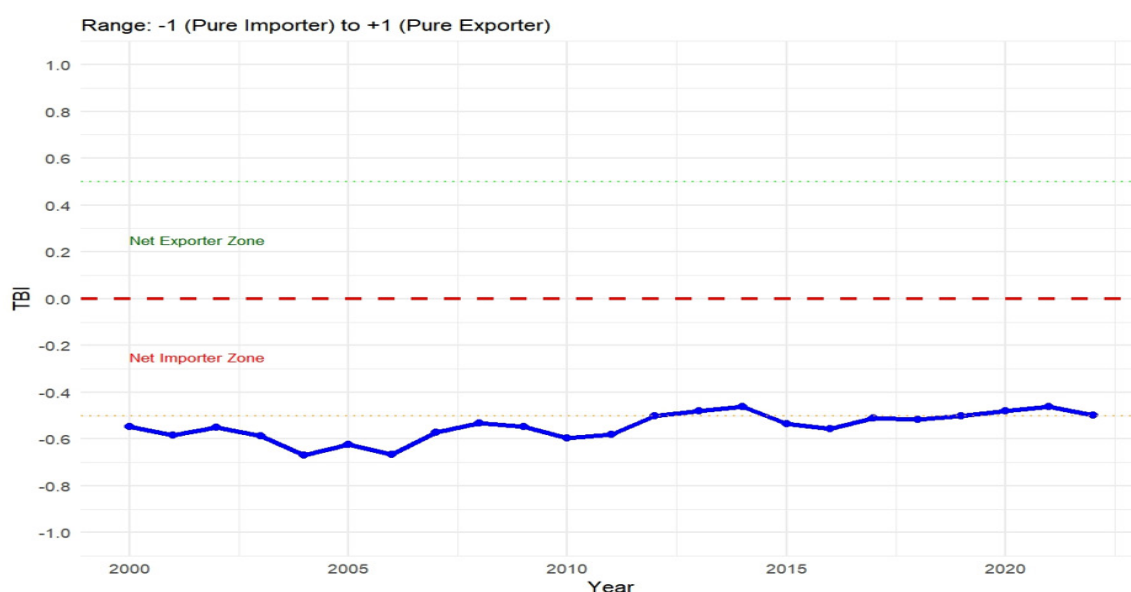


Figure 11: Trade Balance Index for U.S. eggplant

Although the TBI trend is weakly improving over time, its negative magnitude indicates persistent and substantial reliance on foreign supply. The absolute trade balance further supports this characterization, averaging -43.4

million USD, ranging from -69 million USD to -19 million USD, confirming a widening trade deficit as import growth consistently outpaces export growth.

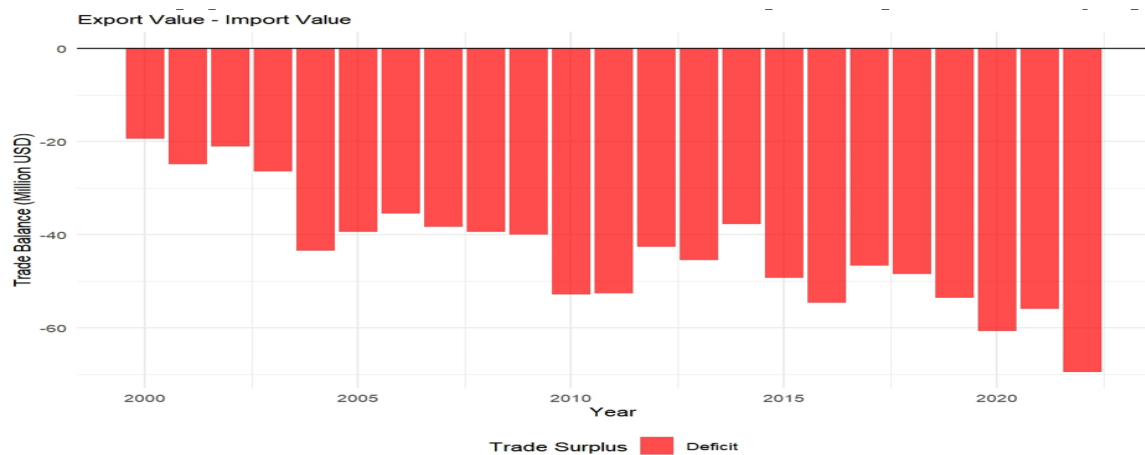


Figure 12: Absolute Trade Balance of U.S. eggplant

The Import Dependency Ratio averages 0.773, indicating that more than 77% of U.S. eggplant availability is sourced from imports. Although this ratio shows a slight decreasing trend, it remains high, reflecting continued dependency on foreign production. The Export–Import Ratio, averaging only 0.296, reinforces this imbalance by showing that exports cover less than one-third of import value on average. Although this ratio shows a modest improvement, imports still account for a significant share of trade flows. The Self-Sufficiency Ratio, calculated from quantity data, averages 0.210, meaning that only about 21% of the U.S. eggplant supply comes from domestic sources. This ratio declines slightly over time, indicating a growing domestic reliance on imported eggplants to meet consumer demand.

Price competitiveness was assessed using the export-to-import unit value ratio, which averaged 1.111, indicating

that U.S. eggplant exports fetch a price premium compared to imports. This difference typically reflects higher quality, stronger branding, or targeting niche markets in export destinations. Although this premium shows a slight upward trend, it doesn't offset the large scale of imports relative to exports. The correlation matrix for the competitiveness indicators further clarifies structural relationships: the TBI is almost perfectly negatively correlated with the Import Dependency Ratio (-1.00) and strongly positively correlated with the Export–Import Ratio (0.999), confirming that trade balance improvements only happen when dependency decreases, and export performance improves. Self-sufficiency shows weaker correlations, indicating that changes in production capacity are, or are only weakly correlated with, price-related competitiveness metrics.

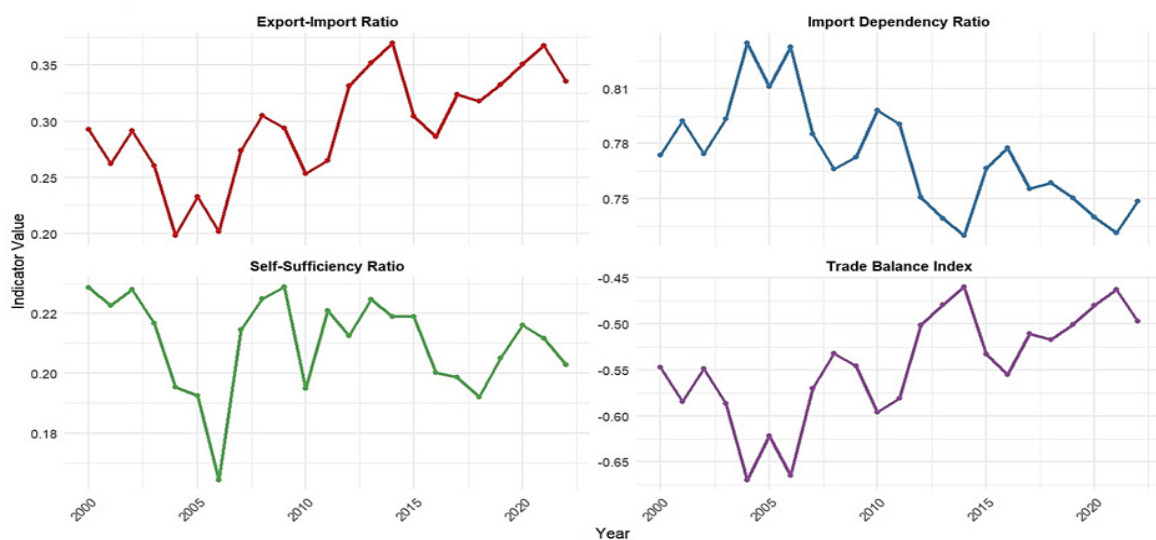


Figure 13: U.S. eggplant trade competitiveness indicators

These competitiveness indicators show that the United States remains firmly import-dependent, with only modest improvements in the trade balance despite increases in export values and unit price premiums. Persistent deficits, high import dependence, limited domestic self-sufficiency, and moderate but insufficient gains in export competitiveness characterize the overall structure of the U.S. eggplant trade.

Discussion

The results of this study reveal a consistent picture of the U.S. eggplant trade system, in which structural import dependence, strong co-movement among trade variables, and atypical price responsiveness are all shaped by underlying economic forces. The persistent trade deficit, high Import Dependency Ratio, and low Self-Sufficiency Ratio are not random outcomes but directly reflect the predictions of the Heckscher-Ohlin theory of comparative advantage (Leamer, 1995). Eggplant production is inherently labor-intensive (Hayashi *et al.*, 2002) and climate-sensitive (Adamczewska-Sowińska *et al.*, 2016; Faiz *et al.*, 2020; Paterson, 2019), while the United States is capital-abundant (Harkness & Kyle, 1975) and faces farm labor scarcity (Zahniser *et al.*, 2018). Countries with warmer climates and lower labor costs, such as Mexico and Central American exporters, hold a natural comparative advantage in eggplant production (Fisher, 2015; Murray-Tortarolo, 2021). This explains why the United States consistently imports far more eggplants than it exports and why domestic production plays only a minor role in supply. The data reflect this long-term structural condition: imports dominate trade flows every year, trade balances remain negative, and import dependency remains extremely high. These outcomes are precisely what factor-endowment models would predict for a temperate, high-wage economy attempting to compete in a crop best suited to low-cost, warm-climate production systems.

The strong positive correlations between quantities and values for both imports and exports demonstrate the high degree of market integration between the United States and global eggplant markets. The close co-movement of import and export prices, although to a lesser degree, suggests that cost and price shocks in global markets are transmitted directly into the U.S. market. This pattern is consistent with market integration theory, which holds that globalized supply chains synchronize price and volume movements across countries (Asche *et al.*, 2007; Knetter & Slaughter, 2001). It is also explained by the Armington model, which states that products are differentiated by their country of origin (Armington, 1969). Consumers might treat imported and domestic eggplants as imperfect substitutes, meaning that prices in one segment cannot fully offset shortages or shocks in the other. This theoretical framework helps explain why import quantities do not fall even when prices rise: the demand for imported eggplants is partially insulated from domestic supply conditions because of differences

in quality, availability, and seasonal timing. Similarly, the strong correlation between import and export quantities reflects shared underlying forces, such as global supply conditions, domestic demand growth, and shocks that affect multiple countries simultaneously. These results illustrate that the U.S. eggplant market operates not in isolation but as a deeply interconnected part of the global horticultural economy.

The elasticity results provide particularly rich theoretical insights. The positive price elasticity of import demand, which runs counter to standard economic expectations, can be explained through multiple theoretical lenses. First, the concept of Giffen-like behavior explains why import quantities increase when prices rise: eggplants may be a necessity item within certain dietary segments, and the United States has limited domestic substitutes, forcing consumers and suppliers to maintain or increase import volumes regardless of price changes. This phenomenon is also consistent with Ferrier & Zhen (2017), where rising incomes lead to increased consumption of fresh vegetables irrespective of price movements. Additionally, the positive elasticity may not reflect demand-driven behavior at all; rather, it may indicate supply-driven price changes. When world supplies tighten, prices rise, but the United States may simultaneously import more to stabilize domestic availability. This aligns with theories of price-quantity dynamics in supply-constrained markets, where quantities respond not to price but to shortages and supply shocks (Geroski & Hall, 1995; Marchand *et al.*, 2016; Shin *et al.*, 2025).

Conversely, the export elasticity result, also positive but much larger, supports theories of vertical product differentiation and Linder's hypothesis. U.S. eggplant exports command higher prices than imports, and higher prices are associated with larger export quantities. This indicates that U.S. exports consist of higher-quality, differentiated products targeted toward high-income markets such as Canada. Vertical differentiation theory predicts exactly this behavior: higher prices signal premium quality and can stimulate demand, particularly in markets with similar income levels and consumer preferences (Sutton, 1986). Linder's hypothesis reinforces this interpretation by suggesting that trade is most intense between countries with similar income and taste structures (Hallak, 2010; McPherson *et al.*, 2001; Rauh, 2010; Thursby & Thursby, 1987). The U.S., therefore, might have exported eggplants not as a bulk commodity but as a niche, higher-value product. This explains the strong, positive export elasticity and also why the United States remains competitive in exporting specialized eggplant products despite being a net importer overall. Competitiveness indicators provide additional theoretical support for these conclusions. The Export-Import Ratio and the Self-Sufficiency Ratio illustrate the structural nature of U.S. import dependence, which aligns with comparative advantage theory and the high opportunity cost of domestic horticultural production. The improving trend in price competitiveness, indicated by an export-to-

import unit value ratio greater than one, fits neatly within the quality-differentiation framework by showing that U.S. exports are positioned in a premium segment rather than competing on price. At the same time, the negative but slightly improving Trade Balance Index suggests that while the U.S. may be making incremental efficiency gains, these are overshadowed by the structural scale of imports, consistent with the persistence of comparative advantage in agricultural trade.

Finally, the volatility observed in key years such as 2003, 2008-2009, 2013, and 2020-2022 reflects the mechanisms of global shock transmission. According to international trade theory and global supply chain literature, shocks such as financial crises, energy price spikes, weather disruptions, and pandemics propagate rapidly through integrated markets, affecting both prices and quantities simultaneously (Bonadio *et al.*, 2021; Cerdeiro & Komaromi, 2022; Escaith & Gonguet, 2011). The synchronous movement of U.S. import and export prices and volumes during these periods confirms that eggplant trade is highly sensitive to global supply and demand conditions. The United States, lacking domestic insulation due to its low self-sufficiency rate, experiences these shocks more directly than countries with strong domestic horticultural bases.

CONCLUSION

The overall findings clearly demonstrate that the U.S. eggplant trade operates as a structurally import-dependent system shaped by deep-rooted economic forces, including comparative advantage, global market integration, and vertical product differentiation. The persistent trade deficit, high import dependence, and low self-sufficiency ratio all stem from the United States' inherent production disadvantages relative to labor-abundant, warm-climate exporting countries, as predicted by the Heckscher-Ohlin framework. At the same time, the strong co-movement between quantities and values, the atypical positive import elasticity, and the premium pricing of exports reflect the influence of market integration, supply-driven price dynamics, and quality-differentiated export niches. These theoretical and empirical insights show that current U.S. eggplant trade patterns are not temporary anomalies but the predictable outcome of structural economic conditions, reinforcing the need for policies that enhance domestic production capacity, strengthen supply chain resilience, and support competitive participation in differentiated export markets.

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