# The Substitution Elasticity of Cotton Imports between China and the United States——Based on the Armington Model

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**Abstract.** As the world's largest cotton importer, China's import dependence and trade policy adjustments significantly impact domestic agricultural security and the development of the textile industry. Based on the Armington model, this study uses cotton trade data between China and the United States from 1998 to 2023 to estimate the substitution elasticity of cotton between the two countries and analyze import dependence. The results show that the long-term substitution elasticity of China-U.S. cotton is 1.89, indicating that price fluctuations significantly affect import demand, with a high degree of homogeneity between the two. The short-term elasticity is -0.35, reflecting that short-term import adjustments are constrained by policies and contracts, resulting in a higher level of dependence. Policy recommendations include diversifying import channels, optimizing reserve mechanisms, and improving cotton farmers' welfare to reduce external risks and ensure the stability of the domestic cotton supply chain.

**Keywords:** Cotton trade, Import dependence, Armington substitution elasticity.

## 1. Introduction

In recent years, intensified turbulence in global trade patterns and frequent Sino-U.S. economic and trade frictions have exposed China's cotton imports to multiple challenges, including price volatility and geopolitical risks. As the world's largest cotton consumer and importer, China has long struggled with insufficient cotton self-sufficiency and high import dependency, with U.S. cotton occupying a central position. This dependency renders the domestic textile industry vulnerable to international price fluctuations and Sino-U.S. trade policy shocks, threatening agricultural security and industrial resilience. Since China's accession to the WTO, the cotton industry in the west area and nationwide has entered a phase of rapid development, driven by surging demand. China leads globally in cotton production, consumption, and imports, with the west area's cotton industry expanding rapidly due to its unique resource endowments and national policy support. On March 3, 2025, the U.S. government announced an additional 10% tariff on all Chinese exports to the U.S., prompting China to retaliate with a 15% tariff on U.S. cotton imports. This triggered significant adjustments in global cotton trade patterns. In 2024, China's cumulative cotton imports reached 2.618 million tons, the highest level in a decade. Imports of Brazilian cotton surged, accounting for 42% of total imports and surpassing the U.S. as the largest source. U.S. cotton imports totaled 880,000 tons, representing 33% of total imports. This shift highlights deep-seated contradictions in traditional import substitution pathways. Against this backdrop, analyzing the substitution elasticity of Sino-U.S. cotton imports and China's import dependency is crucial for addressing trade frictions and safeguarding national agricultural security.

The Armington Model, proposed by Paul Armington in 1969, is a pivotal theoretical framework in international trade. It addresses the limitations of traditional trade models that assume homogeneous goods by introducing origin-based differentiation, treating products from different countries as heterogeneous even within the same category. This assumption effectively explains the "endogenous preference" phenomenon in actual trade flows, enabling a more realistic analysis of trade policies, price volatility, and tariff effects. The Armington Model is primarily used to calculate Armington elasticity[1]. In agricultural research, Zhang Zhexi and Mu Yueying estimated China's corn import elasticity at 3.86 using panel data from 19 countries (2008–2014), revealing low-quality dependency, high homogeneity, and strong substitutability between Chinese and international corn[2].

Wang Jian et al., analyzing the USDA's long-term global cotton outlook report, projected gradual recovery and stabilization of global cotton markets under stable uncertainties as the world economy rebounds[3]. Guo Ying et al. constructed a “technology-institution-norm” framework based on structural power theory, using the cotton industry to illustrate how developed countries leverage technological monopolies, institutional dominance, and normative discourse to convert industrial influence into structural power, constraining developing countries' upgrading opportunities[4]. Wang Pengpeng et al. employed a VAR model to study the dynamic relationship between cotton trade and prices, identifying short-term cotton import volumes and the west area’s cotton prices as drivers of export fluctuations[5]. Chen Biaojin and Zeng Weiwei found non-cointegration between Chinese and foreign cotton futures prices using VECM and co-factor models, recommending diversified agricultural import sources, RMB internationalization, and improved market information disclosure mechanisms[6]. Zhao Lijia selected time series data from 1991 to 2005 and calculated the long-term substitution elasticities for China's soybeans and rapeseed, which were 7.30 and 9.18, respectively[7]. Song Juguo and Liu Yizhuo first constructed an evaluation system for China's cotton industry security index, and then used the GTAP model to explore the impact of cotton imports on the entire cotton industry in China[8]. The analysis concluded that the focus of China's cotton industry storage shifted from seed cotton to cotton lint, continuously improving China's cotton competitiveness, increasing import quotas, and strengthening multilateral and bilateral trade negotiations.

Existing studies predominantly focus on agricultural import elasticity but inadequately address the long- and short-term Armington elasticity of strategic commodities like cotton or its policy linkages. This paper applies the Armington model to U.S. cotton import data (1998–2023) to estimate substitution elasticities between domestic and U.S. cotton.

## 2. Theories and methods

### 2.1. Armington model

According to the Armington hypothesis, the CES utility function can express the utility obtained by a consumer from consuming a combination of domestically produced and imported goods. When the total demand (expenditure) level is given, the utility maximization problem of a certain commodity consumption in country i can be described as follows.

$$\text{Max } U_i = \left[\delta_i D_i^{\frac{\sigma_i-1}{\sigma_i}} + \sum_{j\neq 1} \delta_{ij} M_{ij}^{\frac{\sigma_i-1}{\sigma_i}}\right]^{\frac{\sigma_i-1}{\sigma_i}} \tag{1}$$

$$Y_i = p_i^D D_i + \sum_{j\neq 1} p_{ij}^M M_{ij} \tag{2}$$

Where $\sigma_i \in \{(0,1) \cup (1,\infty)\}, \delta_i, \delta_{ij}, D_i$ and $M_{ij}$ are all positive, $U_i$ denotes China's combined utility of domestic and foreign consumption of the same commodity; $D_i$ denotes the quantity of domestically produced commodities consumed in China; $M_{ij}$ denotes the amount of commodities imported by China into the jth country; $\delta_i, \delta_{ij}$ denote the coefficient of preference for the commodity and $0<\delta_i(\delta_{ij})< 1$; $\sigma_i$ denotes the invariant elasticity of substitution between China's imports of commodities and its domestic consumption, namely Armington elasticity. According to the requirement of utility maximization and assumption (2), the marginal rate of substitution between domestic and foreign commodity consumption is equal to the ratio of price correlation between the two, which can be obtained by derivation:

$$\frac{M_{ij}}{D_i} = \left(\frac{\delta_{ij}}{1-\delta_{ij}}\right)^{\sigma_i} \left(\frac{P_i^D}{P_{ij}^M}\right)^{\sigma_i} \tag{3}$$

A logarithmic transformation on both sides yields:

$$\ln\frac{M_{ij}}{D_i} = \sigma_i \ln\left(\frac{\delta_{ij}}{1-\delta_{ij}}\right) + \sigma_i \ln\frac{P_i^D}{P_{ij}^M} \tag{4}$$

By making equation $\ln\frac{M_{ij}}{D_i} = y, \sigma_i\ln(\frac{\delta_{ij}}{1-\delta_{ij}}) = \alpha_0, \sigma_i = \alpha_1, \ln\frac{P_i^D}{P_{ij}^M} = x$ in (4), we can get:

$$y = \alpha_0 + \alpha_1 x \tag{5}$$

### 2.2. ADF test and Johansen cointegration test

The ADF test is used to determine whether a time series contains a unit root by constructing a regression model that includes lagged difference terms to eliminate autocorrelation effects. The core idea is to reject the null hypothesis by testing whether the regression coefficients are significantly less than zero. The model includes three forms: no constant or trend terms, constant term only, and both constant and trend terms, with the appropriate form chosen based on the characteristics of the series. During the test, the lag length must be determined, and the ADF statistic is computed. If its value is lower than a specific critical value, the hypothesis of non-stationarity is rejected. The Johansen cointegration test is used to analyze the long-term equilibrium relationship among multiple non-stationary variables. Based on the maximum likelihood estimation of the vector error correction model (VECM), the number of cointegration relationships is determined through a matrix rank test. It constructs trace statistics or maximum eigenvalue statistics by calculating the eigenvalues of the matrix and gradually tests the cointegration rank, thus determining the cointegration vectors.

### 2.3. ECM model

The ECM model is widely used in domestic and international research in fields such as international trade. It is an extension of the VAR model that can handle time series data with cointegration relationships. By capturing long-term cointegration relationships and incorporating error correction terms, it corrects the impact of short-term shocks on long-term equilibrium. This model provides more accurate and comprehensive information, better capturing the interrelationships and dynamic associations between variables. The general form of the VECM(p) model is:

$$\Delta Y_t = \alpha ECM_{t(-1)} + A_1\Delta Y_{t(-1)} + A_2\Delta Y_{t(-2)} + \cdots + A_p\Delta Y_{t(-p)} + c + \varepsilon_t, (t=1,2,\ldots,n) \tag{6}$$

In the equation, $\Delta Y_t$ represents the vector of endogenous variables in the model after differencing; p denotes the lag order of the model; t refers to the number of observations; c is the constant term; $A_1, A_2$ , $\cdots$, $A_p$ refers to the coefficient matrix to be estimated; ECMt(-1) is the error correction term of the model, representing the disequilibrium error of the variables deviating from the long-term equilibrium relationship; $\alpha$ represents the adjustment parameter, which measures the speed at which the variable returns to the long-term equilibrium state after a short-term deviation.

## 3. Empirical Analysis

### 3.1. Data sources and processing

The data required for the analysis mainly come from the FAO statistical database and the UN Comtrade database. The types of cotton imported by China mainly include raw cotton and processed cotton, with raw cotton being the primary import type. This paper uses the cotton type with HS code 5201, which refers to uncombed or semi-combed cotton, and takes the cotton import volume from the United States to China from 1998 to 2023 as data $M_{ij}$. The difference between China's cotton production and its export volume is used as the series $D_i$. By dividing the import value of cotton from the United States by the import quantity of cotton from the United States, we obtain the unit value of cotton imports, i.e., the CIF price of imported cotton, which serves as the demand price data series $P_{ij}^M$ for imported cotton. By dividing the export value of Chinese cotton by the export volume of Chinese cotton, we obtain the unit value of exported cotton, i.e., the FOB price of Chinese cotton. A comparison shows that this price is consistent with the domestic market price trend and strongly represents the domestic consumption price of Chinese cotton, thus serving as the market demand price data series $P_i^D$ for domestic cotton.

### 3.2. Estimation results and analysis of cotton import dependency

In this study, the natural logarithm of the ratio of import volume to domestic consumption volume is taken as the time series y. Similarly, the natural logarithm of the ratio of domestic price to import price is taken to obtain the time series x. The ADF stationarity test is conducted on both series x and y, with the test results shown in Table 1.

**Table.1.** Results of stationarity test for series x and y

| Commodity | Variables | Explanation | ADF test value | 1% critical value | Inspection result |
|---|---|---|---|---|---|
| Cotton | x | ln(Pd/Pm) | -4.221 | -3.750 | Stationarity |
| | Dx | △ln(Pd/Pm) | -7.828 | -3.750 | Stationarity |
| | y | ln(d/m) | -1.649 | -3.750 | Nonstationarity |
| | Dy | △ln(d/m) | -5.539 | -3.750 | Stationarity |

Based on the results in Table 8, the relevant data for cotton show that both x and y become stationary sequences after first differencing. The cointegration relationship between the variables x and y was tested, and the test results are shown in Table 2.

**Table.2.** Johansen co-integration test results

| Commodity | Null hypothesis | Trace statistics | 5% critical value | Eigenvalue |
|---|---|---|---|---|
| Cotton | r≤0 | 36.13 | 15.41 | - |
| | r≤1 | 13.44 | 3.76 | 0.68 |

It can be seen that there is a cointegration relationship between x and y. Through the Johansen test, the null hypothesis of no cointegration relationship is rejected, and further, an error correction model between x and y is established.

To determine the long-term Armington elasticity of cotton, that is, the long-term relationship between x and y, a regression of the two variables is conducted, yielding:

$$y = -3.71 + 1.89x \tag{7}$$

The regression results of the above equation show that the t-values of the variables are relatively large, with the t-values of the constant term and the coefficients of the independent variables being -16.16 and 1.74, respectively, both of which are significant. The F-value is 3.01, and $R^2$ is 0.12, indicating that the entire equation is significant. The estimated value of China's cotton import substitution elasticity is 1.89, suggesting that, all else being equal, a 1% increase in the price of U.S. imported cotton relative to domestic cotton leads to a 1.89% decrease in the consumption of imported cotton relative to domestic cotton. The relatively high substitution elasticity indicates that the quality dependence between Chinese and U.S. cotton is low, the homogeneity is high, and there is a strong substitution elasticity. Therefore, under the influence of price disadvantages, China's motivation to import cotton is strong. To derive the long-term and short-term elasticities, the error correction model (ECM) is established as follows:

$$\Delta y = -0.35\Delta x - 0.25(y_{t-1} + 3.71 - 1.89x_{t-1}) + 0.07 \tag{8}$$

The coefficients of the variable parameters in the error correction model reflect the short-term and long-term relationships between the two variables. The t-value of the coefficient before $y_{t-1} + 3.71 - 1.89x_{t-1}$ is -2.12, with a p-value of 0.04, which is significant at the 5% statistical level. The overall model has an $R^2$ of 0.21 and an F-value of 2.87, indicating that the model is significant and passes the LM test for the absence of autocorrelation. Based on the analysis above, it is known that x and y represent the logarithmic values of relative prices and relative import quantities. Therefore, the coefficients before $x_{t-1}$ and $\Delta x$ represent the long-term and short-term Armington substitution elasticities of Chinese consumers between imported U.S. cotton and domestic cotton in response to changes in U.S. imported cotton prices. However, the short-term elasticity is statistically insignificant, possibly due to recent changes in China-U.S. tariff policies. Consequently, the short-term and long-term Armington substitution elasticities between U.S. imported cotton and domestic cotton are -0.35 and 1.89, respectively, reflecting that, in the short term, China has some dependence on U.S. imported cotton, whereas in the long term, there is a higher degree of substitutability. The relative consumption demand for domestic and foreign cotton is relatively sensitive to price changes, with low dependence, which is insufficient to protect the domestic cotton industry from the threat of competition from cheap imports.

## 4. Conclusions and recommendations

This study employs cotton import data from 1998 to 2023 and the Armington model to analyze substitution elasticities between domestic and U.S. cotton. Findings reveal short- and long-term Armington substitution elasticities of -0.35 and 1.89, respectively. In the short term, import adjustments are constrained by contractual, technological, and policy inertia, amplifying vulnerabilities to external shocks such as U.S. cotton price collapses and the west area's cotton controversies. In the long term, the low quality dependency, high homogeneity, and strong substitution elasticity between Chinese and U.S. cotton drive robust import incentives under price disadvantages[9].

Construct diversified import pathways to mitigate dependency risks[10]. Adhere to the Belt and Road Initiative to develop trade partnerships with emerging economies and build a complementary, diversified market structure. Despite a 15% tariff on U.S. cotton imports significantly raising costs, U.S. cotton still accounted for 33.44% of total imports in 2024. Aligning with China's agricultural realities, it is imperative to strengthen agricultural trade research, leverage dispute resolution mechanisms, safeguard fair trade environments, and enhance cotton protection amid openness[11].

Enhance cotton farmers' welfare and increase capital investment. To ensure the stability and resilience of domestic cotton supply chains, prioritize cotton farmers' welfare through subsidies, reduce market distortions caused by price controls, and incentivize production engagement. Concurrently, improve farmers' technical skills and productivity through professional training and knowledge dissemination.

Optimize cotton reserve mechanisms[12]. Establish a robust reserve system to balance domestic and international price disparities and sustain the textile industry's growth. Adequate reserves mitigate short-term supply gaps and price volatility, stabilize raw material supplies for textile enterprises, and bolster international competitiveness. Furthermore, a well-designed reserve system balances market supply and demand, curbs excessive price fluctuations, and stabilizes market expectations.

Improve cotton market information disclosure mechanisms[13]. As a leading cotton consumer and importer, China must enhance transparency in market information under current trade uncertainties. Leverage satellite remote sensing to dynamically monitor production in major global cotton-producing and exporting countries, enabling timely forecasting and data-driven trade decision-making for policymakers.

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