

Article

Non-Tariff Barriers and China's Fruit Exports: An Empirical Analysis Based on APEC Countries

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Abstract

With the global green transition of trade and rising sustainable development demands in agri-food trade, non-tariff barriers (NTBs) have become a critical factor influencing the sustainable development of agricultural trade. As a major global producer and exporter of fruits, China's fruit trade is inevitably affected by non-tariff barriers. This study therefore examines the impacts of NTBs on China's fruit exports to APEC countries. We use panel data of 13 APEC countries from 2001 to 2023 and apply an extended gravity model. This study takes the total number of TBT and SPS notifications as the proxy variable for NTBs. It empirically tests the trade effect of NTBs on China's fruit exports and conducts heterogeneity analysis via quantile regression and grouped regression. Baseline results show that NTBs significantly reduce China's fruit exports. The negative effects of NTBs are more pronounced for small-scale export markets and processed fruit products. Furthermore, China's economic development can effectively mitigate the adverse trade impacts of NTBs. These findings furnish actionable implications for balancing food safety governance and sustainable agricultural development.

Keywords: non-tariff barriers; China; fruit export; APEC; extended gravity model

1. Introduction

With deepening economic globalization and trade integration, global challenges such as resource scarcity and environmental degradation have become increasingly prominent. Food safety and sustainable development have become universal consensus and important governance goals in current agri-food trade [1,2]. Concurrently, countries worldwide have strengthened green regulations on imported agricultural products and elevated green market access thresholds. Therefore, traditional tariff measures continue to decline under multilateral trade agreements, while non-tariff measures (NTMs) are gradually replacing them in global agri-food trade. Against this backdrop, Sanitary and Phytosanitary (SPS) measures and Technical Barriers to Trade (TBT) are the dominant forms of non-tariff measures (NTMs) [3–5]. These measures have been widely carried out globally. They serve as key institutional arrangements to safeguard food safety, regulate production practices and lower cross-border health risks [6]. However, these measures may exceed their legitimate regulatory boundaries and their implementation processes may also lack adequate transparency. Under such circumstances, they transform from neutral

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regulatory instruments into protectionist non-tariff barriers (NTBs). These barriers may restrict market access and cross-border trade. Therefore, this paper selects the notified quantity of TBT and SPS as the proxy variable to measure non-tariff barriers.

Among all types of NTMs, TBT and SPS measures are the most prevalent and restrictive trade regulations. They accurately capture changes in importing countries' regulatory stringency and market access thresholds. Thus, TBT and SPS measures serve as the core proxy variables for measuring non-tariff barriers in academic research. For example, Jongwanich examines processed food exports from developing countries [1]. He uses panel data of 79 countries from 1990 to 2006 and incorporates SPS standards into the export model for econometric analysis. The study finds that SPS standards imposed by developed countries significantly impede processed food exports from developing countries. Disdier et al. extend the research scope to overall agricultural trade [4]. They systematically evaluate the trade impacts of SPS and TBT measures. After controlling for bilateral tariffs, the study draws two core conclusions. First, SPS and TBT measures imposed by OECD countries significantly reduce overall agricultural imports. Second, these barriers have no significant negative impact on trade between OECD countries. However, they impose severe constraints on exports from developing and least-developed countries. Subsequently, extensive research has examined the trade effects of NTBs from diverse perspectives and produced abundant theoretical and empirical results. Most studies confirm that NTBs impose a significant dampening effect on trade flows [7–11]. However, some studies suggest that NTBs can increase trade. They further emphasize that the trade effects of NTBs are specific to each case. This highlights the importance of accounting for context-specific characteristics and circumstances [12–15]. Therefore, this study adopts the number of SPS and TBT notifications submitted by importing countries to the WTO as the core proxy variable for NTBs [4]. It empirically examines the trade effects of NTBs on China's fruit exports to the Asia-Pacific Economic Cooperation (APEC) countries.

This study specifically focuses on fruit product categories and the APEC regional market. Fruits constitute a distinctive category within agricultural trade. They are perishable agricultural goods with high added value, featuring strict requirements on production, processing, transportation and quarantine. Therefore, fruits are highly vulnerable to stringent TBT and SPS requirements, particularly those pertaining to pesticide residue limits, microbiological safety thresholds, and phytosanitary certification [16]. As a major global fruit producer and exporter, China's fruit industry occupies a key position in its agricultural economy and plays a critical role in driving rural economic growth and increasing farmers' incomes [17,18]. Over the years, China's fruit exports have maintained robust growth marked by expanding scale, growing product variety, and diversifying markets. Its export value rose sharply from 435 million USD in 2001 to 5.93 billion USD in 2023. Meanwhile, APEC economies are the primary market for China's fruit exports. Their share of China's total fruit export value remained stable at 65–85% between 2001 and 2023. Nevertheless, the growing number of TBT and SPS notifications issued by APEC countries has continuously raised the market access threshold for Chinese fruits in recent decades. Therefore, this study selects 13 APEC members as its research sample. The findings provide empirical evidence for advancing the high-quality and sustainable development of China's fruit export trade. Accordingly, examining the effects of NTBs on China's fruit exports has significant practical significance. This study addresses three core research questions. First, do NTBs exert a significant inhibitory effect on China's fruit exports to APEC countries? Second, what heterogeneous effects do NTBs impose on China's fruit exports in various dimensions? Third, what regionally targeted policy measures can address the trade effects of NTBs?

To answer these questions, this study constructs a panel data of China's fruit export values to 13 APEC countries over the period 2001–2023. It adopts the gravity model for

baseline regression to identify the trade effect of NTBs on China's fruit exports. The sample and time window are carefully selected to guarantee empirical accuracy and rationality. Of the 21 APEC member economies, some present persistent zero fruit-trade flows with China, which would cause estimation bias and reduce regression consistency in gravity model analysis. Thus, this study excludes economies with long-term zero-trade records and selects 13 APEC economies with stable fruit-trade links with China as valid research samples. In terms of the time scope, the sample period starts in 2001 when China acceded to the WTO. This milestone event profoundly transformed China's agricultural trade scale and operational rules, facilitating an accurate assessment of NTBs' trade effects under a formal multilateral trade framework. Heterogeneity analysis is further conducted from two dimensions: export scale and fruit product category. This paper further explores the moderating effect of per capita GDP on the relationship between NTBs and China's fruit trade. This study delivers three key contributions to the extant literature. First, it fills the regional research gap by systematically analyzing the impacts of NTBs on China's fruit exports across APEC countries. Second, it enriches the heterogeneity research by simultaneously examining export scale and product category differences. Third, it expands the analytical framework by clarifying the boundary conditions of NTB effects via the moderating effect of economic development. The findings not only provide solid theoretical and empirical support for China to optimize its fruit export layout, but also offer valuable implications for coordinating food safety governance and agricultural sustainable development in agri-food trade.

2. Theoretical Basis and Research Hypotheses

2.1. Main Effect Hypothesis

In recent years, green trade barriers represented by TBT and SPS notifications have proliferated across global fruit and agricultural markets and have gradually become a core constraint on the growth of China's fruit exports. The theoretical logic can be summarized into two restraining channels formed by TBT and SPS measures. First, the compliance cost effect. Tighter trade barriers force export firms to bear extra expenditures on inspection, quarantine, certification and production process reconstruction. These additional costs raise per-unit export costs, weaken the price competitiveness of Chinese fruits in foreign markets, and cut export volumes [19]. Second, the market access restriction effect. Strict SPS standards such as maximum pesticide residue limits and specific pest quarantine requirements act as rigid entry thresholds [4,20]. When Chinese fruit shipments fail to meet updated standards within the required period, they will be denied market access directly, resulting in suspended exports or forced shifts to alternative markets with higher trading costs. Within the gravity model framework, green trade barriers function as additional trade resistance, which is expected to impose a prominent negative influence on China's fruit export value [21]. As a result, green trade barriers represented by TBT and SPS notifications exert a significant trade-inhibiting impact on China's fruit exports. The more fruit-related TBT and SPS notifications issued by importing APEC economies, the lower China's corresponding fruit export value.

Hence, the following research hypothesis is posited:

H1. *Green trade barriers erected by importing countries exert a significant inhibitory effect on China's fruit exports.*

2.2. Moderating Effect Hypothesis

The economic development level of the exporting economy serves as a fundamental factor shaping green trade barriers' trade impacts. It reflects domestic export enterprises' aggregate capacity to meet overseas technical and regulatory requirements [22]. Sustained

growth in China's per capita GDP fosters can expand investment in agricultural R&D and supporting infrastructure [23]. Capital flows into advanced fruit cultivation technologies, cold chain logistics systems, and food safety inspection facilities. These inputs steadily improve domestic fruit quality and safety performance, narrowing the gap with international regulatory benchmarks. Economic development also facilitates the advancement of trade-supporting institutional arrangements. These institutional developments effectively reduce information and adaptation costs, enabling firms to track foreign standard revisions timely and adjust practices at lower cost. Furthermore, higher economic development strengthens export enterprises' capital and technological reserves [24]. Firms gain greater capacity to reconfigure production processes to satisfy stringent import requirements. Conditional on a given barrier stringency, improved compliance capacity attenuates green trade barriers' actual trade-restrictive effect [25]. In other words, the exporting country's economic development level exerts a negative moderating effect on the inhibitory link between green trade barriers and fruit exports. As China's per capita GDP rises, the inhibitory effect of green trade barriers on China's fruit exports tends to weaken accordingly.

Hence, the following research hypothesis is posited:

H2. *China's economic development level negatively moderates the inhibitory effect of green trade barriers on its fruit exports.*

3. Overview of China's Fruit Trade

3.1. The Overall Situation of China's Fruit Exports

From 2001 to 2023, both China's total fruit export value and its fruit export value to APEC economies showed an overall upward trend (Figure 1). In terms of phases, 2001–2019 was a period of sustained growth with a slight decline in 2017–2018. This phase of growth was driven by improved domestic fruit cultivation technology and cold chain logistics, which enhanced fruit output, quality, and export compliance. Meanwhile, trade facilitation measures under the APEC framework reduced market access costs and barriers. In 2020, both types of exports reached a phased peak, at USD 7.064 billion and USD 5.470 billion, respectively. They declined modestly between 2021 and 2022 due to the impact of the COVID-19 pandemic and trade protectionism, but rebounded again in 2023. From a market structure perspective, the share of China's fruit exports to APEC economies in its total fruit exports remained stable between 65% and 85% from 2001 to 2023, indicating that APEC economies have always been the core target markets for China's fruit exports. The persistent and stable status provides a practical basis for the subsequent analysis of the impacts of NTBs focusing on the APEC sample.

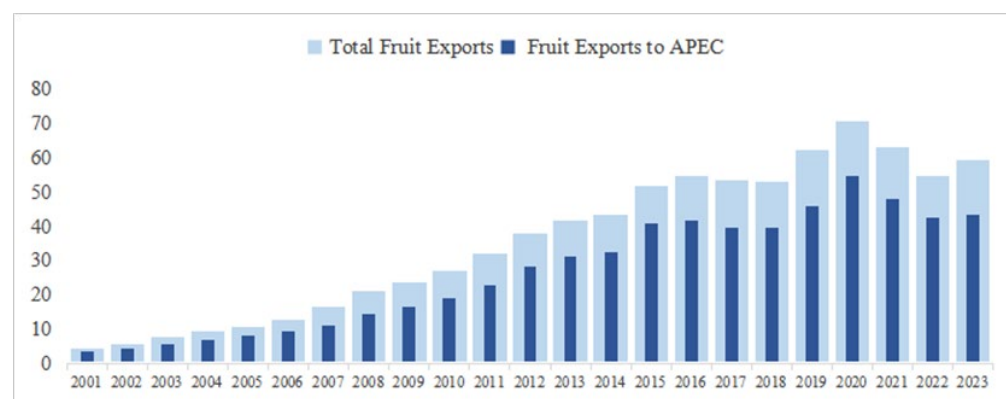


Figure 1. China's total fruit export value and export value to the APEC Region, 2001–2023. (Unit: 100 million USD) Source: UN Comtrade [26].

3.2. Product Structure of China's Fruit Exports

Turning to China's fruit export category structure (2001–2023), trade remained highly concentrated in four core varieties: citrus, apples, grapes, and pears. Their combined share of total national fruit exports rose from 42.21% to 61.36%, reflecting the growing dominance of bulk fruits (Table 1). All core categories posted positive compound annual growth rates (CAGRs) over the period. As the top category, citrus exports rose from 0.40 to 12.49 (Unit: 100 million USD) at 16.93% annually. Grapes grew fastest, at 31.89%, while apples and pears grew steadily at 10.83% and 12.39%, respectively. Collectively, core categories grew at 14.53%, outpacing the national average of 12.61%. Market share dynamics also reveal notable shifts. Citrus and grapes gained share with respective CAGRs of 3.80% and 17.87%. In contrast, apple exports rose from 1.01 to 9.70 (Unit: 100 million USD). Yet apples' share fell from 23.14% to 16.36%. Pears' share also declined modestly (CAGR = −0.17%). This suggests a potential expansion in China's fruit export category. Other fruit varieties have crowded out part of the market share of apples and pears.

Table 1. China's fruit exports by major product category, 2001–2023 (Unit: 100 million USD).

Fruit Category	HS Code	Export Value		Export Value CAGR (2001–2023, %)	Share of Total National Fruit Exports (%)		Market Share CAGR (2001–2023, %)
		2001	2023		2001	2023	
Citrus	080510–080590	0.40	12.49	16.93	9.28	21.07	3.80
Apples	080810	1.01	9.70	10.83	23.14	16.36	−1.56
Grapes	080610–080620	0.02	8.83	31.89	0.40	14.89	17.87
Pears	080830	0.41	5.36	12.39	9.39	9.04	−0.17
Subtotal of Core Categories	-	1.84	36.39	14.53	42.21	61.36	1.72
Total National Fruit Exports	0801–0814	4.35	59.30	12.61	100	100	-

Export value data are sourced from UN Comtrade [26]. Market share is calculated as the ratio of each category's export value to China's total national fruit export value in the corresponding year. CAGR (Compound Annual Growth Rate) is calculated by the standard formula: $CAGR = \sqrt[n]{\frac{Ending\ value}{Beginning\ value}} - 1$, where $n = 22$ is the number of years in the sample period.

Overall, bulk fruits, primarily citrus, apples, pears and grapes, remain the cornerstone of China's fruit export trade. Meanwhile, the gradual growth of other fruit categories injects new momentum into the optimization of China's fruit export structure.

3.3. Country-Specific Comparison of the Competitiveness of China's Fruit Exports

Using the Trade Competitiveness (TC) index of China's fruit exports to major APEC economies (Figure 2), China's fruit competitiveness shows substantial cross-market heterogeneity. Singapore's TC index consistently exceeded 0.97 over the sample period, indicating an absolute competitive advantage for Chinese fruit in this market. This is driven by geographical proximity, bilateral FTA trade facilitation, inelastic demand, and aligned green standards that impose minimal constraints on exports. Meanwhile, China maintains persistent competitiveness ($TC > 0$) in markets including South Korea, Japan, Indonesia, Malaysia, Russia, and Canada. Most of these economies are geographically close to China or have close regional cooperation ties, sustaining a net export advantage for Chinese fruit. Conversely, Chinese fruit faces persistent competitive disadvantages ($TC < 0$) in Chile, Thailand, the Philippines, and the United States. These economies either have robust domestic fruit industries or impose high-intensity NTBs that weaken Chinese fruit's competitive edge. Furthermore, the competitiveness of Chinese fruit shows significant volatility in Australia and Vietnam, likely driven by major policy shocks. Overall, the

competitiveness of Chinese fruit in APEC markets follows a three-tier pattern: advantages in most markets, disadvantages in a subset, and volatility in a small number of markets.

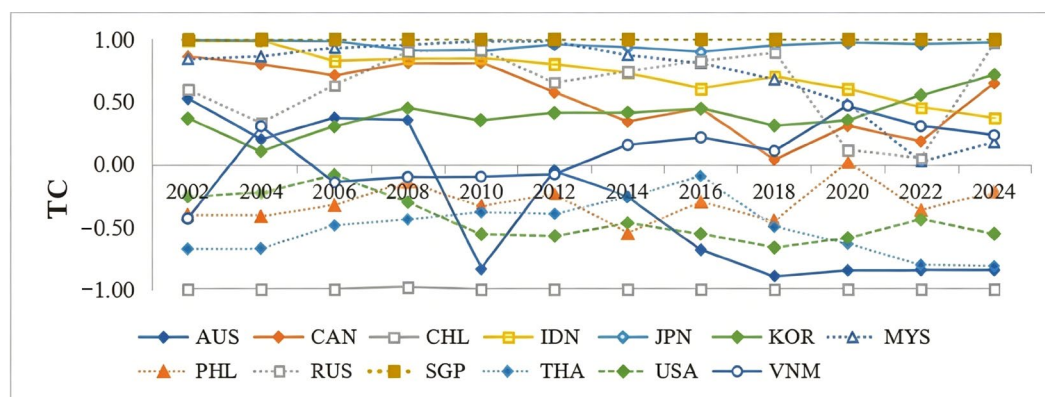


Figure 2. Competitiveness comparison of China's fruit exports, 2001–2023. Source: Calculated from UN Comtrade [26] trade volume data. The TC index is defined as $TC = (X - M)/(X + M)$. X represents the export value. M represents the import value. ISO 3166-1 [27] alpha-3 country codes are used.

3.4. TBT and SPS Notification Trends for China's Fruit Exports

From a structural perspective, SPS notifications occupy the dominant share of total notifications for China's fruit products over the sample years (Figure 3). In terms of phases, SPS notifications maintained an overall rising trend across the whole sample period, with the highest volume appearing in 2019. Meanwhile, TBT notifications stayed at a low numerical level during the entire research interval. The overall expanding trend of two categories of regulatory notifications reflects rising market access thresholds imposed by APEC destination countries. These evolving structural and temporal features provide the empirical foundation for the subsequent analysis of non-tariff barrier effects on trade.

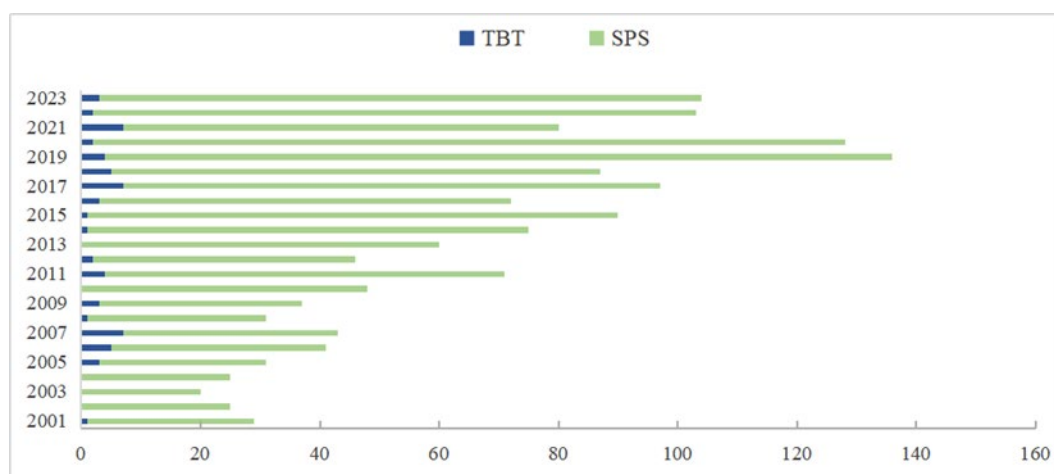


Figure 3. Annual TBT and SPS notifications targeting China's fruit products from APEC countries, 2001–2023. Source: WTO ePing SPS/TBT Notification Alert System.

4. Materials and Methods

4.1. Gravity Model

Originating from Newton's law of universal gravitation, the trade gravity model was first applied to international trade by Tinbergen (1962) [28] and Pöyhönen (1963) [29] in the early 1960s. Over the following decades, it has become a fundamental tool for analyzing the determinants of bilateral trade flows. This model provides a basic analytical framework for empirical economic research. It quantifies how economic size, geographic dis-

tance and other key variables affect trade flows. Against this backdrop, this study adopts the classical trade gravity model for empirical analysis. The basic model is specified as

$$Y_{ij} = A \frac{Y_i^\alpha \times Y_j^\beta}{D_{ij}^\gamma} \quad (1)$$

In Equation (1), Y_{ij} denotes the trade volume between economies i and j ; Y_i and Y_j denote economic sizes of the two economies; D_{ij} denotes the geographic distance between them; A , α , β , and γ are the coefficients.

4.2. The Model and Data

4.2.1. Model Specification

Based on Equation (1), this study extends the basic gravity model by adding explanatory variables: the number of TBT and SPS notifications issued by APEC countries, per capita GDP of China and each APEC member, population of each APEC member, a COVID-19 pandemic dummy variable. The extended gravity model is specified as

$$\ln EX = \beta_0 + \beta_1 \ln TS + \beta_2 \ln GDP_{it} + \beta_3 \ln GDP_{jt} + \beta_4 \ln DIS_{ij} + \beta_5 \ln POP + \beta_6 COVID + \lambda_t + \varepsilon_{ij} + \mu_{ijt} \quad (2)$$

In Equation (2), where i refers to China, j refers to an APEC member and t refers to the time period. EX represents the fruit export value from economy i to economy j in period t . TS is the total number of TBT and SPS notifications on fruit products submitted by economy j to the WTO in period t . GDP_{it} stands for per capita GDP of economy i in period t . GDP_{jt} stands for per capita GDP of economy j in period t . DIS_{ij} denotes the geographic distance between economy i and economy j . POP refers to the population of economy j in period t . $COVID$ is a dummy variable for the COVID-19 pandemic impact. β denotes the parameters to be estimated. μ_{ijt} is the individual fixed effect. λ_t is the time fixed effect. ε_{ijt} represents the random error term. All variables are transformed into logarithms. This treatment mitigates heteroscedasticity and improves model robustness. For TS , which takes zero values for some economies, $TS + 1$ is used for logarithmic transformation. All variables are detailed in Table 2.

The dependent variable EX denotes the value of China's fruit exports to APEC countries. Fluctuations in China's export share in these markets provide a direct measure of the impact of NTBs on China's fruit exports.

Turning to the core explanatory variable, TS measures the intensity of NTBs. This study uses the total number of TBT and SPS notifications targeting fruit products issued by APEC countries as a proxy for NTBs. To ensure measurement precision, notifications are filtered using the Harmonized System (HS) classification to retain only those specifically related to fruit products.

Following the standard trade gravity model specification, we include the following control variables to account for other potential confounding factors: (1) GDP_{it} : Per capita GDP of the exporting economy (China) in period t , capturing its overall export capacity. (2) GDP_{jt} : Per capita GDP of importing APEC countries in period t , reflecting their aggregate import capacity. (3) POP : Population of importing APEC countries in period t , proxying for their aggregate fruit demand. (4) DIS_{ij} : Time-varying bilateral distance. Following Jiang G and Jiang D (2012), we construct this variable as the product of the straight-line distance between national capitals and annual international crude oil prices [30]. (5) $COVID$: Dummy variable capturing the COVID-19 pandemic shock. Based on the World Health Organization (WHO) definition of the global pandemic period, this dummy variable equals 1 for 2020–2022 and 0 otherwise.

Table 2. Definition and measurement of variables.

Variable Category	Abbreviation	Variable Interpretation	Measurement Method
Dependent Variable	EX	Fruit export value	Annual bilateral fruit export value from China to each APEC country
Core Explanatory Variable	TS	Intensity of non-tariff barriers	Total number of fruit-related TBT and SPS notifications released by APEC member
Control Variable	GDP _{it}	Export supply capacity of the exporting country (China) in year t	Per capita GDP of China in year t
	GDP _{jt}	Import purchasing power of each APEC importing economy in year t	Per capita GDP of each APEC country in year t
	POP	Total domestic fruit consumption demand of each APEC country economy in year t	Total resident population of each APEC country in year t
	DIS _{ij}	Bilateral geographic distance	Product of the straight-line distance between national capitals and annual international crude oil prices
	COVID	COVID-19 pandemic shock	Binary dummy variable; assigned a value of 1 for years 2020–2022 (WHO-defined global pandemic phase), and 0 for all other years

4.2.2. Data

This study defines fruit products per the international HS classification, covering 14 categories of fresh and dried fruit under Chapter 08 (codes 0801–0814), detailed as Table 3.

Table 3. Fruit HS codes and classification.

Category	HS Code	Product Description
Dried Fruits	0801	Coconuts, Brazil nuts and cashew nuts
	0802	Other nuts, other than coconuts, Brazil nuts and cashew nuts
Fresh Fruits	0803	Bananas, including plantains
	0804	Dates, figs, pineapples, avocados, guavas, mangoes, etc.
	0805	Oranges, grapefruits, mandarins, and other citrus fruits
	0806	Grapes
	0807	Fresh melons, including watermelons and papayas
	0808	Fresh apples and pears
	0809	Fresh apricots, cherries, plums, peaches, and other stone fruits
	0810	Fresh berries and other fresh fruits
Other Categories	0811	Frozen fruits and nuts (whether or not cooked by steaming or boiling)
	0812	Fruits and nuts provisionally preserved, but unsuitable for direct consumption
	0813	Mixtures of dried fruits and nuts
	0814	Peel of citrus fruits and melons

Data for China’s fruit exports to APEC countries come from UN Comtrade [26]. We use 4-digit HS codes (HS1996) to ensure data consistency. The number of TBT and SPS notifications comes from the WTO ePing SPS/TBT Notification Alert System. Per capita GDP and population data for China and APEC countries are obtained from the World Bank. Bilateral capital-to-capital straight-line distance is from the CEPII database. International crude oil prices come from the IMF. Relevant information on APEC economies is retrieved from the official website of the APEC Secretariat.

4.3. Study Area

This study restricts its sample to APEC countries with an average annual Chinese fruit export value exceeding 2 million USD during 2001–2023, yielding a final sample of 13 countries. Accordingly, the analysis uses balanced panel data for these 13 APEC countries over the 2001–2023 period. The sample period is selected for two reasons: First, China’s 2001 WTO accession marked a new era for fruit exports. Second, this period balances data timeliness and availability. Specifically, the sample includes APEC countries that maintain robust fruit-trade ties with China: Japan and South Korea in East Asia; Indonesia, Malaysia, Thailand, the Philippines, Singapore, and Vietnam in Southeast Asia; Australia in Oceania; the United States, Canada, and Chile in the Americas; and Russia in Europe. These economies maintain steady trade ties with China, ensuring sample representativeness.

5. Results and Discussion

Based on the panel data of 13 APEC countries over the period 2001–2023, this study conducts empirical analysis using Stata 18.0 and presents the corresponding results. Notably, the impact of NTBs on China’s fruit exports is not instantaneous, as there is a time lag between notification, implementation, and their actual trade effects. Thus, notifications issued in a given year typically exert a stronger impact on exports in the subsequent year. Accordingly, we lag the core explanatory variable ($\ln TS$) by one period in empirical specification.

5.1. Descriptive Statistics

Table 4 reports the descriptive statistics for the main variables as follows.

First, $\ln EX$ has a mean of 18.01 and ranges from 4.22 to 21.08, suggesting substantial heterogeneity in China’s fruit export scale across APEC countries. Turning to the core explanatory variable, $\ln TS$ has a mean of 1.00 and spans 0–4.43, reflecting significant variation in NTBs stringency across sample countries. Next, $\ln GDP_{it}$ has a mean of 9.50, a standard deviation of 1.19, and spans 7.23–11.10, indicating moderate differences in economic development levels. $\ln GDP_{it}$ has a mean of 8.70 and a small standard deviation. For bilateral geographic distance, $\ln DIS_{ij}$ has a mean of 12.58, a standard deviation of 0.90 and spans 10.22–14.54, with no extreme outliers detected and conforming to the standard distribution of geographic distance. $\ln POP$ has a mean of 4.06 and spans 1.43–5.81, implying notable variation in market size across destinations. Finally, COVID (COVID-19 pandemic dummy) has a mean of 0.13 and a standard deviation of 0.34, meaning 13% of sample observations fall within the pandemic period. In summary, all variables show reasonable dispersion and valid distributions, meeting the prerequisites for gravity model regression.

Table 4. Descriptive statistics of variables.

Variables	Observed	Mean	Standard Deviation	Min	Max
$\ln EX$	299	18.01	2.16	4.22	21.08
$\ln TS$	286	1.00	1.09	0	4.43
$\ln GDP_{it}$	299	8.70	0.51	7.77	9.43
$\ln GDP_{jt}$	299	9.50	1.19	7.23	11.10
$\ln POP$	299	4.06	1.11	1.43	5.81
$\ln DIS$	299	12.58	0.90	10.22	14.54
COVID	299	0.13	0.34	0	1

Lagging $\ln TS$ reduces observations by 13.

5.2. Correlation Analysis and Multicollinearity Test

To check potential multicollinearity bias, this study conducts correlation analysis and multicollinearity tests (Tables 5 and 6). Correlation results show that pairwise correlation coefficients for all explanatory variables are below 0.5 in absolute value, indicating no severe linear dependence. The variance inflation factor (VIF) shows values of all explanatory variables range from 1.15 to 1.72. The mean value is 1.45 and far below the standard threshold of 10. Collectively, multicollinearity does not materially affect the model estimates. This confirms the validity of the baseline regression results.

Table 5. Correlation test results.

	lnEX	lnTS	lnGDP _{it}	lnGDP _{jt}	lnPOP	lnDIS _{ij}	COVID
lnEX	1.0000						
lnTS	−0.1931	1.0000					
lnGDP _{it}	0.3635	0.2148	1.0000				
lnGDP _{jt}	−0.2221	0.4400	0.1274	1.0000			
lnPOP	0.4698	0.2339	0.0559	−0.3514	1.0000		
lnDIS _{ij}	−0.2604	0.2252	0.2186	0.2651	−0.1206	1.0000	
COVID	0.1315	0.0752	0.4663	0.0568	0.0270	0.0170	1.0000

Table 6. Multicollinearity test results.

Variables	VIF	1/VIF
lnGDP _{jt}	1.72	0.58
lnTS	1.64	0.61
lnPOP	1.47	0.68
lnGDP _{it}	1.39	0.72
COVID	1.29	0.77
lnDIS _{ij}	1.15	0.87
Mean VIF	1.45	

5.3. Baseline Regression Results

To obtain more reliable regression results, this study employs a two-way fixed effects model. It controls for individual and time fixed effects. Columns (1) and (2) of Table 7 report the baseline regression results. Column (1) reports results with only core explanatory variable (lnTS) included. The coefficient on lnTS is −0.331 and statistically significant at the 1% level, indicating that NTBs exert a significant dampening effect on China's fruit exports. The model yields an R² of 0.519. Column (2) presents full regression results incorporating all control variables. The coefficient on lnTS remains negative at −0.214 and statistically significant at the 5% level ($p = 0.017$), confirming that the dampening effect of NTBs is robust to controlling for economic scale, geographic distance, population, and the pandemic shock.

Table 7. Benchmark regression.

Variables	(1)	(2)
lnTS	−0.331 *** (−3.84)	−0.214 ** (−2.393)
lnGDP _{it}		−
lnGDP _{jt}		2.510 *** (4.161)
lnPOP		0.443

		(0.344)
lnDIS _{ij}		10.159 *
		(1.754)
COVID		−2.562 *
		(−1.664)
Constant	16.336 ***	−74.988 **
	(68.98)	(−2.195)
Observations	286	286
R ²	0.519	0.556
Country FE	YES	YES
Year FE	YES	YES

lnGDP_{it} is omitted from the table as it is time-invariant across economies and fully absorbed by year fixed effects in the two-way fixed effects specification. Robust t-statistics in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Turning to control variables, their effects on China's fruit exports are summarized as follows. First, the coefficient on lnGDP_{it} is positive and significant at the 1% level, indicating that higher per capita GDP in importing countries boosts China's fruit exports by strengthening market demand and purchasing power, making it the most important positive driver of export growth. Second, the coefficient on lnPOP is positive but statistically insignificant, implying that population size alone does not exert a material effect on export flows. Third, the coefficient on lnDIS_{ij} is 10.159 and significant at the 10% level, which runs counter to the prediction of the classical gravity model. This positive coefficient on the time-varying variable (constructed as the product of distance and international oil prices) in the two-way fixed effects framework can be explained by two key channels. On the one hand, pure geographic distance is time-invariant and its traditional "distance decay" effect has been largely absorbed by individual fixed effects; thus, the distance × oil price variable primarily captures oil price fluctuations rather than geographic resistance. On the other hand, rising international oil prices are typically associated with global economic recovery, expanding import demand and improving trade conditions [31]. The pro-cyclical relationship between international oil prices and global macroeconomic activity creates a positive correlation with China's fruit exports. This correlation masks the expected dampening effect of transportation costs, which explains the positive coefficient on the distance–oil price interaction term. Fourth, the coefficient on the COVID-19 pandemic dummy (COVID) is negative and significant at the 10% level. This result shows that the pandemic exerted a negative impact on China's fruit exports through logistics disruptions, reduced consumer demand, and prolonged customs clearance. Collectively, these frictions generated a severe short-term shock to export values.

Regarding the overall performance of the baseline regression model, the inclusion of control variables increases the R² to 0.556. This indicates a meaningful improvement in the model's explanatory power.

5.4. Robustness Checks

To verify the robustness of baseline regression results, this study conducts three groups of robustness checks as follows: (1) Replacement of the dependent variable. This study substitutes fruit export volume for original export value to construct an alternative dependent variable. (2) Alternative estimation methods [32,33]. This study re-estimates the benchmark model using pooled OLS that ignores individual heterogeneity and the random effects model that assumes no correlation between individual fixed effects and explanatory variables. (3) Shortened time window [34]. This study excludes sample data covering the 2008–2009 global financial crisis to eliminate interference stemming from ex-

treme economic fluctuations. The results are reported in Table 8. (4) Replacement of control variable. Considering that the specific construction of geographic distance in the baseline model may lead to model specification bias and undermine the reliability of empirical results, this paper conducts robustness tests by replacing control variables and adjusting the estimation model. First, this study replaces the interaction term of oil price and geographic distance with the time-invariant bilateral geographic distance adopted in the standard gravity model [21], while all other variables remain unchanged. Second, we adjust the regression specification. This paper abandons the country-year two-way fixed effects and adopts Pooled OLS estimation with only year fixed effects included.

Table 8. Robustness tests for benchmark regression.

Variables	Replace the Dependent Variable	Alternative Estimation Methods		Shortened Time Window	Replace Control Variable
	(1)	(2)	(3)	(4)	(5)
lnTS	−0.225 ** (−2.39)	−0.842 *** (−8.732)	−0.328 *** (−3.923)	−0.220 ** (−2.29)	−0.841 *** (−8.72)
Observations	286	286	286	260	286
R ²	0.233	0.599	-	0.561	0.599
Controls	YES	YES	YES	YES	YES
Country FE	YES	-	-	YES	NO
Year FE	YES	YES	YES	YES	YES

Robust t-statistics in parentheses *** $p < 0.01$, ** $p < 0.05$.

Column (1) reports regression results with identical controls and two-way fixed effects. The core explanatory variable lnTS has a coefficient of −0.225, significant at the 5% level. This matches the baseline lnTS coefficient in sign and significance. NTBs significantly impede China's fruit exports, regardless of measurement by value or volume. Columns (2) and (3) report regression results for pooled OLS and random effects models, respectively. Across both specifications, the coefficient on lnTS is negative and significant at the 1% level, consistent with baseline regression results. This implies that the dampening effect of NTBs on China's fruit exports is not driven by estimation specification choice, corroborating the robustness of our core finding. Column (4) reports two-way fixed effects results excluding the 2008–2009 global financial crisis. The sample size decreases from 286 to 260. The lnTS coefficient is −0.220 and significant at the 5% level. It matches the baseline estimate in both sign and statistical significance. This result rules out confounding effects from the financial crisis period, further corroborating the robust negative association between NTBs and China's fruit exports. Column (5) reports regression results after adjusting the model specification. The coefficient sign of the core explanatory variable TS is consistent with the baseline regression. The magnitude of the coefficient does not deviate substantially and it remains statistically significant. These results show that NTBs still exert a significant inhibitory effect on China's fruit exports after revising the measurement of geographic distance, adjusting fixed effects and switching estimation methods. The core conclusion of this study remains unchanged. This robustness test eliminates estimation bias caused by special variable construction and model forms, and further verifies the reliability of the baseline regression findings.

Overall, lnTS remains significantly negative with no material change in magnitude across all robustness checks. This confirms our baseline results are robust.

5.5. Heterogeneity Analysis

5.5.1. Heterogeneity in Export Levels

The conditional mean approach in the baseline regression identifies the average effect of NTBs on China's fruit exports but does not capture heterogeneity across export levels. Given wide variation in export values across APEC economies, the impact of NTBs may depend structurally on export scale. This study therefore employs quantile regression at five representative percentiles (0.1, 0.25, 0.5, 0.75, 0.9) corresponding to the lower, lower-middle, median, upper-middle, and upper tails of the conditional export distribution. Results reported in Table 9 show that the coefficient on $\ln TS$ is significantly negative at all percentiles, with significance of at least 5%. At the 10th percentile, the coefficient is -0.929 ($p < 0.01$), indicating that NTBs exert the strongest dampening effect on smaller export values. The absolute coefficient declines monotonically from the 10th to the 90th percentile. These results confirm significant heterogeneity: the negative effect of NTBs is more salient at lower percentiles with smaller export values and weakens steadily as export values expand.

Table 9. Quantile regression results.

Variables	(1)	(2)	(3)	(4)	(5)
	10%	25%	50%	75%	90%
$\ln TS$	-0.929^{***} (0.210)	-0.554^{**} (0.180)	-0.493^{***} (0.109)	-0.471^{***} (0.093)	-0.424^{**} (0.139)
Constant	2.100 (19.296)	3.197 (7.195)	5.840 [*] (2.499)	9.636 ^{***} (2.635)	10.683 ^{***} (2.907)
Controls	YES	YES	YES	YES	YES
Observations	286	286	286	286	286
R^2	0.4747	0.3285	0.4029	0.4416	0.4789

Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5.5.2. Heterogeneity in Fruit Categories

While the baseline regression identifies the average dampening effect of NTBs on China's fruit exports, substantial heterogeneity may exist across fruit categories. Fruits vary greatly in biological traits, processing intensity, storage needs, and relevant technical standards. These differences can lead to heterogeneous impacts of green trade barriers by product type. To examine this category-level heterogeneity, fruits are divided into fresh fruit (HS 0803-0810) and dried/other fruit (HS 0801-0802, 0811-0814) for grouped regression. Then, this study re-estimates the model separately for each group using a two-way fixed effects specification (Table 10).

Table 10. Heterogeneity analysis by fruit category.

Variables	(1)	(2)
	$\ln$ Fresh	$\ln$ Others
$\ln TS$	-0.035 (-0.499)	-0.295^{***} (-3.172)
Constant	-73.061^{***} (-2.733)	-76.770^{**} (-2.159)
Controls	YES	YES
Country FE	YES	YES
Year FE	YES	YES
Observations	280	286
R^2	0.603	0.559

t-statistics in parentheses *** $p < 0.01$, ** $p < 0.05$.

For fresh fruit (Column 1), the coefficient on NTB intensity ($\ln TS$) is -0.035 and statistically insignificant. For dried fruit and other product categories (Column 2), the coefficient is -0.295 and significant at the 1% level. This result indicates that NTBs impose a significant negative impact on China's dried fruit and other products, and the dampening effect is much stronger than that on fresh fruit. Several factors explain this divergence. First, fresh fruit is highly perishable. China maintains efficient cold chain logistics and customs clearance with major APEC trading partners. These factors shorten trade cycles and partially offset the disruptive effects of NTBs. This represents a key advantage for perishable horticultural goods. Second, production standards for fresh fruit in China have improved consistently. Pesticide residue limits and quarantine requirements increasingly align with international norms, which reduces the dampening effect of NTBs. In contrast, dried fruit and other products, such as nuts and preserved fruits, have longer shelf lives but involve more complicated processes. These products are more likely to be subject to strict green technical regulations and labeling requirements covering production processes, food additives, and packaging. These goods are also primarily exported to developed economies such as the United States, Canada, and Australia. These countries have more comprehensive environmental and safety regulatory systems and impose higher regulatory compliance costs on Chinese fruit exports.

Overall, the impact of NTBs on China's fruit exports exhibits significant heterogeneity across product categories. NTBs generate relatively mild constraints on fresh fruit exports, while dried fruit and other processed fruit products face substantial dampening effects.

5.6. Extended Analysis

In the baseline two-way fixed effects model, the exporting country's per capita GDP ($\ln GDP_{it}$) varies only over time. It is therefore perfectly collinear with country fixed effects. As a result, its main effect cannot be directly estimated. However, the exporting country's economic development level is a critical structural factor affecting its ability to address NTBs. Omitting this variable may compromise the accuracy of barrier effect estimates. To overcome this econometric limitation and capture the potential impact of the exporting country's economic capacity, this study further introduces the exporting country's per capita GDP as a moderating variable. It includes an interaction term between per capita GDP and green trade barriers. Both the NTB variable ($\ln TS$) and the exporting country's per capita GDP are mean-centered before constructing the interaction term. This study also replaces year fixed effects with a linear time trend. This approach preserves the identification of the moderating variable. Accordingly, the moderating effect model is constructed as follows:

$$\ln EX = \lambda_0 + \lambda_1 C\ln TS + \lambda_2 C\ln GDP_{it} + \lambda_3 (C\ln TS \times C\ln GDP_{it}) + \gamma_1 \ln GDP_{ij} + \gamma_2 \ln DIS_{ij} + \gamma_3 \ln POP + \gamma_4 COVID + \theta trend + \mu_j + \varepsilon_j \quad (3)$$

In Equation (3), $\ln EX$ denotes the logarithm of China's fruit export value to importing country j . $C\ln TS$ denotes the mean-centered logarithm of NTBs. $C\ln GDP_{it}$ denotes the mean-centered logarithm of the exporting country's per capita GDP. The interaction term $C\ln TS \times C\ln GDP_{it}$ tests the moderating effect of the exporting country's economic development on barrier effects. $trend$ denotes the linear time trend, which replaces year fixed effects. μ_j denotes the country fixed effect. ε_j denotes the random disturbance term. λ , γ , and θ denote the corresponding coefficients.

In Equation (3), λ_1 represents the export elasticity of NTBs when the exporting country's per capita GDP is at the sample mean. λ_3 captures the moderating effect. If λ_3 is positive and statistically significant, it indicates that the exporting country's economic development attenuates the inhibitory effect of NTBs on exports.

Table 11 reports the regression results. Column (1) shows the baseline moderating model without the interaction term. The ClnTS coefficient is -0.229 and significant at the 1% level. This confirms the baseline finding that NTBs inhibit China's fruit exports to APEC. Column (2) presents the full model with the interaction term. The ClnTS coefficient remains -0.328 and significant at the 1% level. The interaction term $\text{ClnTS} \times \text{ClnGDP}_{it}$ has a positive and significant coefficient of 0.697 at the 1% level. R^2 rises from 0.5404 to 0.6013 , indicating improved model explanatory power. These results show that exporter per capita GDP positively moderates the effect of NTBs. Higher economic development in China systematically weakens the negative impact of these barriers on fruit exports.

Table 11. Moderating effect regression results.

Variables	(1)	(2)
C lnTS	-0.229^{***} (-2.73)	-0.328^{***} (-4.12)
C lnGDP _{it}	4.198^{***} (4.24)	4.384^{***} (4.75)
ClnTS $\times$ ClnGDP _{it}		0.697^{***} (6.36)
trend	-0.267^{***} (-3.63)	-0.330^{***} (-4.75)
Constant	-5.849 (-0.82)	-26.97^{***} (-3.62)
Controls	YES	YES
Country FE	YES	YES
Observations	286	286
R ²	0.5404	0.6013

t-statistics in parentheses*** $p < 0.01$.

To quantify the dynamic moderating effect, we compute the marginal effects of NTBs from the regression estimates. At the sample mean of China's per capita GDP, the marginal effect of NTBs is -0.328 . A 1% increase in NTBs reduces China's fruit exports to APEC by 0.328% on average. At one standard deviation above the mean, the marginal effect becomes positive at 0.028 . At one standard deviation below the mean, it increases to -0.684 . To illustrate this pattern, we split the sample into high and low economic development groups. A simple slope plot is presented in Figure 4.

Figure 4 clearly illustrates the distinct impacts of non-tariff barriers under two scenarios. At the low level of economic development, the regression slope of non-tariff barriers is approximately -0.684 . A 1% rise in the stringency of non-tariff barriers leads to a significant 0.684% decline in China's fruit export value to APEC economies. This reflects a strong trade-inhibiting effect. At the high level of economic development, the regression slope turns from negative to positive. The adverse impacts of barriers on fruit exports largely disappear when China reaches a relatively high stage of economic development. These findings confirm that the negative effects of non-tariff barriers on China's fruit exports diminish as China's per capita GDP rises.

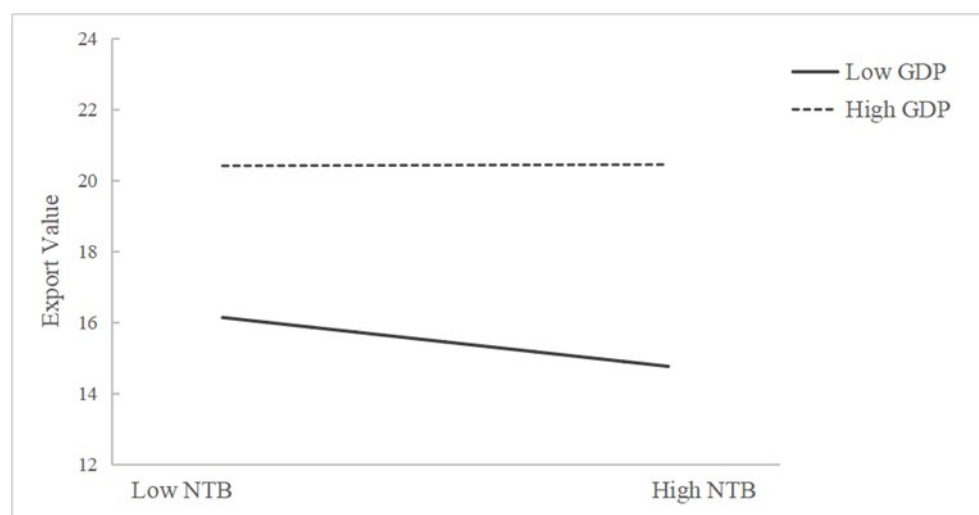


Figure 4. Simple slope plot.

This moderating effect aligns with the socioeconomic risk governance framework proposed by Chen et al. [2]. Economic development does not mitigate the trade-inhibiting effects of non-tariff barriers (NTBs) merely through expanding supply scale. It also enhances the fruit industry's capacity to overcome technical trade barriers through three core channels. First, it increases government fiscal investment in quality infrastructure. Second, it drives the upgrading of inspection and testing technologies. Third, it improves enterprise compliance capacity and industrial supporting systems. Consistent with Tong et al., sustained economic growth in China has continuously optimized the standardized planting, full-process quality traceability, and cold chain logistics systems of the domestic fruit industry [18]. These upgrades have significantly elevated enterprises' technical and managerial capabilities to comply with the stringent green standards of APEC economies. They reduce standard mismatches between domestic products and international market requirements. They also lower the risk of consignment rejection due to non-compliance with pesticide residue and additive limits.

As a result, green trade barriers are no longer insurmountable entry hurdles. They have been transformed into manageable compliance costs. Thus, the trade effects of NTBs are highly contingent on the exporting country's industrial development stage. This confirms the significant positive moderating effect of economic development on the relationship between NTBs and China's fruit exports to APEC economies.

5.7. Discussion

This paper constructs an extended gravity model based on panel data covering China's fruit exports to 13 APEC countries from 2001 to 2023, adopting the total number of WTO TBT and SPS notifications (TS) as the core proxy for NTBs. Prior literature on agricultural non-tariff barriers and export trade mainly falls into two strands. The first strand verifies the general inhibitory effect of TBT/SPS measures on developing countries' agricultural exports by taking aggregate agricultural products as research objects, yet rarely distinguishes fresh and processed fruits to capture product-level heterogeneous effects. The second strand focuses on single commodity or single import country samples, lacking targeted discussion on APEC regional markets which are core destinations for China's fruit exports. Against this backdrop, this paper proposes three core innovations relative to prior research. First, we focus on APEC countries—the core export region of China's fruits, making up the regional research gap in studies concerning non-tariff barriers' effects on agricultural exports. Second, we subdivide fruit samples into fresh and processed categories and detect divergent barrier impacts, which enriches the heteroge-

neous evidence base for agricultural NTB research. Third, we introduce the moderating role of exporter's economic development, revealing that domestic industrial upgrading can offset the negative shock of foreign standards.

The primary limitation of this study lies in the measurement defect of the core explanatory variable. The total number of WTO TBT/SPS notifications only reflects the frequency of regulatory revisions, but cannot effectively capture the intensity, stringency and enforcement differences of each country's specific standards. Second, our sample is limited to 13 APEC countries and the conclusions may not be fully generalized to non-APEC regions such as the EU, Africa or Latin America, where technical standard systems and inspection mechanisms differ substantially. Future research can adopt the following targeted improvements. First, optimize the measurement of non-tariff barrier intensity. Build weighted TS indicators. Attach high weights to strict rules including MRL (Maximum Residue Limit of Pesticides) adjustments, food additive limits and mandatory third-party certification. Attach low weights to trivial administrative label revisions. Meanwhile, add importers' border rejection data. This data reflects real regulatory enforcement. It clearly distinguishes the number of regulatory documents from actual market access restrictiveness. Second, expand the scope of research samples. Add the EU, non-APEC ASEAN nations, Latin American and African importers. Carry out cross-regional comparative analysis. Verify whether TBT and SPS barriers exert consistent heterogeneous impacts across different regions.

6. Conclusions and Policy Implications

6.1. Conclusions

Based on the extended trade gravity mode estimation, this study examines NTBs' impact on China's fruit exports to APEC countries and analyzes export scale and product category heterogeneity, as well as the moderating effect of economic development. Key conclusions are as follows:

First, NTBs imposed by APEC countries significantly inhibit China's fruit exports. Benchmark regression results show that the coefficient of the NTB proxy (lnTS) is significantly negative after controlling for economic size, geographic distance, population, and pandemic effects. Without any control variables included, a 1% rise in NTBs reduces China's fruit export value to APEC countries by an average of 0.331%. After adding all control variables, a 1% increase in non-tariff barriers lowers China's fruit export value to APEC countries by an average of 0.214%. This negative effect remains robust across robustness checks.

Second, the inhibitory effect of NTBs on China's fruit exports weakens as export scale rises. Quantile regression results show that the coefficients of NTBs are significantly negative across all quantiles. The absolute coefficient value decreases continuously with higher quantiles. The effect is strongest at the 10th quantile and weakest at the 90th quantile. NTBs thus exert stronger negative effects on smaller export markets. In contrast, larger export markets have greater resilience owing to more solid trade foundations and stronger regulatory compliance capacity.

Third, the impact of APEC NTBs on China's fruit exports exhibits significant category-specific heterogeneity. The inhibitory effect on fresh fruit exports is smaller than that on dried and other fruit products. Fresh fruit benefits from shorter trade cycles, efficient cold chain logistics, and faster customs clearance, which buffer the delay effects of NTBs. Improved standardization of Chinese fresh fruit production also aligns with international norms and reduces constraints. In contrast, processed products such as dried fruit face stricter standards in processing, additives, and packaging. They are mainly exported to developed economies with comprehensive green barrier systems, leading to higher compliance costs and greater vulnerability under such barriers.

Fourth, economic development level exerts a significant moderating effect on the trade-inhibiting impact of non-tariff barriers. The export inhibition effect of APEC NTBs on China's fruit exports is significantly weakened with the development of China's economic level. The adverse impacts of barriers on fruit exports largely disappear when China reaches a relatively high stage of economic development.

6.2. Policy Implications

Based on empirical findings, this study proposes targeted policy recommendations to promote China's fruit exports.

First, to mitigate the overall inhibitory effect of NTBs imposed by APEC countries, China should deepen economic and trade cooperation with these countries. It should promote mutual recognition of green standards, including those for phytosanitary measures, pesticide residues, and food additives. This will reduce costs caused by duplicate testing and certification. Meanwhile, China should actively participate in formulating green trade rules under the WTO framework. It should coordinate with other developing economies to voice common concerns. This study seeks to build a more equitable institutional environment for China's fruit exports.

Second, to address export scale heterogeneity, China should optimize its fruit export industrial layout. Prioritize neighboring low-barrier markets for small-scale export destinations to expand trade foundations. China can steadily expand its trade base in these markets before entering higher-barrier markets. For large-scale export markets, China should deepen product differentiation and develop high-end fruit products that match target market consumption preferences. Solid trade foundations and strong compliance capabilities can be used to further consolidate competitive advantages.

Third, a category-differentiated development strategy should be implemented. For fresh fruit exports, China should fully utilize advantages of short trade cycles and efficient cold chain logistics. It should further strengthen production standardization at origins and improve cold chain systems. China should also promote quarantine standard mutual recognition with target markets to reduce constraints from NTBs. For dried fruit and other processed fruit products, China should focus on upgrading green processing technologies. It should improve quality traceability systems and proactively align with green technical standards in developed countries such as the United States, Canada, and Australia. Meanwhile, product innovation should be encouraged to develop high-value-added green processed fruit products. This will enhance product irreplaceability and reduce the impact of alternative supply sources.

Fourth, to leverage the positive moderating effect of economic development, China should turn economic growth advantages into competitiveness against trade barriers. First, strengthen investment in agricultural quality infrastructure. Increase fiscal support for standardized planting bases in major fruit-producing regions. Improve the full-process quality traceability system covering production, processing and circulation. Accelerate the upgrading of cold chain logistics networks. These measures will reduce duplicate testing costs and improve pre-export compliance efficiency. Second, enhance compliance capacity across the entire industrial chain. Support fruit export enterprises to introduce advanced inspection and testing equipment. Third, promote balanced regional economic development. Increase fiscal transfer payments to central and western fruit-producing regions. Establish east-west industrial pairing assistance mechanisms and share quality standards and technical resources across regions. This will prevent income inequality from weakening the positive moderating effect of economic growth.

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References

1. Jongwanich, J. The Impact of Food Safety Standards on Processed Food Exports from Developing Countries. *Food Policy* **2009**, *34*, 447–457.
2. Chen, Y.Q.; Chen, Y.H. Economic Growth, Income Inequality and Food Safety Risk. *Foods* **2023**, *12*, 3066.
3. Karagulle, Y.E.; Emlinger, C.; Grant, J.H. Non-Tariff Measures and U.S. Agricultural Exports. *Appl. Econ. Perspect. Policy* **2026**, *48*, 48–86.
4. Disdier, A.C.; Fontagné, L.; Mimouni, M. The Impact of Regulations on Agricultural Trade: Evidence from the SPS and TBT Agreements. *Am. J. Agric. Econ.* **2008**, *90*, 336–350.
5. Cho, S.J.; Oh, S.; Lee, S.H. The Impact of Structure Similarity of Nontariff Measures on Agricultural Trade. *Sustainability* **2020**, *12*, 10545.
6. World Trade Organization. *The Results of the Uruguay Round of Multilateral Trade Negotiation: The Legal Texts*; WTO: Geneva, Switzerland, 1996.
7. Ghodsi, M.; Grübler, J.; Reiter, O.; Stehrer, R. *The Evolution of Non-Tariff Measures and Their Diverse Effects on Trade*; Technical Report; The Vienna Institute for International Economic Studies (wiiw): Vienna, Austria, 2017.
8. Ning, X.; Grant, J.H. *New Estimates of the Ad-Valorem Equivalent of SPS Measures: Evidence from Specific Trade Concerns*; Technical Report; Virginia Tech: Blacksburg, Virginia, 2019.
9. Qian, H.Y.; Sun, H. Research on the Influence of Green Trade Barriers on China's Agricultural Product Exports: An Empirical Analysis Based on APEC Member Countries. *China Bus. Trade* **2025**, *34*, 14–19. (In Chinese)
10. Peng, S.G.; Zhou, Y.H.; Geng, X.H. The Impact of SPS Measures on the Duration of China's Fresh Fruit Exports. *Chin. Rural Econ.* **2020**, *12*, 103–122. (In Chinese)
11. Arita, S.; Mitchell, L.; Beckman, J. *Estimating the Effects of Selected Sanitary and Phytosanitary Measures and Technical Barriers to Trade on U.S.-EU Agricultural Trade*; U.S. Department of Agriculture, Economic Research Service: Washington, DC, USA, 2015.
12. Beghin, J.C.; Disdier, A.C.; Marette, S. Trade Restrictiveness Indices in the Presence of Externalities: An Application to Non-Tariff Measures. *Can. J. Econ.* **2015**, *48*, 1513–1536.
13. Crivelli, P.; Gröschl, J. *SPS Measures and Trade: Implementation Matters*; Technical Report; World Trade Organization: Geneva, Switzerland, 2012.
14. Li, Y.; Beghin, J.C. A Meta-Analysis of Estimates of Technical Barriers to Trade. *J. Policy Model.* **2012**, *34*, 497–511.
15. Santeramo, F.G.; Lamonaca, E. The Effects of Non-Tariff Measures on Agri-Food Trade: A Review and Meta-Analysis of Empirical Evidence. *J. Agric. Econ.* **2019**, *70*, 595–617.
16. Wilson, J.S.; Otsuki, T. To Spray or Not to Spray: Pesticides, Banana Exports, and Food Safety. *Food Policy* **2004**, *29*, 131–146.
17. Wen, S.M.; Su, G.B. Decomposition of China Fruit Export Based on Constant Market Share Model. *Issues Agric. Econ.* **2012**, *33*, 17–23, 110. (In Chinese)
18. Tong, G.J.; Hong, R.; Shi, L. The Growth Effect and Its Influencing Factors: Empirical Evidence Regarding China's Fruit and Vegetable Exports to RCEP Countries. *Agriculture* **2023**, *13*, 1908.

19. Maskus, K.E.; Otsuki, T.; Wilson, J.S. *The Cost of Compliance with Product Standards for Firms in Developing Countries*; World Bank Publications: Washington, DC, USA, 2005.
20. Otsuki, T.; Wilson, J.S.; Sewadeh, M. Saving Two in a Billion: Quantifying the Trade Effect of European Food Safety Standards on African Exports. *Food Policy* **2001**, *26*, 495–514.
21. Anderson, J.E. A Theoretical Foundation for the Gravity Equation. *Am. Econ. Rev.* **1979**, *69*, 106–116.
22. Kwilinski, A. GDP per Capita vs Foreign Direct Investment: Key Drivers of a Country's Technological Leadership. *Technol. Econ. Dev. Econ.* **2025**, *31*, 1320–1344.
23. Sylwester, K. R&D and Economic Growth. *Knowl. Technol. Policy* **2001**, *13*, 71–84.
24. Hasan, I.; Tucci, C.L. The Innovation–Economic Growth Nexus: Global Evidence. *Res. Policy* **2010**, *39*, 1264–1276.
25. Zhao, P.; Gao, S. Green Trade Barriers, Financial Support and Agricultural Exports. *Int. Rev. Econ. Financ.* **2025**, *97*, 103758.
26. United Nations Statistics Division. UN Comtrade: United Nations Commodity Trade Statistics Database. Available online: <https://comtradeplus.un.org/> (accessed on 15 January 2026).
27. ISO 3166-1; Codes for the Representation of Names of Countries and Their Subdivisions—Part 1: Country Code. International Organization for Standardization: Geneva, Switzerland, 2020.
28. Tinbergen, J. *Shaping the World Economy: Suggestions for an International Economic Policy*; The Twentieth Century Fund: New York, NY, USA, 1962.
29. Pöyhönen, P. A Tentative Model for the Volume of Trade between Countries. *Weltwirtschaftliches Archiv* **1963**, *90*, 93–100.
30. Jiang, G.H.; Jiang, D.C. Location Choice of China's Outward Investment: A Panel Data Test Based on the Investment Gravity Model. *World Econ.* **2012**, *35*, 21–40. (In Chinese)
31. Kilian, L. Not All Oil Price Shocks Are Alike: Disentangling Demand and Supply Shocks in the Crude Oil Market. *Am. Econ. Rev.* **2009**, *99*, 1053–1069.
32. Wang, X.Y.; Bu, L.F. International Export Trade and Enterprise Innovation—Research Based on a Quasi-natural Experiment of “CR Express”. *China Ind. Econ.* **2019**, *10*, 80–98. (In Chinese)
33. Li, C.T.; Yan, X.W.; Song, M.; Yang, W. Fintech and Corporate Innovation—Evidence from Chinese NEEQ-Listed Companies. *China Ind. Econ.* **2020**, *1*, 81–98. (In Chinese)
34. Ni, H.F.; Wang, X.X.; Wang, Q.Q. Dynamic Evolution of Trade Restrictiveness Indices and Value-Added Trade. *China Ind. Econ.* **2020**, *12*, 140–158. (In Chinese)

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