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Assessing the impact of non-tariff measures on Sri Lankan mango exports: insights, challenges, and recommendations

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Introduction: With the increase in non-tariff measures (NTMs) in recent years, understanding their impact on trade policies and agricultural exports is of utmost importance for countries like Sri Lanka, where the proliferation of NTMs has posed substantial impediments to its mango export industry. However, studying NTMs can be challenging due to their complex nature, diverse range, and limited information availability.

Methods: This research aims to investigate the significant effect of NTMs on Sri Lankan mango exports, identify the pivotal drivers influencing mango exports, and analyze the performance of mango exports in Sri Lanka. This study utilized a panel dataset of 16 importing countries spanning the period from 2000 to 2021. The primary focus was on examining NTM-related challenges and obstacles faced by the mango export industry in Sri Lanka. The identification and quantification of these obstacles were achieved through a multifaceted approach in which assessment of NTM-related rejections, both domestic and overseas, evaluation of NTM incidences using frequency and coverage ratio measures, and the deployment of various gravity model equations to quantify the effect of NTMs were taken into consideration. Probit, Ordinary Least Square, Random Effects, and Poisson Pseudo Maximum Likelihood estimation techniques were utilized for data analysis.

Results: The findings indicate a significant inverse correlation between the increase in the total count of NTMs and Sri Lankan mango exports if the country aims to export more mangoes to relevant markets, while Sanitary and Phytosanitary Measures (SPS), Technical Barriers to Trade (TBT), and Pre-shipment Inspection (PSI) contributed to increased mango exports. Among other explanatory variables, the GDP of both importing and exporting countries had a positive influence on Sri Lankan mango exports. Surprisingly, the distance to the importing country had no significant effect, though it shows a negative sign.

Discussion: This study provides valuable insights into the impact of NTMs on Sri Lankan mango exports. It highlights the considerable influence of NTMs on the overall fresh fruit export sector. We recommend proactively aligning internal quality testing regulations with the standards required by destination countries to promote future expansion.

KEYWORDS

coverage ratio, frequency ratio, gravity model, incidence approach, non-tariff measures, mango export industry, Sri Lanka, sanitary and phytosanitary measures

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1 Introduction

In today's globalized economy, the free movement of goods across borders is paramount for economic growth and development. However, the imposition of Non-Tariff Measures (NTMs) by nations has emerged as a significant barrier to international trade flows, particularly in the agricultural sector (UNCTAD, 2012). These policy tools, which go beyond simple tariffs and serve good reasons like protecting consumers and the environment, can accidentally add layers of complexity that make exports less competitive, discourage investments from emerging economies, raise costs, and limit market access (Xiong and Beghin, 2014; Santeramo et al., 2018). The agricultural sector remains a critical pillar of Sri Lanka's economy, contributing 7.5% to the country's Gross Domestic Product in 2022 and employing around 26.5% of the nation's workforce (Central Bank of Sri Lanka, 2022). Within this sector, agricultural exports, particularly mangoes, offer significant economic potential and a path to resilience amid the ongoing economic turmoil. Sri Lanka's mango industry encompasses over 29,229 hectares of cultivation and an annual harvest of approximately 529.3 million mangoes, with notable cultivars thriving in major districts like Kurunegala, Anuradhapura, Polonnaruwa, Hambantota, and Rathnapura (Vidanapathirana et al., 2018; Ratnayake and Asian Development Bank, 2019). The country exports mangoes to various nations, including Qatar, Switzerland, the United Arab Emirates, and Saudi Arabia (Trade Earth, 2020). Sri Lanka's mango industry, with its vast potential for global market expansion, finds itself entangled in a web of technical NTMs, including sanitary and phytosanitary (SPS) regulations and technical barriers to trade (TBT). These measures, designed to ensure product quality and safety, have paradoxically become formidable obstacles, restricting market access and suppressing the export potential of this vital agricultural commodity.

NTMs encompass a wide range of measures, classified into three main categories: technical measures, non-technical measures, and export measures (United Nations Conference on Trade and Development, 2019). Initially, NTMs primarily consisted of quantitative restrictions (QRs) such as quotas and voluntary export restraints, leading to a decline in import volumes and trade values. However, in recent years, technical measures like Sanitary and Phytosanitary (SPS) regulations and Technical Barriers to Trade (TBT) have gained prominence, introducing compliance costs, increasing unit values, and potentially restricting market entry (Cadot et al., 2018). SPS regulations, TBT, and pre-shipment inspections (PSI) pose significant obstacles to fruit and vegetable exports within the taxonomy of NTMs (Levantis and Fell, 2019). Both imports and exports meticulously execute these conformity assessment procedures, including inspections, testing, and certifications, as prerequisites for market entry (Ratnayake and Asian Development Bank, 2019). NTMs address market imperfections, including asymmetric information and externalities, making their optimal level challenging to determine (Swinnen and Vandemoortele, 2011; Santeramo and Lamonaca, 2019). However, they can also introduce complexities, sometimes serving protectionist purposes while at other times fostering competitiveness (Xiong and Beghin, 2014; Santeramo and Lamonaca, 2019).

The multilateral trade negotiations under the Uruguay Round and subsequent bilateral, regional, and preferential trade agreements have resulted in substantial reductions in tariff levels for agricultural commodities (Trienekens and Zuurbier, 2008; Kalaba and Kirsten, 2012; Pushpakumara et al., 2022). Concurrently, this trade liberalization shift has drawn increased attention to NTMs as potential alternative barriers to international trade flows (Hwang and Lim, 2017). Various factors, including the growth of global production networks, the aftermath of the recent financial crisis, the need to address climate change concerns, and the maintenance of consumer demands for food safety and environmental protection, particularly in developed countries, have influenced the imposition of NTMs and their economic effects (World Trade Organization and the United Nations, 2012).

SPS measures and TBT have become the most common types of NTMs. This is especially true in the agricultural sector (Ferrantino, 2006; Mohan et al., 2012; Hilal and Ismail, 2020), where NTMs are much more common than in other products. Tariffs and NTMs on agriculture create a price disparity in exporting countries; consequently, they impact trade flows. NTMs have a more complicated effect on trade because they affect almost all food and agriculture imports, compared to only 40% of imports from all other sectors. Food products also face eight different NTMs on average, while products from all other sectors only face two (United Nations Conference on Trade and Development and WORLD BANK, 2018). In addition to increasing trade costs, SPS and TBT may increase trade volumes by strengthening demand for imported products (United Nations Conference on Trade and Development and WORLD BANK, 2018). Cadot et al. (2018) specifically focus on SPS measures in the agricultural sector, demonstrating how adherence to these regulations can effectively instill consumer confidence in imported goods. The harmonization of NTMs among countries is of considerable significance in reducing the costs associated with them and enhancing trade.

Sri Lanka's mango export industry remains largely underutilized due to the formidable barriers posed by NTMs and internal rejections. The number of NTMs applied to mango exports has increased significantly in recent years, as shown in Figure 1 (United Nations, 2022). During this period, export volumes fluctuated. When analyzing the breakdown of specific NTMs imposed on Sri Lankan mango exports from 2000 to 2021, SPS measures played a significant role, accounting for 79 percent of the total NTMs imposed on Sri Lankan mango exports. In the rear of SPS measures were TBT measures, which accounted for 19 percent, while other forms of NTMs accounted for 2 percent.

In light of these dynamics, this research aims to comprehensively examine mango export rejections in Sri Lanka, analyze incidence rates and ratios affecting mango exports, and quantify the impact of NTMs, especially technical NTMs (SPS, TBT, and PSI), through the application of a gravity model. By focusing on Sri Lanka's mango trade and the challenges it faces in accessing premium global markets, this study provides crucial insights for policymakers seeking to enhance mango exports and overcome NTMs. Furthermore, this research's

Abbreviations: NTMs, Non-tariff measures; SPS, Phytosanitary Measures; TBT, Technical Barriers to Trade; PSI, Pre-shipment Inspection; RE, Random Effects; PPML, Pseudo Maximum Likelihood; OLS, Ordinary least square; AVEs, ad valorem equivalents; UNCTAD, United Nations Conference on Trade and Development; ICNTMs, International Classification for NTMs; NPQS, National Plant Quarantine Service.

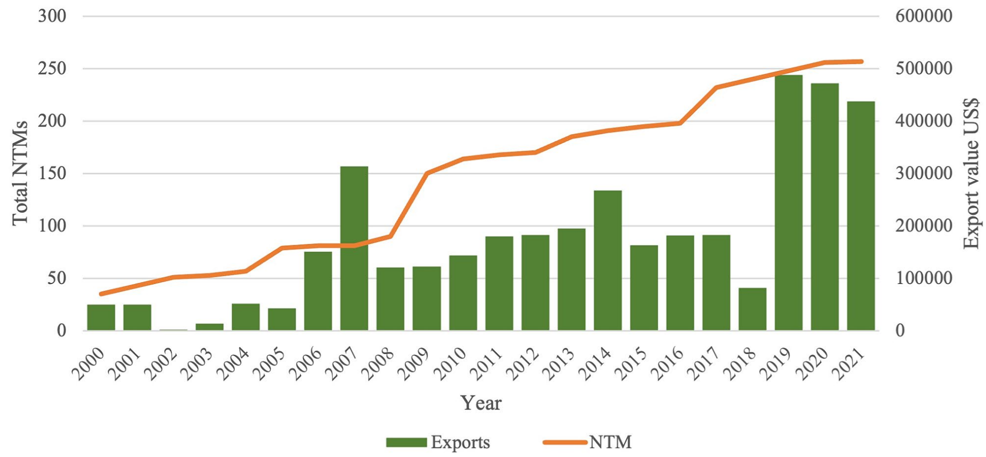

FIGURE 1
Total NTMs and mango export values from 2000 to 2021 in Sri Lanka. Source: Author's calculations based on COMTRADE (United Nations, 2022) and UNCTAD TRAINS databases.

findings serve as a foundational framework for unlocking the export potential of other agricultural products similarly impeded by NTMs.

2 Literature review

NTMs have evolved into crucial policy instruments extending well beyond conventional customs duties and tariffs, exerting a significant impact on international product trade (Niu, 2018; United Nations, 2019). Initially perceived primarily as non-tariff barriers that emphasized their protectionist nature, such as quotas and export restraints, the term "non-tariff measures" has emerged to encompass their potential to either facilitate or hinder trade (Grant and Arita, 2017). According to UNCTAD (2012), NTMs are policy measures other than ordinary customs tariffs that may influence international trade in goods by altering traded quantities and/or prices. NTMs are a wide range of actions that aim to reduce information gaps (TBTs), lower consumption risks, make the environment more sustainable (SPSs), and affect trade and competition decisions (non-technical NTMs) (Xiong and Beghin, 2014; Swinnen, 2016). While the optimal level of tariffs is zero from a social welfare perspective, determining the optimal level of NTMs is challenging due to their complex relationship linking trade and social effects (Swinnen and Vandemoortele, 2011; Sheldon, 2012).

International trade indirectly contributes to sustainability goals through its association with economic growth. NTMs can act as trade barriers, particularly for markets involving developing nations, but they also have direct associations with beneficial outcomes. SPS, TBT measures, prominent in NTMs, aim to safeguard consumer well-being and environmental welfare (United Nations, 2019). NTMs significantly impact Sustainable Development Goals (SDGs), including SDG 2 (zero hunger), SDG 3 (excellent health and well-being), and SDG 12 (responsible consumption and production), contributing to food security, human health, and environmental preservation (Arora and Mishra, 2019; United Nations, 2019).

From a theoretical standpoint, for consumers, NTMs can enhance trust, reduce transaction costs, and increase demand by mitigating risks and asymmetric information, potentially justifying higher prices for regulated products (Crivelli, and Gro€schl, 2016; Swinnen, 2017). However, producers face higher compliance costs, including fixed costs (e.g., facility upgrades, certification) and variable costs (e.g., prolonged delivery times, rejection of shipments), potentially reducing supply and profits (Xiong and Beghin, 2014). The net effect on trade depends on whether demand-enhancing or supply-reducing effects dominate (Swinnen, 2017).

Empirical evidence on NTMs' trade effects has been mixed, with studies suggesting that NTMs can hamper trade (Peterson et al., 2013; Bianco et al., 2016; Santeramo and Lamonaca, 2019; Santeramo and Lamonaca, 2020), foster trade (Cardamone, 2011), or have varying impacts depending on the specific NTM, sector, and country (Xiong and Beghin, 2011; Beckman and Arita, 2016). This heterogeneity may reflect the diverse types of NTMs and their rationales (Schlueter et al., 2009), as well as differences in study design and methodological approaches. In general, Technical Barriers to Trade (TBTs) tend to facilitate trade (Frahan et al., 2006), while Sanitary and Phytosanitary Standards (SPSs) exhibit mixed effects, potentially having substantial positive or negative impacts (Schlueter et al., 2009; Jayasinghe et al., 2010; Crivelli, and Gro€schl, 2016; Santeramo and Lamonaca, 2020). Specific measures like Maximum Residue Levels (MRLs) often act as trade barriers (Otsuki et al., 2001a,b; Chen et al., 2008; Ferro et al., 2015).

NTMs can also have varying trade effects across sectors and products. NTMs appear to impede trade in seafood (Anders and Caswell, 2009; Sandaruwan et al., 2020), meat (Wilson and Otsuki, 2003), fruits, vegetables, cereals, and oilseeds (Otsuki et al., 2001a,b), while having limited impact on fats and oils (Xiong and Beghin, 2011). Moreover, NTMs implemented by developed countries tend to negatively affect trade performance in developing countries (Anders and Caswell, 2009; Disdier and Marette, 2010), whereas their effects among developed or developing countries are mixed (Frahan et al., 2006; Yue and Beghin, 2009; Melo et al., 2014).

Furthermore, the proxies used to measure NTMs can influence the observed trade effects. Studies that use ad valorem equivalents (AVEs), frequency indices, or coverage ratios tend to find negative trade effects (Jongwanich, 2009; Grant and Arita, 2017; Fernandes et al., 2019). On the other hand, studies that use dummy or count variables show mixed results, with some showing positive effects (Cardamone, 2011; Shepherd and Wilson, 2013) and others showing negative effects (Peterson et al., 2013; Bianco et al., 2016). The level of data aggregation can also play a role, with more disaggregated data potentially providing crisper policy implications (Li and Beghin, 2012). As stated by Malouche et al. (2013), observing frequency and coverage ratios is useful for comprehending the prevalence of NTMs but provides little insight into their economic consequences, such as their impact on private sector competitiveness or consumer welfare. Saini (2009) looked at the effect of NTMs on Indian exports using quantitative methods like frequency and coverage ratios. He discovered that NTMs had a big effect, changing over 60% of the value of Indian exports at different times. This finding illuminated the pervasive role that NTMs play in influencing India's trade relations with key partners, highlighting the significance of NTMs in trade dynamics. In light of this, Jha and Bathla's (2021) study examined the Association of Southeast Asian Nations (ASEAN) as a case study, with a concentration on agricultural commodity protectionism. Their research highlighted the importance of NTMs, specifically SPS regulations, in explaining India's relatively modest share of global exports. This highlighted the significant impact of NTMs, particularly SPS measures, on agricultural exports, thereby reinforcing their centrality in the Asian agricultural trade landscape.

Studies in the tea sector have found that NTMs, particularly SPS measures and maximum residue levels (MRLs) for pesticide residues, have a negative impact on the tea trade (Dong and Zhu, 2015; Hwang and Lim, 2017; Ranjan and Edirisinghe, 2020). Ranjan and Edirisinghe (2020), for example, estimated that a 1% increase in the controlling severity of the pesticide Endosulfan could lead to a 0.67% decrease in Sri Lankan tea exports. The study by Pushpakumara et al. (2022) examines the impact of NTMs on Sri Lanka's tea exports and reveals a rising trend in NTMs affecting the value of Sri Lankan tea exports. They found that each additional NTM led to a substantial 48% reduction in tea exports, with NTMs demonstrating a significant tariff equivalent effect of 66%. These findings underscore the urgency of revising NTM policies to enhance export competitiveness, a concern pertinent to other agricultural exports like mangoes in Sri Lanka.

In summary, the existing literature highlights the intricate and diverse nature of NTMs in international trade, with their trade effects influenced by numerous factors requiring a comprehensive and context-dependent understanding. There is a knowledge gap about how the NTMs policies impact mango trade in Sri Lanka. Given the significant implications for trade policy and the achievement of the Sustainable Development Goals (SDGs), we need further research to uncover the complex mechanisms that NTMs operate in international trade across various sectors and countries.

3 Model and data

We initially focused on identifying mango rejections within and outside the country. Initially, mango rejection data was gathered from the National Plant Quarantine Service (NPQS), followed by NPQS stakeholder interviews. When collecting mango rejection data, at first, main internal rejections were identified by collecting internal rejection data at NPQS, and thereafter, external rejections were identified using NPQS notification data. This paper employs a two-pronged approach to assess the impact of NTMs on Sri Lankan mango exports. We first use the incidence approach to quantify the prevalence and coverage of NTMs by calculating frequency ratios and coverage ratios. Second, we adopt the gravity model approach to examine the trade dynamics influenced by factors such as the size of economies, distance between trading partners, and the presence of NTMs.

3.1 Incidence approach

The incidence approach provides insights into the extent of regulation imposed by NTMs without considering their direct impact on trade or economic outcomes (Deardorff and Stern, 1998). The frequency ratio and coverage ratio are calculated using data from the UNCTAD TRAINS database, which maintains a comprehensive record of NTMs at the Harmonized System (HS) 6-digit level for various countries and products. These indicators are derived from a roster of detected NTMs and serve to summarize the prevalence of NTMs on trade. The prevalence score indicates the average number of NTMs applied to items, whereas the coverage ratio and frequency index indicates the proportion of trade exposed to NTMs (Deardorff and Stern, 1998). These indicators are frequently calculated on total trade, considering all forms of NTMs, and can indicate the prevalence of specific NTMs on specific groups of items, such as the amount of SPS controls on agricultural crops.

The incidence of NTMs is used to measure the extent of protection accorded by NTMs (Mehta, 2000). To quantify the incidences of NTMs frequency ratio and coverage ratio were used. The index's key component is a dummy variable that takes the value of unity when one or more indexes are applied to it. The index's natural extension is an import coverage index, which weights the current NTM structure on home country imports or global imports. The frequency index is calculated as in Equation (1).

$$F_j = \frac{(\Sigma D_i N_i)}{N_i} \times 100 \tag{1}$$

Where D_i is a dummy variable that takes the value if one or more NTMs are applied to this transaction (or zero if otherwise), and N_i is the total number of transactions in the product groups. Thus, F_j indicates the proportion of mango trade transactions subject to NTMs.

In this study, we adopt the coverage ratio as a key metric to gauge the significance of imported NTMs imposed by the importing country on the trade of a specific product. The coverage ratio represents the percentage of trade subject to NTMs, thereby offering insights into the extent to which these measures impact international trade dynamics (United Nations Conference on Trade and Development, 2015). This metric has been extensively utilized in prior researches (Wood et al., 2017; Permata and Handoyo, 2019; Pushpakumara et al., 2022), underlining its relevance and applicability in assessing the regulatory landscape governing global trade. The coverage ratio (C_j) is calculated as in Equation (2).

$$C_j = \frac{(\Sigma D_i V_i)}{V_i} \times 100 \tag{2}$$

Where V_i represents the value of mango exports in the year under consideration, and D_i is a dummy variable with a value of 1 if an NTM is imposed on mango exports in that year, and 0 otherwise. C_j reflects the proportion of total mango export value covered by NTMs.

3.2 Gravity model approach

In this research secondary data on NTMs on mango at HS 6-digit level (mango HS code 080450) was collected for 16 different countries (Qatar, United Arab Emirates, the United States of America, Switzerland, Canada, the United Kingdom, Germany, Italy, France, Spain, the Netherlands, China, Russia, Singapore, and Norway). Bilateral export values and other related data were obtained from the COMTRADE database and Trade map. Sri Lanka is considered as a source country and 16 countries are considered as destination countries.

Jan Tinbergen introduced the gravity model in 1962 to explain international bilateral trade (Tinbergen, 1963). The model was named for its similarity to Newton's law of universal gravitation. Based on Newtonian theory, the gravity model suggests that bilateral trade can be explained by the size of economies and their distance or proximity. Gravity models have become a popular method for assessing the impact of NTMs on trade restrictions over the past decade. The gravity model has the benefit of utilizing trade data, which is more readily available at the disaggregated product level than price data. It can be used for panel data analysis of multiple countries and products with different NTMs over time (Niu et al., 2020). The gravitation model may not adequately account for trade costs (De Melo and Nicita, 2018). Therefore in recent years, researchers have developed a variety of proxies for multilateral trade resistance, such as export destination distance, trade prices, consumer preferences, preferential trade agreements, tariffs, and NTMs (Dou et al., 2015).

The study used descriptive data and a deductive approach. The elasticities of NTMs were determined using the gravity model. The gravity technique is a popular method for analyzing the impact of trade cost factors such as distance, tariffs, NTMs, shared borders, and other trade costs on trade flow (Xiong, 2012). Despite several apparent flaws, the model was usually applied in the trade literature. The data set was built upon the annual bilateral trade value of mango exported to 16 importing countries from 2000 to 2021. The country selection is done according to the export development board data. Normally Sri Lanka's main mango export destination is Middle Eastern countries and exports a moderate amount of mango to the European Union and the United States. All 16 destination countries were selected for the estimation as trading partners from North America, South America, the European Union, the Middle East, and Asia.

The correlation test, heteroscedasticity, multicollinearity test using variance inflation factor (VIF) and autocorrelation were performed to identify the nature of the data set before selecting the appropriate model. Ordinary least square (OLS), Random Effects (RE), Probit approaches were used as a robust estimation technique even though these methods are vulnerable to heteroscedasticity and do not count zero trade data. To overcome these obstacles widely used Poisson Pseudo Maximum Likelihood (PPML) estimation technique was used to analyze the data. PPML has two major advantages over other techniques and overcomes both econometric issues. First, heteroscedasticity will not result in skewed estimates. Second, zero-trade observations can be included; the PPML estimator is consistent with and without the zero-trade observations and Heckman sample selection estimator (Silva and Tenreyro, 2006).

The potential endogeneity of trade barriers could introduce bias in the assessment of trade effects. It is plausible to posit that trade expansion occurs before the implementation of regulations, such as TBTs, which may be enacted as a means of protectionism or to address consumer protection concerns (Li and Beghin, 2012). Trefler (1993) and Lee and Swagel (1997) have demonstrated that the issue of endogeneity might result in the underestimation of the adverse effects of NTMs on trade. Baier and Bergstrand (2007) highlighted the efficacy of employing a panel data strategy in addressing the issue of endogeneity, particularly when dealing with panel data and fixed-time effects. Therefore, panel data with time-fixed effects was employed as a method to mitigate the issue of endogeneity in technical measures.

The gravity equation could be written as an empirical way as mentioned below where e_{ij} is the random error.

$$lnXijt = \alpha_0 + \beta_1 lnGDP_{it} + \beta 2lnGDPjt + \theta\ lnTijt + eij \tag{3}$$

The variable X_{ijt} represents the annual average trade volume from ith country (exporter) to jth country (importer) in year t. The variables GDP_{it} and GDP_{jt} represent the GDP of ith country and jth country in year t, respectively. T_{ijt} represents trade cost of which can be further disaggregate into three components as represented in Equation (4). The variables are defined as shown in Table 1.

$$\ln Tijt = \ln distance_{ij} + \ln\left(1 + Tariff\right)ijt + \ln\left(1 + NTM\right)ijt \tag{4}$$

NTM_{ijt} is a dummy variable indicating the presence or absence of NTMs imposed on mango imports by the importing count at time t. As mentioned above distance, tariffs and NTMs are components of the trade cost. By substituting Equations (3) and (4) we could obtain as Equations (5) and (6),

$$\begin{aligned} \ln X_{ijt} = \alpha 0 + \beta_1 \ln GDP_{it} + \beta_2 lnGDP_{Jt} + \beta_3 \ln distance_{ij} \\ + \beta_4 \ln\left(1 + tariff\right)_{ijt} + \beta_5 \ln\left(1 + NTM\right)_{ijt} + e_{ij} \end{aligned} \tag{5}$$

$$\begin{aligned} \ln X_{ijt} &= \alpha 0 + \beta_1 \ln\left(GDP\right)_{it} + \beta_2 lnGDP_{jt} \\ &+ \beta_3 \ln distance_{ij} + \beta_4 \ln\left(1 + tariff\right)_{ijt} \\ &+ \beta_5 \ln\left(1 + NTM\right)_{ijt} + \beta_6 \ln\left(1 + SPS\right)_{ijt} \\ &+ \beta_7 \ln\left(1 + TBT\right)_{ijt} + \beta_8 \left(1 + PSI\right)_{ijt} + e_{ij} \end{aligned} \tag{6}$$

Since the data set had 65.57 percent zero values in trade flows, the PPML estimator was used as the statistical model. In addition to the trade costs mentioned above, the population (Pop_{it} and Pop_{jt}) and GDP (GDP_{it} and GDP_{jt}) of country i and j in year t were used as independent variables. The modified equations for PPML are stated as Equations (7) and (9).

$$\begin{aligned} X_{ijt} &= \alpha 0 + \beta_1 lnGDP_{it} + \beta_2 \ln ln\ distance_{ij} \\ &+ \beta_3 \ln\left(1 + tariff\right)_{ijt} \\ &+ \beta_4 \ln\left(1 + NTM\right)_{ijt} + e_{ij} \end{aligned} \tag{7}$$

TABLE 1 Description of the variables and data sources.

Variables	Description	Source
X_{ijt}	Annual bilateral mango export value from Sri Lanka (*i*) to *j*th importing country in year *t*	COMTRADE
Y_{ijt}	Dummy variable, $Y_{ijt} = 1$ if Sri Lanka exported mango to country *j* in year *t* or 0 otherwise	–
GDP_{it}	Gross Domestic Product of Sri Lanka in year *t*	World Bank
GDP_{jt}	Gross Domestic Product of the importing country in year *t*	World Bank
$distance_{ij}$	Geographical distance between Sri Lanka (*i*) and *j*th importing country	CEPII
$tariff_{ijt}$	Annual average Tariff rate imposed on mango imports by *j*th importing country in year *t*	TRAINS
NTM_{ijt}	Total number of non tariff measures imposed on mango imports by the *j*th importing country in year *t*	TRAINS
Pop_{it}	Population of Sri Lanka (*i*) in year *t*	World Bank
Pop_{jt}	Population of *j*th importing country in year *t*	World Bank
SPS_{ijt}	Number of SPS measures imposed on mango imports by the *j*th importing country in year *t*	TRAINS
TBT_{ijt}	Number of TBT measures imposed on mango imports by *j*th importing country in year *t*	TRAINS
PSI_{ijt}	Number of PSI requirements imposed on mango imports by the importing country in year *t*	TRAINS

The annual data for the variables in the gravity model estimations span the period from 2000 to 2021, with the exception of the distance variable, which is time-invariant.

$$\begin{aligned} \ln X_{ijt} = {} & \alpha 0 + \beta_1 \ln GDP_{it} + \beta_2 lnGDP_{jt} \\ & + \beta_3 \ln distance_{ij} + \beta_4 \ln\left(1 + tariff_{ijt}\right) \\ & + \beta_1 \ln Pop_{it} + \beta_2 \ln Pop_{jt} + \beta_5 \ln\left(1 + NTM\right)_{ijt} \\ & + \beta_6 \ln\left(1 + SPS\right)_{ijt} + \beta_7 \ln\left(1 + TBT\right)_{ijt} \\ & + \beta_8 \left(1 + PSI\right)_{ijt} + e_{ij} \end{aligned} \tag{8}$$

$$\begin{aligned} X_{ijt} = {} & \alpha 0 + \beta_1 \ln GDP_{it} + \beta_2 lnGDP_{jt} \\ & + \beta_3 \ln distance_{ij} + \beta_4 \ln\left(1 + tariff_{ijt}\right) \\ & + \beta_1 \ln Pop_{it} + \beta_2 \ln Pop_{jt} + \beta_5 \ln\left(1 + NTM_{ijt}\right) \\ & + \beta_6 \ln\left(1 + SPS_{ijt}\right) + \beta_7 \ln\left(1 + TBT_{ijt}\right) \\ & + \beta_8 \left(1 + PSI_{ijt}\right) + + e_{ij} \end{aligned} \tag{9}$$

Where SPS_{ijt}, TBT_{ijt}, and PSI_{ijt} indicates number of SPS, TBT, and PSI measures imposed on mango imports by the importing country, *j* in year *t*. While the use of dummy variables for NTMs may not capture the varying levels of stringency or restrictiveness, constructing stringency indices requires detailed data on the specific characteristics and potential trade impact of each NTM measure (Malouche et al., 2013; Cadot et al., 2018). Due to data limitations and the scope of this study focused on a single product, the use of dummy variables serves as a simplification to assess the presence or absence of these measures, consistent with approaches taken in similar studies examining specific agricultural products (Xiong and Beghin, 2011; Santeramo and Lamonaca, 2019, 2020).

In addition to the above estimation technique, we employed a Probit model to analyze the impact of NTMs on the probability of mango exports from Sri Lanka. The Probit model is a widely used econometric approach for modeling binary outcome variables (Wooldridge, 2019), such as the decision to export or not. It estimates the probability of an event occurring (in this case, the probability of exporting mangoes) based on one or more independent variables, including NTMs and other potential determinants. The Probit model can be represented as follows:

$$\Pr\left(Y_{ijt} = 1 | X_{ijt}\right) = \Phi\left(X_{ijt}\beta\right). \tag{10}$$

Where: Y_{ijt} is a binary dependent variable indicating whether mango exports occurred between country *i* (Sri Lanka) and country *j* ($Y_{ijt} = 1$) or not ($Y_{ijt} = 0$) for country j at time t,

- Φ is the cumulative distribution function (CDF) of the standard normal distribution.
- X_{ijt} is a vector of independent variables for country *i* or between country *i* and *j* at time *t*, including NTMs and other factors affecting export probability.
- β is a vector of coefficients to be estimated.

After incorporating independent variables in the Probit model Equation (10), the model can be represented as follows.The Probit model estimation with panel data allows quantifying the impact of NTMs on the likelihood of mango exports, while accounting for cross-sectional and time-varying factors. This approach is widely employed in the literature to examine the effects of trade policies and other factors on export participation using panel data (Bergstrand et al., 2015; Martin and Pham, 2015; Baltagi et al., 2017). Finally, three separate equations (Equations 8, 9 and 10) were estimated using different estimation techniques.

4 Results and discussion

4.1 The trend of mango rejection and its underlying factors

Analysis of mango rejection patterns reveals a multifaceted landscape both within Sri Lanka and at international borders. Internally, rejections occur across the export-oriented supply chain, predominantly stemming from quality defects, pest infestations, and inadequate certification protocols. Externally, importing countries often reject mango shipments due to similar issues, such as pest contamination and certification discrepancies. Mango rejections within Sri Lanka are largely attributed to the presence of hazardous organisms, with seed weevils and fruit flies being primary concerns (Figure 2). These findings are consistent with previous studies highlighting the detrimental effects of pests on agricultural exports (Jeger et al., 2021). Additionally, quality defects and non-compliance with certification requirements contribute significantly to internal rejection rates.

According to NPQS internal rejection data, nearly 4,500 kilograms of mangoes were rejected for insect infestation. In 2021, roughly 250 kilograms of rejected mangoes will be due to quality defects and lack of a Phyto certificate (Figure 2A). Typically, external rejections occur in the importing country; here, the primary causes of external rejections are the presence of hazardous organisms, the absence of a Phyto certificate, and the absence of additional documentation. Approximately 50 percent of external rejections in 2021 will be due to the presence of pests and hazardous organisms, as depicted in Figure 2B. The absence of a phytosanitary certificate is responsible for 45 percent of all external rejections. In most cases, nearly 10 percent of internal rejections are attributable to the absence of additional documents. In terms of parasites and harmful organisms, seed weevils are responsible for more than 70 percent of mango rejections, according to NPQS data. Fruit flies account for 23 percent of rejections, while other parasites account for 7 percent of rejections (Figure 2C).

The frequency ratio of NTMs on mango exports in Sri Lanka is depicted in Figure 3. As depicted, the United States, Russia, China, Norway, and Singapore regulate all mango tariff lines with NTMs. Typically, Qatar, Italy, and Switzerland regulate more than 80 percent of tariff lines via NTMs, whereas Germany, the Netherlands, and the United Kingdom regulate a smaller number of tariff lines via NTMs. In countries such as Norway, Russia, China, the United States, France, Singapore, the United Arab Emirates, and Qatar, virtually all mango imports are subject to NTMs.

Moreover, based on data from Germany and the United Kingdom, nearly 60 percent of mango imports are subject to NTMs. The coverage ratio of NTMs on mango exports in Sri Lanka is depicted in Figure 4.

The analysis reveals that the frequency ratio of SPS, TBT, and PSI measures, China and Russia control all mango exports with SPS and TBT regulations. The United States, Singapore, and Norway regulate Sri Lankan mango exports with 100 percent SPS and TBT measures, as shown in the graph. Qatar, the UAE, Germany, and the Netherlands regulate mango exports with a moderate level of SPS, TBT, and PSI measures, as do other nations. And taking into account the coverage ratio of SPS, TBT, and PSI measurements. Typically, all mango imports from China, Russia, and Norway are subject to SPS, TBT, and PSI regulations. Except for the United Kingdom and Germany, mango imports from all other countries are subject to all SPS measures.

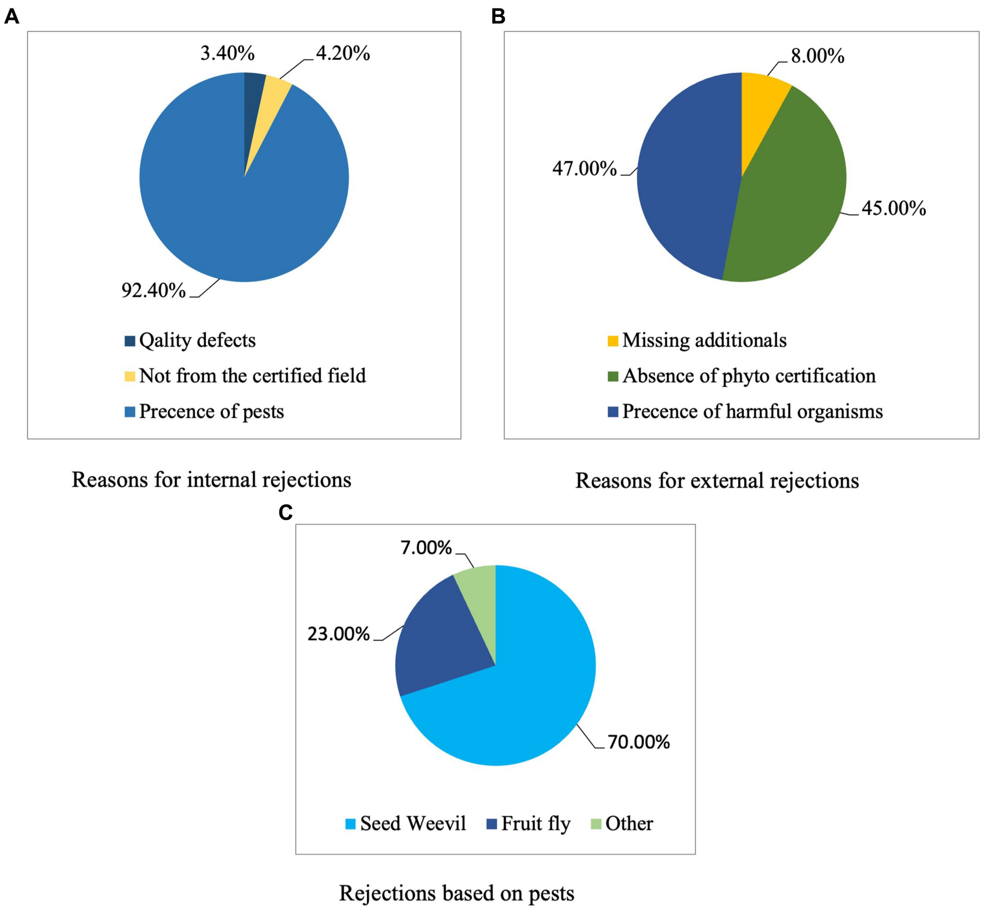

FIGURE 2
Reasons for internal and external rejections. **(A)** Reasons for internal rejections, **(B)** Reasons for external rejections, **(C)** Rejections based on pests. Source: Author's calculations based NPQS external and internal rejection data.

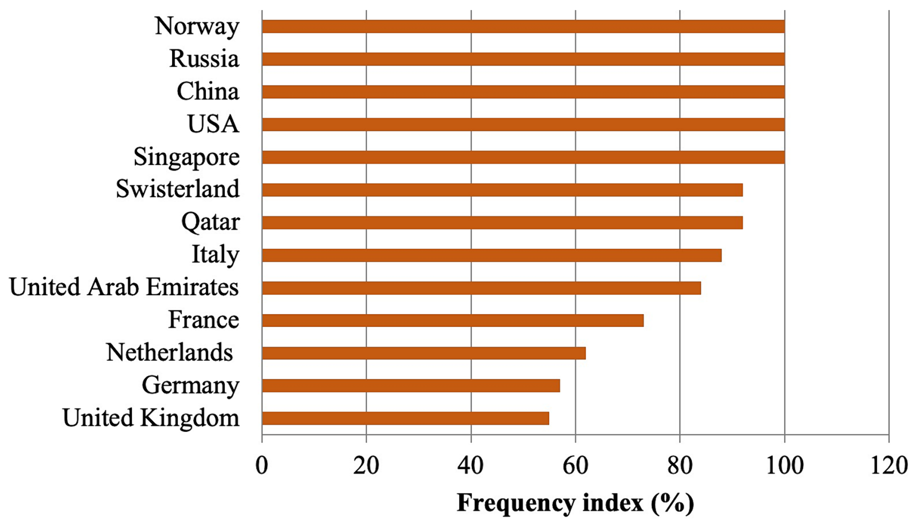

FIGURE 3
Frequency ratio (percentage) of NTMs in selected countries. Source: Author's calculation based on UNCTAD TRAINS database and COMTRADE data base.

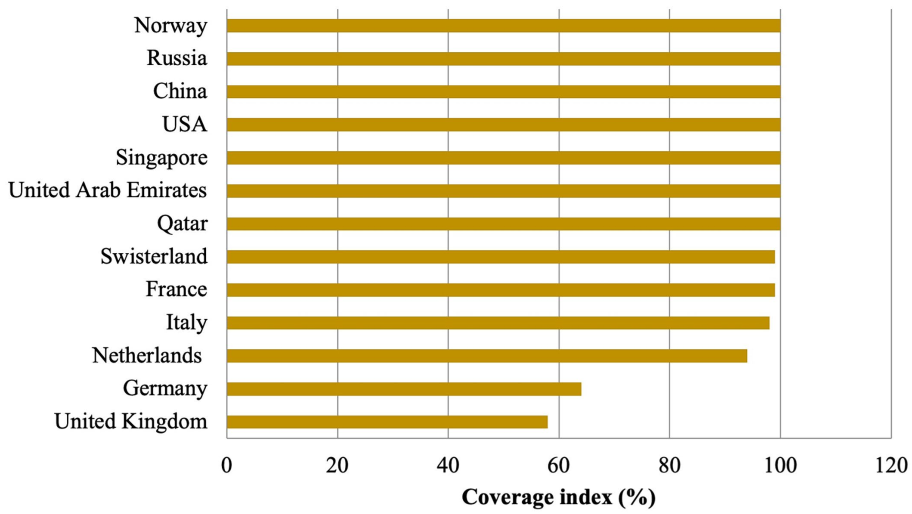

FIGURE 4
Coverage ratio of NTMs in selected countries. Source: Author's calculation based on UNCTAD TRAINS database and COMTRADE data base.

Considering the disaggregated level of NTMs (Figure 5), the most applicable SPS measures on mango imports to the United States are hygienic practices during production related to SPS conditions (A42), authorization requirements for SPS reasons for importing certain products (A14), fumigation requirements (A53), and processing history documents related to SPS measures (A852). In the United States, labeling requirements (B31), testing requirements (B82), and certification requirements (B83) are the most frequently affected TBT measures. The most applicable SPS types for mango are labeling requirements relating to SPS measures (A31), importer authorization requirements for SPS reasons (A15), and tolerance limits for residues or contamination by certain (non-microbiological) substances (A21). And the TBT measure most frequently affected is labeling requirements (B31).

The most frequently used SPS types on mango in Qatar are testing requirements related to SPS requirements (A82), certification requirements (A83), inspection requirements (A84), systems approach (A13), and authorization requirements for SPS reasons for importing certain products (A14), while the most frequently used TBT measures are labeling requirements (B31), certification requirements (B83), and inspection requirements (B84). The PSI measure most frequently impacted is PSI (C1). The SPS measures that are most applicable to mango imports into Singapore are the authorization requirement for SPS reasons for importing certain products (A14), treatments to eliminate plant and animal pests or disease-causing organisms in the final product not otherwise specified or prohibition of treatment (A59), certification requirements related to SPS measures (A83), and inspection requirements related to SPS measures (A8). Product quality, safety, and performance requirements (B7) are the TBT measures most commonly affected in Qatar. The frequency distribution chart reveals that PSI (C1) is the only PSI measure that affects mango imports.

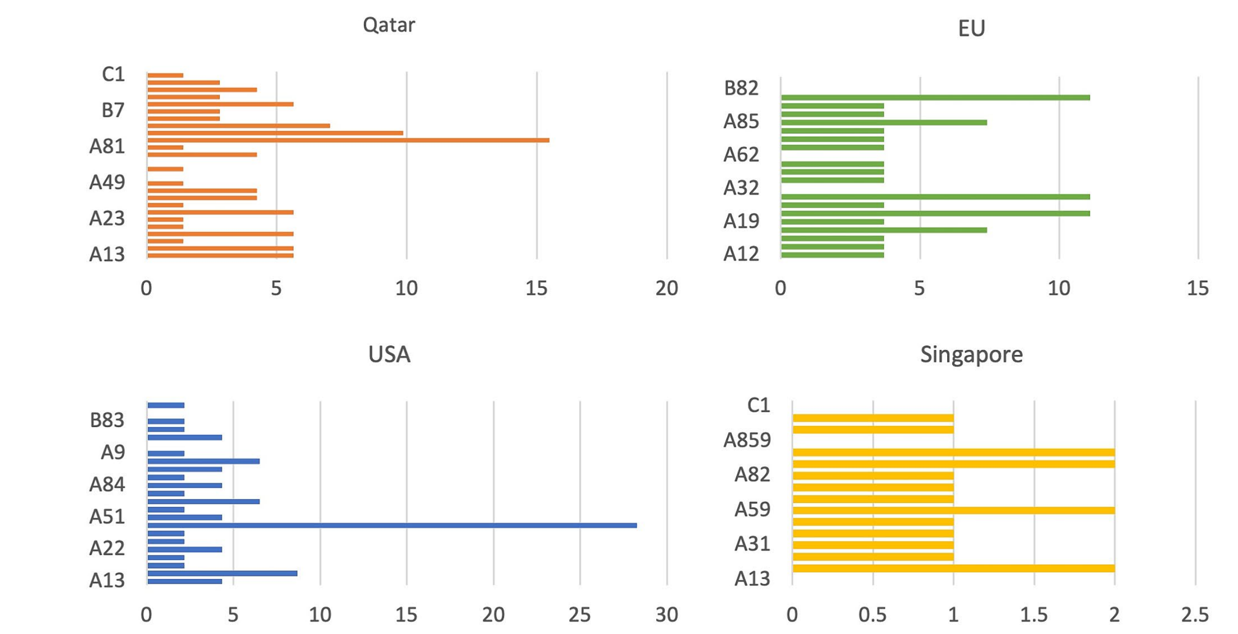

FIGURE 5
Disaggregated level of NTM in Qatar, EU, United States, and Singapore. Source: Author's calculation based on UNCTAD TRAINS database and COMTRADE data base.

The measurement of the impact of NTMs on mango exports from Sri Lanka was conducted in accordance with the third objective of the study. Here 352 observations were used to the analysis. Table 2 presents the summary statistics of the dataset utilized for the analysis.

The GDP values were taken as nominal to take into account the multilateral resistance and based theoretical literature of gravity model since these values are observed as price indices. Thus, deflating by other factors will give misleading results (Shepherd, 2013). The total number of NTMs imposed on the selected mango products by selected countries was (7317) measures.

4.2 Key drivers of Sri Lankan mango exports

This study examines the effect of NTMs on Sri Lankan mango exports employing four different estimation techniques: Probit, OLS, RE, and PPML techniques. Probit, OLS and RE techniques were used as robust estimation techniques. The results are presented in Table 3.

The export volume variable (the dependent variable) contained 65.57 percent zero values. To circumvent the heteroscedasticity issue, the PPML method was employed. According to Yotov et al. (2016), the PPML-obtained elasticity values can be utilized without transformation and take into consideration zero trade flows. The time fixed effect is utilized to capture the unobserved heterogeneity of the countries across distinct time intervals.

SPS, PSI, and total NTMs are the variables of interest. The Probit model revealed a significant positive association between SPS measures and importer's GDP, indicating that economically robust importing countries and adherence to SPS standards are crucial for mango export success. The SPS represent 79 percent of the total NTMs imposed on Sri Lankan mango exports. In contrast, the results indicate an inverse relationship between the total number of NTMs and the likelihood of Sri Lankan mango exporters gaining access to international markets. This finding suggests that an increase in NTMs corresponds with a decreased probability of mango exports. The cumulative effect of NTMs appears to function as a trade barrier by increasing the compliance burdens and costs faced by exporters, ultimately limiting their market access opportunities. This observation aligns with the existing literature, which has consistently demonstrated the trade-restrictive impact of NTMs across various industries and countries. For instance, Rindayati and Kristriana (2018) reported a similar trend in their study on Indonesian fish exports to major destination countries. Likewise, Sandaruwan and Weerasooriya (2019), Sandaruwan et al. (2020), and Pushpakumara et al. (2022) found comparable results in their analyses of the seafood and tea export industries in Sri Lanka, respectively. The consensus among these studies highlights the potential benefits of streamlining and reducing NTMs, as it could alleviate the compliance burdens and facilitate increased market access and export opportunities for Sri Lankan mango producers. Importantly, importer's population exhibited a substantial negative correlation with exports probability. The ability of Sri Lankan mango exporters to effectively penetrate the markets of larger importing nations may be hindered by higher entry barriers or stiffer competition. This results compatible with the results of Disdier et al. (2006).

The OLS, RE, and PPML models shed additional light on the relationship between NTMs and export volumes of Sri Lankan mango. Total NTMs continued to have a negative impact on export volumes (p 0.01), highlighting the difficulties posed by regulatory barriers in impeding export expansion. Importantly, we find that importer's GDP has a positive and statistically significant relationship with mango exports across all models, highlighting the role of economic strength of importing countries in driving demand for Sri Lankan mangoes. In

TABLE 2 Summary statistics.

Variables	Units	Mean	Std. Dev.	Minimum	Maximum
GDP_{it}	USD Billion	53.99	27.58	15.75	87.96
GDP_{jt}	USD Billion	2,576.65	4,218.87	17.54	23,000
X_{ijt}	USD	24,704.55	65,953.02	0	559,625
Pop_{it}	Number Million	20.35	0.99	18.78	22.16
Pop_{jt}	Number Million	138.86	331.58	0.65	1,412.36
$distance_{ij}$	km	7,799.18	3,100.07	2,733.40	14,338.92
$tariff_{ijt}$	Percentage	1.69	6.67	0	30
SPS_{ijt}	Number	15.28	16.67	0	93
TBT_{ijt}	Number	5.09	9.23	0	53
PSI_{ijt}	Number	0.40	1.01	0	7
NTM_{ijt}	Number	20.78	20.23	0	100

TABLE 3 Results of Probit, OLS, RE, and PPML estimations.

	Probit	OLS	RE	PPML
Dependent variable	Export dummy ($Y_{ijt} = 1$)	$lnX_{ijt} \geq 0$	$lnX_{ijt} \geq 0$	$X_{ijt} \geq 0$
GDP_{it}	1.79 (10.49)	−7.16 (13.30)	−7.16 (14.90)	−1.33* (0.69)
GDP_{jt}	2.20*** (0.85)	2.85*** (0.80)	2.85*** (0.90)	1.56** (0.63)
$distance_{ij}$	−0.59 (0.76)	−0.65 (1.02)	−0.65 (1.14)	−0.87 (0.80)
Pop_{it}	−38.43 (32.89)	−51.48 (34.72)	−51.48 (38.89)	–
Pop_{jt}	−1.68*** (0.60)	−2.14*** (0.56)	−2.14*** (0.63)	−1.22** (0.47)
SPS_{ijt}	2.67*** (0.30)	3.84*** (1.40)	3.84** (1.57)	3.29** (1.52)
TBT_{ijt}	0.35 (0.24)	0.50 (0.36)	0.50 (0.40)	0.81*** (0.29)
PSI_{ijt}	0.27 (0.58)	1.64** (0.79)	1.64* (0.88)	1.04** (0.47)
NTM_{ijt}	−2.61*** (0.33)	−3.77*** (1.42)	−3.77** (1.59)	−3.40** (1.60)
Constant	106.70 (121.17)	192.55 (142.55)	192.55 (142.55)	80.89 (61.60)
R^2	0.32	0.44	0.44	0.39
Number of observations	331	199	199	331
Time FE	Yes	Yes	Yes	Yes

Cluster robust standard errors are in parentheses.
***, **, and * denote significance at 1, 5, and 10% levels.

addition, SPS has a consistently strong and positive effect on mango exports across all models, indicating that compliance with SPS standards substantially improves Sri Lanka's export competitiveness on the mango market, as demonstrated by Probit analysis. In addition, Total NTMs are found to have a significant and negative impact on mango exports, indicating that reducing NTMs could result in increased market access and export opportunities for Sri Lankan mango producers.

The advantage of the PPML model is its compatibility with count zero data and its ability to manage overdispersion and heterogeneity, resulting in more accurate parameter estimates for the relationship between NTMs and export volumes. According to the PPML estimation results, the relationship between the GDP of the importing country, SPS measures, TBT measures, and PSI measures is a statistically significant positive relationship. The estimation results of the GDP importer country are consistent with the previous studies, which found that the GDP of the importer country has a positive effect on exports (Nardella and Boccaletti, 2004; Kalaba and Kirsten, 2012; Hwang and Lim, 2017; Permata and Handoyo, 2019; Sandaruwan et al., 2020; Pushpakumara et al., 2022). As anticipated, distance to the importing country has a negative correlation with Sri Lankan mango exports, but this relationship is insignificant. The population of importing countries has a negative impact, which may be attributable to a saturation effect or the size of the domestic market's competitiveness. According to the results, a 1 % increase in the importing country's GDP increased mango exports by 1.56 percent on average, while a 1 % increase in SPS, TBT, and PSI measures increased mango exports by 3.29 percent, 0.81 percent, and 1.05 percent on average, respectively. According to the literature on trade, TBTs may serve as a catalyst for trade. Indicating a tremendously beneficial effect of TBTs. While the literature on trade presents conflicting views on the impact of NTMs, the findings of this study align with the perspective that NTMs can foster trade in certain contexts. Some studies indicate that NTMs hamper trade (Peterson et al., 2013; Bianco et al., 2016), while others suggest that they can act as catalysts for trade (Cardamone, 2011). Additionally, numerous studies have reported mixed effects of NTMs on trade (Xiong and Beghin, 2011; Beckman and Arita, 2016; Santeramo et al., 2018; Santeramo and Lamonaca, 2020). This heterogeneity in the literature may stem from the diverse types of NTMs and their varying rationales (Schlueter et al., 2009). It could also be a consequence of the study design and methodological approaches employed. The positive impact of SPS, TBT, and PSI measures on mango exports observed in this study suggests that these specific NTMs may enhance trade in the context of mango exports, potentially by promoting product quality, safety, and market access.

The empirical findings highlight the importance of NTMs in determining the exports of mango from Sri Lanka. Total NTMs have a substantial impact on both the likelihood of exporting and export volumes. These challenges must be addressed by policymakers and industry stakeholders to promote sustainable export development and strengthen the mango industry's position on the global market. Importantly, the negative relationship between importer population and probability of exporting indicates that Sri Lankan mango exporters will have a more difficult time entering larger importation markets. Understanding the complexities of larger markets and adapting export strategies accordingly will be crucial for gaining access to and expanding market share in these nations.

5 Conclusion and policy implications

The study focused on fresh mango exports from Sri Lanka, examining the intricacies of mango rejections, NTMs affecting mango exports, and their consequential impact. The study identified the primary factors contributing to mango export rejections to major destinations and highlighted diverse models within the mango industry's value chain.

Pests and quality defects were the primary causes of internal rejections. To address these issues, farmers should adopt sound agricultural practices, and the government can conduct farmer education programs and provide pest and disease resistant planting materials. In addition, postharvest practices such as proper harvesting, packaging, transportation, categorizing, and grading can mitigate quality defects. Pests and pesticide residues were the leading causes of export rejections from importing nations. To reduce external rejections, both the government and mango exporters should follow appropriate inspection procedures. In major mango-growing regions, the study suggests implementing novel inspection procedures to detect pesticide residues, employing pest irradiation techniques, and adopting a total quality management (TQM) approach.

The research also investigated the incidences of NTMs on mango exports, revealing that the majority of NTMs imposed on Sri Lankan mangoes were SPS measures. We observed that the United States, China, Russia, and the Middle East regulated a substantial portion of mango exports via NTMs. The study also noted the contribution of TBT and PSI measures to the expansion of mango exports. To expand mango exports, the study highlighted the need for the government and exporters to comprehend and adapt to these NTMs, particularly SPS measures.

In addition, the study examined the effect of NTMs on mango exports and found that an increase in the total number of NTMs may have a negative impact on Sri Lankan mango exports. The study also revealed a positive influence of the importing countries' GDP on Sri Lankan mango exports.

Based on these findings, the study provided policymakers with actionable recommendations regarding the expansion of Sri Lanka's mango exports. It emphasized the importance of improving internal quality testing regulations to meet international standards and recommended further research in this area to gain a better understanding of the impact of non-target microorganisms on Sri Lankan mango exports.

Using the PPML model, the econometric analysis sheds light on the impact of NTMs on Sri Lankan mango exports. Total NTMs emerged as substantial obstacles, negatively impacting both the probability of exporting and export volume. This emphasizes the difficulties mango exporters face in accessing international markets due to excessive regulatory burdens and compliance expenses. It is essential to address NTMs in order to cultivate a trade-friendly environment and promote the sustainable growth of the mango export industry. Furthermore, the findings highlighted the importance of targeting economically resilient importing countries, as indicated by the highly significant positive correlation between importer GDP and export volumes. To optimize export opportunities, exporters should strategically concentrate on high-demand, high-spending markets. Compliance with international health and safety standards, exemplified by the substantial favorable impact of SPS measures on export volumes, has emerged as a key factor in gaining access to quality-conscious markets. Exporters of mango should prioritize compliance with stringent SPS regulations to acquire consumer trust and expand market access.

In light of our research findings, a number of crucial policy recommendations can be highlighted to promote the sustained growth of mango exports from Sri Lanka. We should prioritize simplifying and harmonizing NTMs to streamline bureaucratic complexities and reduce trade barriers. By implementing international standards and best practices, we can improve exporters' visibility and predictability on the international market. Moreover, investment in capacity building and technical assistance programs is essential, as these initiatives can equip mango exporters with the knowledge and skills necessary to comply with NTMs compliance requirements. This will enhance their competitiveness and increase their market penetration.

By meticulously implementing these policy recommendations, Sri Lanka has the opportunity to strengthen its mango export sector, foster sustainable growth, and strengthen its position in the global market. Addressing NTMs, targeting high-demand markets, and ensuring compliance with international standards are crucial to maximizing Sri Lankan mango exports and substantially contributing to the nation's economic growth.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

SPW: Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft. NBK: Data curation, Formal analysis, Investigation, Methodology, Validation, Writing – review & editing. TW: Conceptualization, Supervision, Project administration, Resources, Writing – review & editing. JW: Conceptualization, Supervision, Project administration, Resources, Funding acqusition, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Anders, S. M., and Caswell, J. A. (2009). Standards as barriers versus standards as catalysts: assessing the impact of HACCP implementation on US seafood imports. *Am. J. Agric. Econ.* 91, 310–321. doi: 10.1111/j.1467-8276.2008.01239.x

Arora, N. K., and Mishra, I. (2019). United Nations sustainable development goals 2030 and environmental sustainability: race against time. *Environ. Sustain.* 2, 339–342. doi: 10.1007/s42398-019-00092-y

Baier, S. L., and Bergstrand, J. H. (2007). Do free trade agreements actually increase members' international trade? *J. Int. Econ.* 71, 72–95. doi: 10.1016/j.jinteco.2006.02.005

Baltagi, B. H., Egger, P. H., and Erhardt, K. (2017). The estimation of gravity models in international trade the econometrics of multi-dimensional panels. *Theory App.*, 323–348. doi: 10.1007/978-3-319-60783-2_11

Beckman, J., and Arita, S. (2016). Modeling the interplay between sanitary and phytosanitary measures and tariff-rate quotas under partial trade liberalization. *Am. J. Agric. Econ.* 99, 1078–1095.

Bergstrand, J. H., Larch, M., and Yotov, Y. V. (2015). Economic integration agreements, border effects, and distance elasticities in the gravity equation. *Eur. Econ. Rev.* 78, 307–327. doi: 10.1016/j.euroecorev.2015.06.003

Bianco, D., Andrea, V. L., Boatto, F. C., and Santeramo, F. G. (2016). Tariffs and non-tariff frictions in the world wine trade. *Eur. Rev. Agric. Econ.* 43, 31–57. doi: 10.1093/erae/jbv008

Cadot, O., Gourdon, J., and Van Tongeren, F. (2018). Estimating ad valorem equivalents of non-tariff measures: combining price-based and quantity-based approaches.

Cardamone, P. (2011). The effect of preferential trade agreements on monthly fruit exports to the European Union. *Eur. Rev. Agric. Econ.* 38, 553–586. doi: 10.1093/erae/jbq052

Central Bank. (2022). "Central Bank of Sri Lanka Annual Report." Available at: https://www.cbsl.gov.lk/sites/default/files/cbslweb_documents/publications/annual_report/2022/en/6_Chapter_02.pdf.

Chen, C., Yang, J., and Findlay, C. (2008). Measuring the effect of food safety standards on China's agricultural exports. *Rev. World Econ.* 144, 83–106. doi: 10.1007/s10290-008-0138-z

Crivelli, P., and Gro€schl, J. (2016). The impact of sanitary and phytosanitary measures on market entry and trade flows. *World Econ.* 39, 444–473. doi: 10.1111/twec.12283

De Melo, J., and Nicita, A.. (2018). Non-tariff measures: Data and quantitative tools of analysis.

Deardorff, A. V., and Stern, R. M. (1998). *Measurement of nontariff barriers*, vol. *179* University of Michigan Press.

Disdier, A. C., Fontagné, L., and Minouni, M. (2006). The Impact of Regulations on Agricultural Trade: Evidence from SPS and TBT Agreements,". In INRA Paris-Grignon seminar.

Disdier, A.-C., and Marette, S. (2010). The combination of gravity and welfare approaches for evaluating nontariff measures. *Am. J. Agric. Econ.* 92, 713–726. doi: 10.1093/ajae/aaq026

Dong, Y., and Zhu, Y. (2015). "Impact of SPS measures imposed by developed countries on China's tea export-A perspective of differences in standards," in *Applied Economics and Finance*. Vol 2, 160–169.

Dou, L., Yanagishima, K., Li, X., Li, P., and Nakagawa, M. (2015). Food safety regulation and its implication on Chinese vegetable exports. *Food Policy* 57, 128–134. doi: 10.1016/j.foodpol.2015.09.007

Fernandes, A. M., Ferro, E., and Wilson, J. S. (2019). Product standards and firms' export decisions. *World Bank Econ. Rev.* 33, 353–374. doi: 10.1093/wber/lhw071

Ferrantino, M. J. Quantifying the trade and economic effects of non-tariff measures. (2006).

Ferro, E., Otsuki, T., and Wilson, J. S. (2015). The effect of product standards on agricultural exports. *Food Policy* 50, 68–79. doi: 10.1016/j.foodpol.2014.10.016

Frahan, D., Henry, B., and Vancauteren, M. (2006). Harmonisation of food regulations and trade in the single market: evidence from disaggregated data. *Eur. Rev. Agric. Econ.* 33, 337–360. doi: 10.1093/eurrag/jbl015

Grant, Jason, and Arita, Shawn. (2017). Sanitary and phyto-sanitary measures: Assessment, measurement, and impact.

Hilal, M., and Ismail, M. (2020). Sri Lanka's tea economy: issues and strategies. *J. Pol. L.* 13:1. doi: 10.5539/jpl.v13n1p1

Hwang, C. W., and Lim, S. S. (2017). Effect of non-tariff measures on international tea trades. *J. Korea Trade* 21, 309–323. doi: 10.1108/JKT-05-2017-0054

Jayasinghe, S., Beghin, J. C., and Moschini, G. C. (2010). Determinants of world demand for U.S. corn seeds: the role of trade costs. *Am. J. Agric. Econ.* 92, 999–1010. doi: 10.1093/ajae/aaq056

Jeger, M., Beresford, R., Bock, C., Brown, N., Fox, A., Newton, A., et al. (2021). Global challenges facing plant pathology: multidisciplinary approaches to meet the food security and environmental challenges in the mid-twenty-first century. *CABI Agric. Biosci.* 2, 1–18. doi: 10.1186/s43170-021-00042-x

Jha, A., and Bathla, S. (2021). "Non-tariff measures and India's agricultural exports: the case of India-ASEAN trade agreement" in *Indian agriculture under the shadows of WTO and FTAs: Issues and concerns* (Singapore: Springer Singapore)

Jongwanich, J. (2009). The impact of food safety standards on processed food exports from developing countries. *Food Policy* 34, 447–457. doi: 10.1016/j.foodpol.2009.05.004

Kalaba, M., and Kirsten, J.. (2012). "Estimating the quantity effects of non-tariff measures on SADC meat and milk trade." Department of Agricultural Economics, Extension and Rural Development, University of Pretoria

Lee, J.-W., and Swagel, P. (1997). Trade barriers and trade flows across countries and industries. *Rev. Econ. Stat.* 79, 372–382. doi: 10.1162/003465300556968

Levantis, G., and Fell, J. (2019). Non-tariff measures affecting Australian agriculture. *Agric. Commod.* 9, 100–106.

Li, Y., and Beghin, J. C. (2012). A meta-analysis of estimates of the impact of technical barriers to trade. *J. Policy Model* 34, 497–511. doi: 10.1016/j.jpolmod.2011.11.001

Malouche, Mariem, Reyes, José-Daniel, and Fouad, Amir. (2013). "Making trade policy more transparent: a new database of non-tariff measures." World Bank Economic Premise 128

Martin, Will J., and Pham, Cong S.. (2015). "Estimating the gravity model when zero trade flows are frequent and economically determined." World Bank Policy research working paper 7308

Mehta, R. (2000). Removal of QRs and impact on India's import. *Econ. Polit. Wkly.*, 1667–1671.

Melo, O., Engler, A., Nahuehual, L., Cofre, G., and Barrena, J. (2014). Do sanitary, phytosanitary, and quality-related standards affect international trade? Evidence from Chilean fruit exports. *World Dev.* 54, 350–359. doi: 10.1016/j.worlddev.2013.10.005

Mohan, S., Khorana, S., and Choudhury, H. (2012). Barriers to prosperity-developing countries and the need for trade liberalisation 2182096

Nardella, M., and Boccaletti, S.. (2004). *The impact of EU and US agro-food non tariff measures on exports from developing countries*.

Niu, Zhaohui. (2018). "The rising importance of nontariff measures in China's trade policy." In *Non-tariff measures: Economic assessment and policy options for development*, ed. MeloJ. De and A. Nicita, United Nations Conference on Trade and Development

Niu, Z., Milner, C., Gunessee, S., and Liu, C. (2020). Are nontariff measures and tariffs substitutes? Some panel data evidence. *Rev. Int. Econ.* 28, 408–428. doi: 10.1111/roie.12457

Otsuki, T., Wilson, J. S., and Sewadeh, M. (2001a). What price precaution? European harmonization of aflatoxin regulations and African groundnut exports. *Eur. Rev. Agric. Econ.* 28, 263–284. doi: 10.1093/erae/28.3.263

Otsuki, T., Wilson, J. S., and Sewadeh, M. (2001b). Saving two in a billion: quantifying the trade effect of European food safety standards on African exports. *Food Policy* 26, 495–514. doi: 10.1016/S0306-9192(01)00018-5

Permata, S. P., and Handoyo, R. D. (2019). NTMs effects on Indonesian fishery export. *J. Dev. Econ.* 4:1. doi: 10.20473/jde.v4i1.12686

Peterson, E., Grant, J., Roberts, D., and Karov, V. (2013). Evaluating the trade restrictiveness of phytosanitary measures on US fresh fruit and vegetable imports. *Am. J. Agric. Econ.* 95, 842–858. doi: 10.1093/ajae/aat015

Pushpakumara, A. B. A. W., Dissanayake, S. N., and Perera, S. M. S. D. (2022). Effects of non-tariff measures on tea exports from Sri Lanka. *Econ. Res.* 10, 17–36. doi: 10.4038/sljer.v10i1.173

Ranjan, K. R. H. M., and Edirisinghe, J. C. (2020). The impact of non-tariff measures on Sri Lankan tea trade: a Bayesian inference of the gravity model. *J. Agric. Econ.* 21:17. doi: 10.4038/sjae.v21i1.4637

Ratnayake, R.Asian Development Bank. (2019). Potential exports and nontariff barriers to trade: Sri Lanka national study. 112–120

Rindayati, W., and Kristriana, O. W. (2018). Impact analysis of Non-Tariff Measures (NTM) on Indonesian tuna exports to major destination countries. *JMA* 15:172.

Saini, Gordhan K. (2009). *Non-tariff measures and Indian textiles and clothing exports*. Mumbai: Indira Gandhi Institute of Development Research.

Sandaruwan, K. P. G. L., and Weerasooriya, S. A. (2019). Non-tariff measures and sustainable development: the case of the European Union import ban on seafood from Sri Lanka. *J. Agric. Rural. Dev. Trop. Subtrop.* 31, 11–24.

Sandaruwan, K. P. G. L., Weerasooriya, S. A., and Weerahewa, J. (2020). Effects of non-tariff measures on seafood exports from Sri Lanka: a gravity approach. *Trop. Agric. Res.* 31:798. doi: 10.4038/tar.v31i3.8393

Santeramo, F. G., Guerrieri, V., and Lamonaca, E. (2018). On the evolution of trade and sanitary and phytosanitary standards: the role of trade agreements. *Agriculture* 9:2. doi: 10.3390/agriculture9010002

Santeramo, F. G., and Lamonaca, E. (2019). The effects of non-tariff measures on Agri-food trade: a review and meta-analysis of empirical evidence. *J. Agric. Econ.* 70, 595–617. doi: 10.1111/1477-9552.12316

Santeramo, F. G., and Lamonaca, E. (2020). The role of non-tariff measures in the Agri-food sector: positive or negative instruments for trade? *Trade Debate*, 35–59. doi: 10.1007/978-3-030-25662-3_3

Schlueter, S. W., Wieck, C., and Heckelei, T. (2009). Regulatory policies in meat trade: is there evi-dence for least trade-distorting sanitary regulations? *Am. J. Agric. Econ.* 91, 1484–1490. doi: 10.1111/j.1467-8276.2009.01369.x

Sheldon, I. (2012). North–south trade and standards: what can general equilibrium analysis tell us? *World Trade Rev.* 11, 376–389. doi: 10.1017/S1474745612000249

Shepherd, B.. (2013). *The gravity model of international trade: a user guide*.

Shepherd, B., and Wilson, N. L. W. (2013). Product standards and developing country agricultural exports: the case of the European Union. *Food Policy* 42, 1–10. doi: 10.1016/j.foodpol.2013.06.003

Silva, S., and Tenreyro, S. (2006). The log of gravity. *Rev. Econ. Stat.* 88, 641–658. doi: 10.1162/rest.88.4.641

Swinnen, J. (2016). Economics and politics of food standards, trade, and development. *Agric. Econ.* 47, 7–19. doi: 10.1111/agec.12316

Swinnen, J. (2017). Some dynamic aspects of food standards. *Am. J. Agric. Econ.* 99, 321–338. doi: 10.1093/ajae/aax022

Swinnen, J. F., and Vandemoortele, T. (2011). Trade and the political economy of food standards. *J. Agric. Econ.* 62, 259–280. doi: 10.1111/j.1477-9552.2011.00294.x

Tinbergen, J. (1963). Shaping the world economy. *Int. Exec.* 5, 27–30. doi: 10.1002/tie.5060050113

Trade Earth. (2020). The top 5 Agricultural export destinations from Sri Lanka. Available at: https://resourcetrade.earth/?year=2020&exporter=144&category=1&units=value&autozoom=1) (Accessed 20 December 2022).

Trefler, D. (1993). Trade liberalization and the theory of endogenous protection: an econometric study of US import policy. *J. Polit. Econ.* 101, 138–160. doi: 10.1086/261869

Trienekens, J., and Zuurbier, P. (2008). Quality and safety standards in the food industry, developments and challenges. *Int. J. Prod. Econ.* 113, 107–122. doi: 10.1016/j.ijpe.2007.02.050

UNCTAD (2012). International Classification of Non-Tariff measures Version (UNCTAD/DITC/TAB/2012/2) (New York, Geneva: UNCTAD, 2012).

United Nations. (2019). *World economic situation and prospects*. New York: United Nations.

United Nations. (2022). UN Comtrade Database. [Online]. Available at: https://comtrade.un.org/.

United Nations Conference on Trade and Development. (2015). Non-Tariff Measures and Sustainable Development Goals: Direct and Indirect Linkages [Policy Brief NO.37].

United Nations Conference on Trade and Development. (2019). International Classification of Non-Tariff Measures.

United Nations Conference on Trade and Development and WORLD BANK (2018). The unseen impact of non-tariff measures: Insights from a new database.

Vidanapathirana, Ruvini, Jayamini Champika, PA, Rambukwella, Roshini, and Wijesooriya, Nalaka. (2018). Quality and safety issues in fruit and vegetable supply chains in Sri Lanka: a review. Hector Kobbekaduwa Agrarian Research and Training Institute

Wilson, J. S., and Otsuki, T. (2003). Food safety and trade: winners and losers in a non-harmonized world. *J. Econ. Integr.* 18, 266–287. doi: 10.11130/jei.2003.18.2.266

Wood, J., Jie, W., Li, Y., and Jang, H. (2017). The economic impact of SPS measures on agricultural exports to China: an empirical analysis using the PPML method. *Soc. Sci.* 6:51. doi: 10.3390/socsci6020051

Wooldridge, J. M.. (2019). *Introductory econometrics: a modern approach*. Boston: Cengage.

World Trade Organization and the United Nations. (2012). *A practical guide to trade policy analysis*. Geneva: World Trade Organization.

Xiong, B. (2012). *Three essays on non-tariff measures and the gravity equation approach to trade* Iowa State University.

Xiong, B., and Beghin, J. (2011). Does European aflatoxin regulation hurt groundnut exporters from Africa? *Eur. Rev. Agric. Econ.* 39, 589–609. doi: 10.1093/erae/jbr062

Xiong, B., and Beghin, J. (2014). Disentangling demand-enhancing and trade-cost effects of maximum residue regulations. *Econ. Inq.* 52, 1190–1203. doi: 10.1111/ecin.12082

Yotov, Y. V., Piermartini, R., and Larch, M.. (2016). An advanced guide to trade policy analysis: the structural gravity model. WTO iLibrary.

Yue, C., and Beghin, J. C. (2009). Tariff equivalent and forgone trade effects of prohibitive technical barriers to trade. *Am. J. Agric. Econ.* 91, 930–941. doi: 10.1111/j.1467-8276.2009.01306.x