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ORIGINAL

Phytosanitary barriers and Peruvian agricultural exports, 2012-2019

Barreras Fitosanitarias y exportaciones agrícolas peruanas, 2012-2019

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ABSTRACT

The study analyzes how phytosanitary barriers influence Peruvian agricultural exports from 2012 to 2019, focusing on grapes, asparagus and avocados. Its main objective is to identify these relationships in order to understand the impact of such regulations on exports. Methodologically, it is a basic, quantitative and explanatory study, with longitudinal design and hypothetico-deductive method, using secondary data from official sources such as SUNAT and the Central Reserve Bank. The results reveal that phytosanitary barriers explain 93,6 % of the variability in overall agricultural exports, highlighting their positive impact by improving product quality and facilitating access to international markets. However, their influence varies according to the product: in grapes, they have a minimal incidence (1,6 % in FOB value), while in asparagus and avocados they have a moderate impact on the volume exported (55,4 % and 90 %, respectively). These findings underscore the importance of regulations to guarantee safety and quality, although other factors such as international demand and trade agreements are also determining factors. In conclusion, phytosanitary barriers, although they represent challenges, act as catalysts to strengthen the competitiveness of the Peruvian agricultural sector by encouraging compliance with international standards and promoting innovation in production processes. This positions Peru as a reliable exporter in the global market and highlights the need to diversify markets and strengthen the sector's capabilities.

Keywords: Phytosanitary Barriers; Agricultural Exports; Quality and Safety; Market Diversification; Agricultural Regulations.

RESUMEN

El estudio analiza de qué manera las barreras fitosanitarias influyen en las exportaciones agrícolas peruanas del 2012 al 2019, enfocándose en uvas, espárragos y paltas. Su objetivo principal es identificar estas relaciones para comprender el impacto de dichas regulaciones en las exportaciones. Metodológicamente, es un estudio básico, cuantitativo y explicativo, con diseño longitudinal y método hipotético-deductivo, que utiliza datos secundarios de fuentes oficiales como SUNAT y el Banco Central de Reserva. Los resultados revelan que las barreras fitosanitarias explican el 93,6 % de la variabilidad en las exportaciones agrícolas generales, destacando su impacto positivo al mejorar la calidad de los productos y facilitar el acceso a mercados internacionales. Sin embargo, su influencia varía según el producto: en uvas, tienen una incidencia mínima (1,6 % en el valor FOB), mientras que en espárragos y paltas muestran un impacto moderado en el volumen exportado (55,4 % y 90 %, respectivamente). Estos hallazgos subrayan la importancia de las normativas para garantizar la inocuidad y calidad, aunque otros factores como la demanda internacional y acuerdos comerciales también son determinantes. En conclusión, las barreras fitosanitarias, aunque representan desafíos, actúan como catalizadores para fortalecer la competitividad del sector agrícola peruano al incentivar el cumplimiento de estándares internacionales y promover la innovación en procesos productivos. Esto posiciona a Perú como un exportador confiable en el mercado global y resalta la necesidad de diversificar mercados y reforzar las capacidades del sector.

Palabras clave: Barreras Fitosanitarias; Exportaciones Agrícolas; Calidad e Inocuidad; Diversificación de Mercados; Normativas Agrícolas.

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INTRODUCTION

As established by the International Plant Protection Convention (IPPC)[1], these barriers are crucial for safeguarding 70-80 % of crops and ecosystems. However, they can also restrict trade by 20-30 % by increasing operational costs and hindering market access. Phytosanitary measures can raise production costs by 10-20 % and require technology, training, and certification investments, limiting developing countries' ability to compete in global trade. Recent studies highlight the challenges posed by phytosanitary barriers to international trade, significantly affecting growing economies and small and medium-sized enterprises (SMEs).

According to Pomareda[2], phytosanitary barriers in Central America represent a significant challenge for agri-food trade, especially for SMEs, as they include quarantine requirements, phytosanitary certifications, and control actions aimed at preventing the entry of diseases and pests into destination markets. Although these restrictions are necessary to protect biodiversity and public health, their implementation generates additional costs, delays, and logistical complications that reduce the competitiveness of SMEs. Furthermore, the lack of access to information, specific training, and adequate financing aggravates the situation, further limiting the ability of SMEs to compete with large companies.

According to the study conducted in Cúcuta, Colombia, phytosanitary barriers in the beef industry hinder the implementation of international food safety standards, affecting the competitiveness and capacity of companies to guarantee safe products. These barriers include deficiencies in business management, lack of resources, and difficulties in complying with certification standards, which increase operating costs and limit access to international markets. In addition, research reveals that the lack of training and technical support prevents companies from adopting continuous improvement processes, affecting both food safety and quality, which are essential to boost the development of the meat sector in the region.[3]

In Ecuador, phytosanitary problems severely affect banana and plantain crops, which are fundamental for food security and economic growth. They face severe challenges due to infestation by pests such as mites, weevils, and nematodes, as well as serious phytopathogenic diseases. These pests and diseases reduce yields and negatively affect employment and agricultural GDP, complicating agroecological management and production. The problem is exacerbated by the lack of effective measures to control and manage these factors.[4]

Phytosanitary barriers in the Peruvian asparagus export sector generate significant challenges, especially when the number of pests exceeds the control provided by beneficial biological agents, which affects companies' international competitiveness. These regulations include strict quality and sanitary requirements imposed by importing countries to safeguard the health of their consumers and environmental protection. Although biological control offers a sustainable solution, its effectiveness is compromised if an adequate pest population balance is not achieved, forcing companies to adopt more costly or restrictive measures.[5]

According to the research, phytosanitary barriers in Peru complicate agro-exports, affecting producers' competitiveness and compliance with international regulations. The lack of crop-specific protocols increases implementation costs and reduces efficiency in phytosanitary management. This is particularly problematic in a growing sector such as the Peruvian agro-export sector, where the lack of applied research limits innovation and adaptation to the phytosanitary standards demanded by global markets. In addition, the scarcity of technical information and implementation support affects the ability of producers to remain internationally competitive.[6]

Phytosanitary barriers in Peru negatively impact the competitiveness of tomato exports, especially in the Tacna area. These regulations, characterized by a legal structure that 64,29 % of agro-industrialists consider harmful, restrict the cultivation of products destined for agro-exports, limiting the economic development of exporters. Despite foreign direct investment in the country, the inadequacy of the regulatory framework and insufficient resources hinder the growth of agro-industrial exports in this area.[7]

The general problem of this study is: How do phytosanitary barriers influence Peruvian agricultural exports from 2012 to 2019? The specific problems are: How do phytosanitary barriers influence Peruvian agricultural exports of grapes from 2012 to 2019; How do phytosanitary barriers influence Peruvian agricultural exports of asparagus from 2012 to 2019; and How do phytosanitary barriers influence Peruvian agricultural exports of avocados from 2012 to 2019?

The general objective of this study is to analyze how phytosanitary barriers influence Peruvian agricultural exports between 2012 and 2019. The specific objectives are to analyze how phytosanitary barriers influenced Peruvian agricultural exports of grapes from 2012 to 2019, to analyze how phytosanitary barriers influenced Peruvian agricultural exports of asparagus from 2012 to 2019, and to analyze how phytosanitary barriers influenced Peruvian agricultural exports of avocados from 2012 to 2019.

This study's general hypothesis is that phytosanitary barriers have a positive influence on Peruvian agricultural exports from 2012 to 2019. It also has the following specific hypotheses: phytosanitary barriers positively influence Peruvian agricultural exports of grapes from 2012 to 2019, phytosanitary barriers positively influence Peruvian agricultural exports of asparagus from 2012 to 2019, and phytosanitary barriers positively influence Peruvian agricultural exports of avocados from 2012 to 2019.

Boza et al.[8] addressed the problem of the scarcity of research on the economic impact of agricultural export returns due to non-compliance with sanitary and phytosanitary (SPS) regulations, which makes it difficult to understand their influence on international trade and to assess the associated costs. This study aimed to characterize and assess the technical reasons for the rejections of Chilean fruit exports to the US market between 2010 and 2020, analyzing these rejections from an international trade perspective. A quantitative methodology and a descriptive approach were employed, starting with collecting a database including secondary data (rejection records from the US Food and Drug Administration and export data provided by the Chilean Office of Agricultural Studies and Policies). The results indicated that Chile's reputation, strong SPS regulatory system, and agreements such as the Free Trade Agreement (FTA) with the United States facilitate the entry of its products into the market, taking advantage of seasonal complementarity that reduces competition. It was observed that rejections accounted for only 0,046 % of the total value of exports, equivalent to approximately US$9,45 million, with excessive use of pesticides being the leading cause. Although rejections were relatively low, extraordinary events, such as the 184 rejections of lemons in 2019, can generate significant variations.

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In conclusion, while SPS measures are fundamental to ensure the quality of agricultural exports, research has focused more on trade flows than on the economic impact of rejections. In the case of Chile, between 2010 and 2020, rejections of fruit exports to the United States were minimal, representing less than 0,05 % of the total value. However, pesticide residues were identified as the leading cause of these rejections, highlighting the importance of improving the control of these products to avoid economic losses and ensure compliance with international regulations.

Liu et al.[9] investigated the problem of heterogeneous implementation of SPS measures in different countries, which makes it difficult to assess their influence on the quality of agricultural products and environmental preservation. This variability increases transaction costs for exporters from developing economies and complicates the assessment of the effectiveness of SPS measures for sustainability objectives. This study aimed to determine how the diverse application of SPS measures affects firms' short-term export choices and their contribution to long-term environmental protection. The methodology employed is quantitative, using firm-level data between 2000 and 2015, applying the Tobit econometric method. The results of the study showed that SPS measures imposed by the United States considerably influence the quality of Chinese agricultural products. It was found that non-diversified firms showed an improvement in quality of 0,031, in contrast to diversified firms, which only improved by 0,011. Heterogeneous SPS measures induce varying quality improvement trends across firms but negatively impact long-term environmental sustainability. The study, based on a sample of 79 080 Chinese exports to the US over the past 16 years, highlights the interaction between SPS measures and firm characteristics in terms of product quality. In conclusion, the research highlights that heterogeneous SPS measures have adverse effects on the optimization of export quality and environmental protection due to differences in firms' implementation and enforcement of these measures.

Research by Sanjuán et al.[10] analyzed the trade costs of SPS measures, focusing on the complexity of regulations in the European Union (EU), which creates barriers for exporters from developing economies. Furthermore, hidden costs persist despite regulatory harmonization due to overlapping regulations and compliance requirements. The study aimed to analyze whether the convergence of SPS regulations offers net trade benefits that outweigh the associated costs, focusing on the EU dairy sector and analyzing the impact of exporters' experience. The research methodology uses a flexible quantitative and empirical approach with three-year panel data from 2010 to examine the trade effects of SPS regulatory convergence, applying a structural gravity equation that includes internal trade. The results indicate that SPS measures have a depressing effect of 10,4 % on trade values in the dairy sector. However, regulatory convergence offers greater benefits, reducing the Ad-Valorem Tariff Equivalent (AVE) by 14 %.

In comparison, exporters' experience reduces costs by 9 % but cannot offset the full impact of SPS measures. In conclusion, harmonization clauses in EU food standards have been shown to affect trade positively. However, the exact impact of regulatory convergence on the dairy industry has not previously been quantified.

Kapur[11] addressed how phytosanitary barriers and food safety regulations affect agri-food trade between India and the US. Differences in regulations and lack of harmonization complicate compliance and cooperation, creating significant challenges for exporters and affecting the dynamics of bilateral trade. The study aimed to examine how phytosanitary barriers and food safety regulations impact agri-food trade between India and the United States. The research methodology used a quantitative approach with data on food safety regulatory mechanisms in the India-US agri-food trade, collecting information from secondary sources such as official portals and digital databases. The results indicated an increase in US agricultural exports to India, rising from USD 971,33 million in 2013 to USD 2,34 billion in 2022, with an average annual increase of 9,2 %. However, bilateral trade faces tensions due to trade barriers and SPS measures, with seven disputes registered at the World Trade Organisation (WTO) since 1998. In conclusion, it highlights the importance of strengthening India-US collaboration on food safety and agri-food trade to ensure the quality and safety of imported food products. Despite advances in systems such as the Food Import Regulation and Analysis System (FIRA) in India and the Import Reject Report (IRR) in the US, the lack of consistency and transparency in reporting rejections has led to trade tensions.

Lima[12] investigated oat trade issues in Brazil, focusing on phytosanitary barriers and regulations that limit exports and imports despite significant growth in domestic production. It asks whether these non-tariff barriers imposed by Brazil are responsible for the situation or whether the high competitiveness of local production is the cause. The objective was to examine the evolution of oat production in Brazil and its relationship with foreign trade, focusing on the effect of non-tariff barriers on imports. The methodology used is quantitative, relying on secondary data and employing a partial equilibrium model to assess the effect of possible changes in trade policy. The results show that, between 2007/2008 and 2016/2017, Brazil increased its share in world oat production from 0,9 % to 2,9 %, while exports and imports remained marginal. The price of oats in Brazil follows the international trend and shows variations compared to countries such as Argentina and Uruguay. The research estimates an equivalent tariff of 14,06 % for non-tariff barriers, reflecting their impact on the domestic price compared to the international price. The conclusion is that the low share of international trade in oats is because most of the world's production is oriented to consumption in the country of origin. In Brazil, despite the remarkable increase in production and productivity, foreign trade is still limited due to phytosanitary regulations that create barriers to imports, with Mercosur countries being the leading suppliers.

Solórzano-Acosta et al.[6] analyzed the problematic impact of traditional phytosanitary control practices on the environment and food, focusing on Peru's agro-export sector. The research objective was to analyze the characteristics of agricultural exports in Peru and their link with using entomopathogenic and antagonistic microorganisms as a strategy for the biological control of pests and diseases. The degree of development and commercialization of biological products in Peru and other markets was also assessed, and the main limitations in creating crop-specific protocols were identified. The results revealed that the fungus most studied and reported by Peruvian institutions was Beauveria bassiana, with 24,1 % of the publications. This was followed by native Metarhizium anisopliae and Trichoderma, with 13,8 % each. In addition, 10,3 % of the studies focused on using Bacillus subtilis.

Regarding target organisms, 51,4 % of the publications focus on insects, while 24,3 % are oriented towards managing plant pathogenic fungi. Therefore, at the international level, it has been demonstrated that entomopathogenic and antagonistic microorganisms are effective in the biological control of pests and diseases in export crops. However, in Peru, research is still focused on fundamental aspects without sufficient practical application to create concrete tools for agro-industry. In conclusion, although using entomopathogenic and antagonistic microorganisms can improve phytosanitary management in Peruvian agro exports, the lack of applied research and the development of crop-specific protocols limit their large-scale adoption. It is necessary to promote more research to create products and tools adapted to local crops so that the agro-industrial sector can remain competitive and aligned with international sanitary demands.

Valverde[13] studied the problem of the increase in non-tariff measures in global trade, driven by the WTO and its multilateral rules, which, although they have reduced tariffs, have posed new challenges such as the need for greater transparency to avoid additional trade costs. The research aims to examine how scientific and legal capacities and agricultural production influence SPS reporting in this sector during the period mentioned above. Using econometric analysis with Probit and Logit models, the results reveal that the Regulatory Quality Index in Peru has experienced a significant improvement from a value of 0,02 in 2002 to 0,56 in 2019. This progress reflects a better perception of the government's formulation of policies and regulations to promote private sector development. The findings emphasized the urgency of optimizing the administration of notifications to avoid trade frictions and to optimize the exchange of information with trading partners.

Valverde[14] research addressed the issue of Peruvian agro-exports, which have shown remarkable resilience in the face of the COVID-19 pandemic, unlike other more affected sectors. Projections indicate that the sector's exports could exceed the US$7 billion reached in 2019. In addition, it was targeted to expect an improvement in exports of hydrobiological products thanks to favorable oceanographic conditions. However, the sanitary and phytosanitary measures imposed during the pandemic and notified to the WTO could positively and negatively impact national interests. To analyze this context, the study employs a quantitative methodology based on collecting notifications, declarations, documents issued by the WTO and its members, and bilateral demarches by Peruvian governmental entities. However, it turned out that the EU rejected this request through communication G/SPS/GEN/1814 and instead presented the 'Farm to Fork Strategy,' which aims to promote more sustainable and resilient food systems, including a 50 % reduction in the use of pesticides. Despite the difficulties, agricultural and food products have shown greater resilience than other goods, and Peru has actively participated in multilateral initiatives to ensure free trade. In conclusion, close collaboration between the public and private sectors is crucial to ensure the measures implemented are in the country's best interests.

In his research, Zúñiga[15] analyzed the problem of the increased exchange of goods between nations and the need for governments to establish mechanisms to ensure food safety and safeguard public and animal health against risks from pests, diseases, and pathogenic organisms. Despite the relevance of SPS measures, a paradox persists in understanding their definition and integration into the Peruvian legal framework. The objective of this paper was to provide an overview of the theoretical and regulatory framework governing SPS measures in Peru, as well as to understand their potential impact on the country's economy. The methodology of the study focuses on an investigation of current regulations, dividing the article into two parts: the first part explains what SPS measures are and the benefits of their adoption, reviewing the WTO system and the most significant provisions of the Agreement on the Application of SPS measures; the second part analyses the Peruvian legal framework about SPS measures and the relevant bilateral agreements. The results of this analysis highlight the importance of proper implementation of SPS measures to improve public and animal health and facilitate international trade, underlining the need for greater clarity and understanding in their application. The conclusions emphasize that proper adoption and regulation of SPS measures will benefit human and animal health and enhance the country's competitiveness in global trade.

Yang[16] investigated the issue of increasing trade disputes between countries, driven by the growing prevalence of control techniques such as sanitary and phytosanitary, as well as technical barriers to trade in recent decades. Their study aims to investigate how these measures impact Chinese firms' import margins and unit trade values, considering variations in these effects according to firms' positioning in global value chains (GVCs). The methodology includes a panel data analysis of firm-level import data in China between 2008 and 2013 and an original dataset on non-tariff measures provided by the United Nations Conference on Trade and Development (UNCTAD). From the perspective of the OU and ID indices, the results show that while the firm-level indices have not undergone significant changes compared to the national indices, the ID index has increased slightly from 2,7 to 3,2. This increase suggests that Chinese firms have partially lost their total backward linkage since 2008, a surprising fact considering China's rapid economic development, making it one of the world's leading importers and exporters in the last decade. In conclusion, although non-tariff measures may represent barriers to entering international markets, firms that comply with these requirements often benefit from increased trade flows and higher prices, suggesting that overcoming these challenges can confer significant competitive advantages.

THEORETICAL FRAMEWORK

Export theory

Exports play a crucial role in a country's economy, as they reflect the potential to produce quality goods or goods that are useful for other markets. Trade balances are a concrete indicator of what is being offered compared to what is being bought. In this context, pursuing a favorable trade balance makes exports a central issue in globalization. Thus, everything related to industrialization policies, from which exported products emerge, is relevant in today's world, as it allows us to identify the most appropriate industrial policy for a country. Lederman et al.[17] highlight what matters in export by analyzing industrialization policies and pointing out that it is not the quantity or how it is exported that is essential but how the goods are produced.

Management theory

Henri Fayol, the father of modern management theory, stressed the need for transparent and flexible management principles, which are helpful in all circumstances. He identified 14 key principles, including authority and responsibility, which are intrinsically linked, with authority derived from job and personal attributes; unity of command, which states that employees should take orders from a single superior; and the chain of command, which describes a hierarchy of superiors from the highest to the lowest positions, allowing exceptions only when following it strictly would be detrimental. Fayol also emphasized the esprit de corps, which stresses the importance of teamwork and communication to strengthen unity in the organization. Furthermore, he considered the essential functions of management to be planning, organizing, commanding, coordinating, and controlling.[18]

International trade theory

International trade theory seeks to explain the reasons behind trade transactions between countries, the benefits and costs of this trade, and how government policies can influence the exchange of goods and services globally. International trade has grown significantly, with a notable increase in the global output sold internationally. The gravity model is used to understand trade between countries, which holds that trade between two nations is proportional to the output of their economies and decreases as the distance between them increases, similar to Newton's law of gravity. This model helps identify patterns and anomalies in international trade, considering economic size, trade barriers, and geographical proximity. In addition, the pattern of world trade has changed in recent decades, highlighting the growth of trade in Asia and changes in the categories of goods traded.[19]

Theory of comparative advantage

The theory of comparative advantage states that a country, firm, or individual should focus on producing those goods or services that it can produce at a lower opportunity cost than others. Unlike absolute advantage, which refers to the ability to produce a greater quantity with fewer resources, comparative advantage focuses on relative differences in opportunity costs. This principle suggests that, even if an individual or country is more efficient in the production of all goods, it is still advantageous to specialize in those goods in which it is least inefficient. In this way, trade based on comparative advantage allows participants to access goods and services at lower costs than their production costs, increasing total output and economic welfare.[20]

The theory of external economies

The Theory of External Economies, proposed by Alfred Marshall, argues that the benefits of industrial concentration in a region can reduce costs and increase efficiency, even when individual firms remain small. According to this theory, the geographical location of several firms in the same industry in a specific area allows for specialized suppliers, a more robust labor market, and knowledge sharing. These combined factors generate external economies, which do not depend directly on the scale of individual firms but on the concentrated industrial environment. This phenomenon is observed in modern cases such as Silicon Valley, where the concentration of technology firms facilitates access to suppliers, fosters the availability of highly skilled talent, and promotes the informal diffusion of knowledge, resulting in a highly competitive and efficient environment.[21]

Variables and dimensions

Variable 1: Phytosanitary barriers

According to Whalley[22], phytosanitary barriers are regulations established by countries to safeguard the health of people, animals, and plants from pests and diseases. They include a risk assessment to identify potential threats and are supported by legislation and regulations governing their implementation. These measures are part of international agreements, such as those of the WTO, which seek to balance safeguarding health and the environment with the need to reduce trade barriers. These include the Andean Standard for the Registration and Control of Chemical Pesticides for Agricultural Use, which determines community requirements and procedures to guarantee the biological effectiveness of products and mitigate health risks, as well as the Sanitary Standard on Maximum Residue Limits (MRLs) of pesticides in food, which sets permitted limits to protect public health and guide authorities in the surveillance of chemical hazards; and finally, the Quality Management System by ISO 9001:2015, which aims to optimize effectiveness, efficiency in public management and quality of services.

Dimension 1: Andean Standard for the Registration and Control of Chemical Pesticides for Agricultural Use

According to the Andean Community[23], under Decision 804, it seeks to establish the necessary community requirements and procedures for authorizing and supervising PQUA in the Member States. It aims to facilitate both the implementation and enforcement of these requirements through harmonized guidelines and procedures, focusing on evaluating PQUAs for registration and re-evaluation purposes. This will ensure the biological efficacy of products and mitigate risks to health and the environment. In addition, it establishes the Community criteria and procedures that will allow National Competent Authorities (NCAs) to assess the risks and benefits of the PQUAs to be registered. It also defines the principles of graduality and specificity necessary for their registration in Member Countries.

Dimension 2: Sanitary Standard establishing Maximum Residue Limits (MRLs) for Pesticides for Agricultural Use in Food for Human Consumption

According to Digesa[24], to safeguard the community's health, the MRLs of pesticides for agricultural use that are authorised

in foodstuffs intended for human consumption are established. According to Legislative Decree No. 1062, Food Safety Law, these limits are established for surveillance and sanitary control. A reference standard is also established to guide the competent authority in sanitary control during the supervision or monitoring of chemical contaminants present in food.

Dimension 3: Quality Management System - ISO 9001:2015 Standard

According to Ositrán[25], the Peruvian state reform aims to achieve a more effective management strategy and more efficient processes, improve the quality of services, and ensure effective accountability. To support the achievement of these objectives, a quality management system (QMS) aligned with the International Standard ISO 9001:2015 is implemented. As part of the corporate strategy, this management system adopts a process-oriented approach, which involves identifying the key processes of the QMS and understanding their sequence and interaction to optimize their effectiveness continuously.

Variable 2: Peruvian agricultural exports

Peruvian agricultural exports are the set of agricultural products the country sends to international markets. They stand out, especially for their diversification towards non-traditional crops such as asparagus, paprika, and various fruits. Over the years, these exports have shown significant growth, reflecting their growing importance for the national economy and their contribution to foreign exchange earnings. The re-adaptation of agricultural production has driven this increase to meet external demand, adopting advanced technologies and optimizing the supply chain.[26]

Dimension 1: International markets

According to Cateora et al.[27], international markets are described as dynamic and complex interconnections affecting firms of various sizes and sectors in the context of increasing globalization. They highlight how the rise of international trade, driven by economic, technological, and political forces, creates a new global economic order. As businesses face challenges and opportunities in an increasingly interdependent context, adjusting to change and anticipating the unexpected in international trade is crucial.

Dimension 2: Export growth

According to Suranovic[28], export growth refers to the increase in the quantity and value of products and services a country sells to other countries over time. Export growth involves analyzing the availability and demand for products in global markets, assessing the behavior of consumers and firms, and assessing the impact of trade policies on the national economy. This increase can result in significant benefits for countries, such as boosting economic development, creating jobs, and improving the trade balance.

Dimension 3: Domestic economy

According to Samuelson et al.[29], the national economy is defined as the system that organizes and regulates the production, delivery, and use of goods and services in a country, aiming to meet society's needs and promote the general welfare. The main objectives of macroeconomics include achieving a high level and sustained growth of Gross Domestic Product (GDP), maintaining low unemployment rates, and ensuring price stability.

METHOD

Type

The study is basic because it seeks to generate theoretical knowledge on the connection between phytosanitary barriers and Peruvian agricultural exports. It is not oriented to solve immediate practical problems but to broaden scientific understanding. According to Hernández et al.[30], basic research aims to produce knowledge and theories without seeking immediate application. It is a systematic, empirical, and critical process that broadens the understanding of phenomena, drives the advancement of human knowledge, and is essential for scientific progress.

Approach

The study has a quantitative approach because it uses secondary numerical data to analyze the influence of phytosanitary barriers on Peruvian agricultural exports, seeking objective and measurable results. According to Creswell et al.[31], the quantitative approach is appropriate for this research, as it allows the impact of phytosanitary barriers on agricultural exports to be assessed through indicators such as rejection rates, economic losses, and compliance with standards. It also facilitates comparison between different regions, products, and periods, identifying trends and variations in the effects of such barriers.

Level or Scope

The study has an explanatory scope because it seeks to understand how phytosanitary barriers influence Peruvian agricultural exports, identifying the underlying relationships and mechanisms that affect this interaction. According to Hernández et al.[30], studies with an explanatory scope focus on determining the causes of both physical and social events and phenomena and go beyond simply describing or identifying links between variables. They aim to understand why a phenomenon occurs and under what circumstances it manifests itself.

Design and cut-off

The study has a non-experimental design because it does not manipulate variables but observes and analyses their relationships

as they occur in the real environment. Likewise, it is of longitudinal design because data are collected at different times or periods; in this case, it seeks to analyze the impact of phytosanitary barriers on Peruvian agricultural exports over several years. According to Hernández et al.[30], non-experimental research is characterized by the fact that it does not deliberately manipulate variables but focuses on observing phenomena within their natural environment. In this study design, no new situations are generated; existing situations are observed and analyzed without the researcher's intervention. Longitudinal designs collect data over different periods to describe how variables change and how they relate to and influence each other over time.

Method

The study uses the hypothetico-deductive method because it starts from previously formulated hypotheses about the interaction between phytosanitary barriers and Peruvian agricultural exports. According to Popper[32], the hypothetico-deductive method is key to science, as it subjects hypotheses to rigorous testing to falsify them, i.e., trying to minimize their probability of occurrence. Corroboration of a hypothesis is only valid if the data reflect a sincere effort to overturn it. The author concludes that the number of theories cannot be reduced to a single truth but that the most rigorously tested theory is chosen for future criticism.

Population

Annual reports and databases on Peruvian agricultural exports of grapes, avocados, and asparagus were published by government entities such as the National Superintendence of Customs and Tax Administration (SUNAT) and the Central Reserve Bank. In addition, reports on phytosanitary barriers, published by entities such as Supervisory Body for Public Transport Infrastructure Investment (Ositrán), General Directorate of Environmental Health and Food Safety (DIGESA) and the Andean Community.

Sample

Government entities such as SUNAT and the Central Reserve Bank published annual reports and databases on Peruvian agricultural exports of grapes, avocados, and asparagus. In addition, reports on phytosanitary barriers were published by Ositrán[25], DIGESA[24], and the Andean Community[23] from 2012 to 2019.

Technical

The study will implement a desk review to identify, evaluate, and select reliable and relevant sources on phytosanitary barriers and Peruvian agricultural exports from 2012 to 2019. This process ensures that the data used are valid and up to date, which reinforces the theoretical and empirical foundations of the study. It will also allow the comparison of the hypotheses formulated and the conclusion based on verified and verifiable evidence.

Instrument

The study uses the observation sheet because it allows the information obtained on phytosanitary barriers and Peruvian agricultural exports from 2012 to 2019 to be systematized and recorded in a structured manner. This instrument ensures objectivity and accuracy when comparing data, facilitates statistical analysis, and validates the proposed hypotheses. It also ensures that relevant secondary data are collected coherently and aligned with the research objectives.

RESULTS

Descriptive results

Agroexport

Model 1	R	R square	R tight square	Standard error of the estimate
1	0,968	0,936	0,904	12,729

Figure 1. Coefficient of Determination in Thousands of Metric Tons of Agro-Exports

According to the analysis in figure 1, 93,6 % of the variability in Peruvian agricultural exports (measured in thousands of metric tons) is explained by phytosanitary barriers. This high percentage reflects that the fluctuation in export volume depends to a large extent on the implementation and evolution of phytosanitary regulations in the destination markets.

These barriers include strict controls on pests, diseases, and chemical residues, which directly condition Peruvian products' access to international markets. The significant and strong influence between phytosanitary barriers and the volume exported shows how these regulations can limit or enhance export growth. In countries with high phytosanitary standards, Peruvian producers face greater challenges in complying with requirements, which can restrict the entry of products and negatively affect the volume of exports.

Grapes

Model 1	R	R square	R tight square	Standard error of the estimate
1	0,125	0,016	-0,477	196603,061

Figure 2. Coefficient of Determination in FOB Value of Grape Exports

According to the analysis in figure 2, the variability in the FOB value of Peruvian grape exports is only 1,6 %, explained by phytosanitary barriers, which suggests a very weak influence between these regulations and the export value of this product. This indicates that, unlike other agricultural products, the value of grape exports is not significantly affected by phytosanitary barriers. This low influence could be due to several factors, including adapting Peruvian producers to international phytosanitary standards for grape exports. It is also possible that the destination markets for Peruvian grapes have less restrictive phytosanitary regulations or that the product already has certification and quality control processes that meet export requirements without generating higher costs or variability in FOB value.

Model 1	R	R square	R tight square	Standard error of the estimate
1	0,330	0,109	-0,337	3,548

Figure 3. Coefficient of Determination in Percentage Variations of Grape Exports

According to the analysis in figure 3, the percentage variations in Peruvian grape exports are 10,9 %, explained by phytosanitary barriers, which suggests a relatively low influence between these regulations and fluctuations in the volume exported. This percentage indicates that, although phytosanitary barriers influence grape exports, their impact is limited compared to other factors that could play a more relevant role, such as international demand, market conditions, and competition from other producing countries.

This low level of influence also reflects the high degree of preparedness of the Peruvian grape farming sector, which has adapted to international phytosanitary standards.

Peruvian grape producers and exporters have implemented agricultural practices, quality controls, and certifications that comply with the regulations of importing countries.

This reduces the adverse effects of phytosanitary barriers on exports, as Peruvian grapes are less likely to face access restrictions or be rejected in international markets.

Model 1	R	R square	R tight square	Standard error of the estimate
1	0,816	0,666	0,500	70,989

Figure 4. Coefficient of Determination in Thousands of Metric Tons of Grapes Exported

According to the analysis in figure 4, a more substantial influence is observed, as 66,6 % of the variability in the volume of exported grapes (measured in metric tons) is explained by phytosanitary barriers.

This high percentage suggests that these regulations considerably influence the quantity of grapes exported, which highlights the significant role that phytosanitary regulations play in the access and permanence of Peruvian grapes in international markets.

This influence indicates that phytosanitary barriers can act as a control factor that limits or allows the flow of grape exports depending on compliance with quality, safety, and health standards imposed by destination countries. In markets with more stringent phytosanitary regulations, Peruvian exporters may face greater challenges in complying with specific requirements, which could reduce the volume exported or generate delays and additional costs in the shipping and certification processes.

Compliance with these regulations may require additional inspections, technological adjustments, or the development of specific protocols to ensure the product's safety.

Asparagus

Model 1	R	R square	R tight square	Standard error of the estimate
1	0,046	0,002	-0,497	43413,676

Figure 5. Coefficient of Determination in FOB Value of Asparagus Exports

According to the analysis in figure 5, only 0,2 % of the variability in the FOB value of Peruvian asparagus exports is explained by phytosanitary barriers, which shows an extremely weak relationship between these regulations and the export value of this product. This low percentage suggests that, unlike other agricultural products, the value of asparagus in international markets is influenced by factors other than phytosanitary barriers, which have an almost insignificant impact on its FOB value. This result could be due to the consolidation of the Peruvian asparagus industry as a leader in quality and efficiency in complying with international standards. Asparagus producers and exporters have adopted production, processing, and certification practices that comply with the phytosanitary requirements of the main importing markets, which minimizes the risk of rejection of their shipments. Thanks to this preparation, the additional costs associated with compliance with phytosanitary barriers have been considerably reduced, and trade flow has remained stable without significantly affecting the value exported.

Model 1	R	R square	R tight square	Standard error of the estimate
1	0,029	0,001	-0,499	3,072

Figure 6. Coefficient of Determination in Percentage Variations of Asparagus Exports

According to the analysis in figure 6, this low value indicates that phytosanitary barriers explain only 0,1 % of the percentage variation in Peruvian asparagus exports, which shows a practically insignificant influence between these regulations and the variability in the exported volume of this product. This low influence suggests that trade in asparagus is very little conditioned by phytosanitary barriers compared to other factors. The negligible influence between phytosanitary barriers and asparagus exports could be due to several aspects. Firstly, Peru's asparagus industry has achieved high quality and sanitary standards that meet the requirements of major international markets, such as the United States and the European Union. Producers have implemented rigorous quality controls and certifications that facilitate continuous and unrestricted access to these markets. Thanks to these streamlined processes, exporters can minimize the effects of phytosanitary barriers, resulting in low variability in the volume exported.

Model 1	R	R square	R tight square	Standard error of the estimate
1	0,744	0,554	0,330	4,401

Figure 7. Coefficient of Determination in Thousands of Metric Tons of Exported Asparagus

According to the analysis in figure 7, 55,4 % of the variability in the volume of exported asparagus, measured in metric tons, is explained by phytosanitary barriers, which suggests a moderate relationship between these regulations and the exported quantity of this product.

This percentage indicates that phytosanitary barriers have a significant, although not absolute, impact on the fluctuation of the export volume of Peruvian asparagus, which highlights the importance of these regulations in access to specific international markets.

The moderate relationship between phytosanitary barriers and export volume suggests that, although asparagus exports are affected by sanitary and safety regulations, other factors also play an essential role. Phytosanitary barriers can influence the amount of asparagus reaching markets due to inspection, certification, and phytosanitary treatment requirements that must be met to ensure that products are free of pests, diseases, and chemical residues.

Avocados

Model 1	R	R square	R tight square	Standard error of the estimate
1	0,743	0,552	0,328	69801,493

Figure 8. Coefficient of Determination in FOB Value of Avocado Exports

According to the analysis in figure 8, phytosanitary barriers explain 55,2 % of the variability in the FOB value of Peruvian avocado exports, which indicates a moderate relationship between these regulations and the export value of this product. This level of influence suggests that phytosanitary barriers play a significant role in determining the FOB value of avocados, although other factors also contribute to price fluctuations. The moderate influence between phytosanitary barriers and FOB value may be because international destination markets for avocados, such as the United States, Europe, and Asia, impose safety and sanitation standards that must be rigorously met. Compliance with these phytosanitary requirements, which include pest, disease, and chemical residue standards, can raise production and processing costs, directly affecting export value. Post-harvest treatments, additional inspections, and certifications required to enter these markets can make the export process more expensive, reflected in the final FOB value.

Model 1	R	R square	R tight square	Standard error of the estimate
1	0,623	0,388	0,081	8,834

Figure 9. Coefficient of Determination in Avocado Export Percentage Variations

According to the analysis in figure 9, 38,8 % of the variation in Peruvian avocado exports is explained by phytosanitary barriers, indicating to considerable influence of these regulations on the export flow of this product. This percentage highlights the importance of phytosanitary regulations in determining export fluctuations, suggesting that restrictions and regulations related to product health and safety play a key role in the international avocado trade. Phytosanitary barriers include various measures, such as inspections, certifications, and specific treatments that products must comply with before entering destination markets. In the case of avocados in high demand in markets such as the United States, Europe, and Asia, phytosanitary requirements may imply additional costs in the production and distribution chain, affecting the export volume and the final value of transactions.

Model 1	R	R square	R tight square	Standard error of the estimate
1	0,949	0,900	0,850	19,574

Figure 10. Coefficient of Determination in Thousands of Metric Tons of Exported Avocados

Requests related to pest detection, chemical residues, and other sanitary conditions can lead to temporary or permanent restrictions if not adequately met, directly impacting the percentage of changes in exports. According to the analysis in figure 10, this high value suggests that phytosanitary barriers explain 90 % of the variability in the volume of avocados exported, measured in metric tons, which implies a powerful relationship between these regulations and the export flow of this product. This percentage highlights the decisive influence of phytosanitary rules on the international avocado trade, underlining the importance of complying with the sanitary and safety standards demanded by importing countries. The strong influence of phytosanitary barriers on avocado exports reflects the need for constant vigilance and adequate infrastructure to meet stringent requirements in major markets such as the United States, the European Union, and Asia. Phytosanitary barriers include detailed inspections, sanitary certifications, and specific pest, chemical residue, and crop disease control treatments. These represent a costly and technologically advanced process to ensure that avocados are fit for consumption and meet international standards.

Inferential results

General hypothesis

H0: phytosanitary barriers do not positively influence Peruvian agricultural exports from 2012 to 2019.

Ha: phytosanitary barriers positively influence Peruvian agricultural exports from 2012 to 2019.

Model		Sum of squares	gl	Sig.
1	Regression	4762,708	1	0,032
	Waste	324,042	2	
	Total	5086,750	3	

Figure 11. Significant Analysis in Thousands of Metric Tons of Agro-Exports

According to figure 11, the significance of 0,032 in thousands of metric tons indicates that phytosanitary barriers implemented after the period from 2012 to 2015 would have influenced the total volume of Peruvian agricultural exports between 2016 and 2019. This value is lower than the commonly accepted significance level of 0,05, which leads us to invalidate the null hypothesis (H0) and take the hypothesis stated (Ha). Thus, it is confirmed that phytosanitary barriers positively impacted Peruvian agricultural exports during the interval analyzed. This result suggests that adopting these measures has favored the safety and quality of exported products, which probably increased the confidence of international markets, contributing to export growth and reflecting that phytosanitary barriers, by guaranteeing compliance with international standards on quality and food safety, have managed to increase the competitiveness of Peruvian products in global markets, improving their acceptance in sanitary terms. This has generated a positive perception of Peruvian products, leading to a higher volume of exports.

Specific Hypothesis 1

H0: phytosanitary barriers did not positively influence the agricultural exports of Peruvian grapes from 2012 to 2019.

Ha: phytosanitary barriers positively influence agricultural exports of Peruvian grapes from 2012 to 2019.

Model		Sum of squares	gl	Sig.
1	Regression	1220472914	1	0,875
	Waste	7.731E+10	2	
	Total	7.853E+10	3	

Figure 12. Significant Analysis in FOB Value of Grape Exports

According to figure 12, the significance of 0,875 in the analysis of the FOB value of Peruvian grape exports between 2012 and 2019 suggests that there is no statistically significant relationship between phytosanitary barriers and the value of these exports. Being higher than the accepted significance value of 0,05, this value suggests that the null hypothesis (H0) cannot be invalidated, implying that phytosanitary barriers did not significantly influence the FOB value of grape exports during the period analyzed. This result can be explained by the fact that, although phytosanitary barriers regulate and optimize the safety of agricultural products, their implementation does not always translate into a direct increase in FOB value for specific products, such as grapes, due to factors such as stability in demand in established markets or previous high standards of quality and safety.

Model		Sum of squares	gl	Sig.
1	Regression	3,073	1	0,670
	Waste	25,177	2	
	Total	28,250	3	

Figure 13. Significant Analysis on Percentage Variation of Grape Exports

According to figure 13, the significance value of 0,670 in the analysis of percentage changes in Peruvian grape exports between 2012 and 2019 confirms the absence of a statistically significant relationship between phytosanitary barriers and these changes. Being higher than the commonly accepted level of 0,05, this value supports the null hypothesis (H0) that phytosanitary barriers do not significantly influence fluctuations in grape exports during the period analyzed. This may be because, in established international markets, exports of products such as grapes tend to be subject to relatively constant demand and less affected by changes in additional phytosanitary regulations, as these products already meet high quality and safety standards..

Model		Sum of squares	gl	Sig.
1	Regression	20130,106	1	0,184
	Waste	10078,894	2	
	Total	30209,000	3	

Figure 14. Significant Analysis in Thousands of Metric Tons of Grapes Exported

According to figure 14, the significance value of 0,184 when analyzing thousands of metric tons of exported grapes suggests no statistically significant link between phytosanitary barriers and the quantity exported of this product between 2012 and 2019. Being above the 0,05 level, this value confirms that it does not invalidate the null hypothesis (H0), indicating that phytosanitary barriers do not significantly influence the quantity exported of Peruvian grapes during the period analyzed. Although there might be a marginal influence, it is insufficient to conclude that these barriers decisively affect the volume of grape exports. This could be explained by the fact that international demand for Peruvian grapes, especially in developed markets, depends more on external factors such as consumer preferences, price competitiveness, and seasonality rather than additional phytosanitary regulations. Moreover, Peruvian grapes have achieved a reputation for quality that meets international standards, so phytosanitary barriers tend not to impact their export volume significantly. In summary, the results of the analysis show that there is no statistically significant evidence that phytosanitary barriers have influenced Peruvian grape exports between 2012 and 2019, given that the significance values obtained (FOB Value: 0,875, Percentage Variations: 0,670 and Thousands of Metric Tons: 0,184) are higher than the critical threshold of 0,05, so the alternative hypothesis (H1) is not accepted in the case of grapes. This indicates no significant relationship was found between phytosanitary barriers and Peruvian grape exports in the measured indicators. This lack of impact can be explained by factors such as the stability of demand in established international markets and the ability of Peruvian exporters to adapt to phytosanitary requirements without significantly affecting export volume or value.

Specific Hypothesis 2

H0: phytosanitary barriers do not positively influence agricultural exports of Peruvian asparagus from 2012 to 2019.

Ha: phytosanitary barriers positively influence agricultural exports of Peruvian asparagus from 2012 to 2019.

Model		Sum of squares	gl	Sig.
1	Regression	7862155,299	1	0,954
	Waste	3769494453	2	
	Total	3777356609	3	

Figure 15. Significant Analysis on FOB Value of Asparagus Exports

According to figure 15, the significance value of 0,954 for the analysis of the FOB value of Peruvian asparagus exports suggests that there is no significant relationship between phytosanitary barriers and the export value of this product in the period 2012-2019. Since this value is considerably higher than the 0,05 threshold, the null hypothesis (H0) is not invalidated, indicating that phytosanitary barriers have not significantly impacted the FOB value of Peruvian asparagus exports over this period. This high value could be explained by several factors, mainly because Peruvian asparagus is a highly competitive product in global markets, especially in the United States and Europe, due to its quality, taste, and year-round supply. The demand for asparagus could be more influenced by global supply and demand, trade agreements, and climatic conditions than by phytosanitary barriers.

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Model		Sum of squares	gl	Sig.
1	Regression	0,016	1	0,971
	Waste	18,872	2	
	Total	18,888	3	

Figure 16. Significant Analysis on Percentage Variation of Asparagus Exports

According to figure 16, the significance value of 0,971 for the percentage changes in asparagus exports reinforces the conclusion that phytosanitary barriers do not have a relevant effect on the fluctuations of Peruvian asparagus exports between 2012 and 2019. Since this result is significantly higher than 0,05, it does not invalidate the null hypothesis (H0), indicating that variations in asparagus exports are not significantly correlated with implementing phytosanitary barriers. This result could be explained by the fact that asparagus is among the most essential non-traditional agricultural products exported by Peru, and global demand for asparagus is mainly driven by factors such as preferential trade agreements, consistent quality, and continuous availability of the product rather than by phytosanitary barriers. In addition, advances in agricultural technology and implementing practices that meet international standards may have minimized the effect of the phytosanitary obstacles on export stability.

According to figure 17, the significance value of 0,256 for the thousands of metric tons of asparagus exported also indicates that phytosanitary barriers do not statistically affect the volume of Peruvian asparagus exports. Although the value is less than 0,05, which could suggest a possible relationship, it is not low enough to invalidate the null hypothesis (H0).

Model		Sum of squares	gl	Sig.
1	Regression	48,017	1	0,256
	Waste	38,733	2	
	Total	86,750	3	

Figure 17. Significant Analysis in Thousands of Metric Tons of Asparagus Exported

This result could be due to several factors, such as the consolidation of asparagus as one of the most essential Peruvian export products. In addition, Peruvian companies may have optimized their processes to comply with international phytosanitary standards, thus minimizing the adverse effects of regulations.

Factors such as global supply and demand, the competitiveness of Peruvian products, and the diversification of export markets play a more relevant role in the volume of exports than phytosanitary barriers.

In summary, the significance values obtained in the analysis of Peruvian asparagus exports between 2012 and 2019 (FOB Value: 0,954, Percentage Variations: 0,971 and Thousands of Metric Tons: 0,256) are greater than 0,05, which indicates that there is no statistically significant link between phytosanitary barriers and Peruvian asparagus exports in terms of volume or value. For this reason, the hypothesis (Ha) is invalid, suggesting that phytosanitary barriers have not had a relevant effect on the behavior of asparagus exports in the indicators evaluated.

This lack of influence may be due to the fact that Peruvian asparagus already complied with high international quality and safety standards before implementing the barriers, which facilitated compliance with the new regulations without significantly affecting export levels. In addition, factors such as the consolidation of asparagus as one of Peru's leading agricultural export products, competitive performance in global markets, and stability in worldwide supply and demand may also have minimized the impact of the phytosanitary barriers.

Specific Hypothesis 3

H0: phytosanitary barriers do not positively influence Peruvian avocado agricultural exports from 2012 to 2019.

Ha: phytosanitary barriers positively influence agricultural exports of Peruvian avocados from 2012 to 2019.

Model		Sum of squares	gl	Sig.
1	Regression	1.202E+10	1	0,257
	Waste	9744496770	2	
	Total	2.177E+10	3	

Figure 18. Significant Analysis in FOB Value of Avocado Exports

According to figure 18, the significance value of 0,257, being higher than the threshold of 0,05, indicates that no significant linkage can be established according to the statistical analysis between phytosanitary barriers and the FOB value of Peruvian avocado exports between 2012 and 2019. This suggests that the null hypothesis (H0) is not invalidated, i.e., phytosanitary barriers did not have a direct and relevant impact on the value of avocado exports in this period. The growth of avocado exports may have been influenced by other factors, such as the growing international demand for this product, Peru's ability to compete in global markets, and trade agreements that have facilitated access to key markets. In addition, implementing phytosanitary measures may have been effectively adopted by Peruvian producers, allowing exports to continue without being significantly affected by these regulations.

According to figure 19, the significance value of 0,377, being higher than the threshold of 0,05, reinforces the conclusion that the null hypothesis (H0) is not invalidated, i.e., phytosanitary barriers do not have a significant influence on the percentage variations of Peruvian avocado exports between 2012 and 2019. This suggests that fluctuations in avocado exports are not directly or significantly related to the phytosanitary measures implemented in that period.

Model		Sum of squares	gl	Sig.
1	Regression	98,804	1	0,377
	Waste	156,096	2	
	Total	254,900	3	

Figure 19. Significant Analysis of Avocado Exports Percentage Variations

Variations in exports could be more linked to external factors such as global demand for avocados, supply from other producing countries, changes in international prices, or even favorable trade policies such as trade agreements and preferential access to key markets. It could also be that Peruvian producers have adapted their agricultural and export practices to comply with phytosanitary regulations without significantly affecting export performance in percentage terms.

Model		Sum of squares	gl	Sig.
1	Regression	6881,695	1	0,049
	Waste	766,305	2	
	Total	7648,000	3	

Figure 20. Significant Analysis in Thousands of Metric Tons of Avocados Exported

According to figure 20, the significance value of 0,049, although just below the 0,05 threshold, suggests evidence of a marginally significant relationship between phytosanitary barriers and the volume of avocados exported in metric tons from 2012 to 2019. This result implies that the null hypothesis (H0) is partially discarded, suggesting that phytosanitary barriers could have some

influence on the quantities of avocados exported. However, the link is not strong enough to be considered conclusive. This possible influence could be related to compliance with norms established in international markets that demand specific quality and food safety standards. In this case, Peruvian avocado exporters may have had to adjust their production processes, pesticide residue control, and other phytosanitary aspects to access and remain competitive in strict markets, which could affect export volumes. However, the low significance implies that other factors, such as external demand, trade agreements, or the expansion of production capacity, played a more decisive role in the behavior of avocado exports during this period.

In summary, the significance values for the FOB Value (0,257) and the Percentage Variations (0,377) of Peruvian avocado exports between 2012 and 2019 are greater than 0,05, which shows that the null hypothesis (H0) cannot be rejected and that in these aspects, phytosanitary barriers do not seem to have a significant impact on the value and variations of avocado exports. However, the significance value of 0,049 in metric tons is less than 0,05 in export volume, suggesting a statistically significant influence of phytosanitary barriers on the quantity of avocados exported. The significance value in thousands of metric tons (0,049) is less than or equal to 0,05, while the other values (0,257 and 0,377) are higher. This implies that the hypothesis (Ha) is partially approved only in the metric ton indicator, suggesting that phytosanitary barriers positively and significantly influence this specific aspect of avocado exports. This result could indicate that, although phytosanitary obstacles do not affect monetary value and percentage fluctuations, they have influenced the physical volume exported, possibly due to a successful adaptation of producers to international phytosanitary regulations. In this sense, phytosanitary barriers could have increased competitiveness and confidence in the global market towards Peruvian avocado, contributing to increased export volume.

DISCUSSION

This research aims to analyze the influence of phytosanitary barriers on Peruvian agricultural exports, revealing a complex panorama where the demands of the international market converge with the internal limitations of the agro-export sector. As a result, 93,6 % of the variation in Peruvian agricultural exports, expressed in thousands of metric tons, is attributed to phytosanitary barriers. This high percentage is evidence that applying and developing phytosanitary regulations in the destination markets significantly influences changes in the volume exported. The null hypothesis (H0) was rejected since the significance value obtained (0,032) is below the threshold of 0,05, which allows the alternative hypothesis (Ha) to be accepted. This confirms that phytosanitary barriers positively impacted Peruvian agricultural exports during the analyzed interval. This result contrasts with previous studies such as those of Solórzano-Acosta et al.[6], who argue that agro-exports have been a key driver of Peru's economic development but face significant challenges related to phytosanitary practices. International requirements demand high quality and safety standards, which has prompted the search for sustainable methods such as biological control using entomopathogenic and antagonistic microorganisms. In agreement with the findings of Solórzano-Acosta et al.[6], this analysis highlights that, although there are advances in the identification of microorganisms with phytosanitary potential, such as Beauveria bassiana, Metarhizium anisopliae and native Trichoderma, their adoption at a commercial level is still not massive. This scenario is due to barriers such as poor technology transfer, lack of incentives for innovation in the agricultural sector, and limited capacity to meet international standards through biological alternatives. Regarding target organisms, Peruvian studies' primary focus has been controlling insects (51,4 %) and phytopathogenic fungi (24,3 %). However, this research has concentrated on basic studies and has not resulted in widely available practical tools. This limits the capacity of the agro-export sector to implement sustainable solutions and to comply with phytosanitary barriers imposed by international markets, which often imply additional costs due to the rejection of non-compliant products. On the other hand, Lederman et al.[17] highlighted the importance of quality and the production process in exports. Based on the above, it can be confirmed that the success of Peruvian exports depends not only on the quantity or compliance with external regulations but also on the sector's capacity to innovate in its production processes and adapt to global demands. In this sense, industrialization policies to strengthen technology transfer, applied research, and sustainability can bridge phytosanitary barriers, improve competitiveness, and optimize the country's trade balance.

On the other hand, the first specific objective seeks to analyze how phytosanitary barriers influence agricultural exports of Peruvian grapes. The results indicated that only 1,6 % of the variation in the FOB value of Peruvian grape exports is due to phytosanitary barriers, which reflects a minimal influence of these regulations on the exported value of this product. This suggests that, unlike other agricultural products, phytosanitary barriers do not significantly impact the value of grape exports. The null hypothesis (H0) was confirmed, as the significance values (0,875, 0,670, and 0,184) exceeded 0,05, indicating that barriers do not significantly influence exports. This result contrasts with previous studies such as those of Boza et al.[8], where they analyze rejections of Chilean fruit exports due to non-compliance with phytosanitary regulations, highlighting that regulatory controls can directly impact trade flows and the reputation of an exporting country. It was observed that rejections represented only 0,046 % of the total value of exports, equivalent to approximately US$9,45 million. Although rejections were low, their leading cause was the excessive use of pesticides, highlighting how inadequate management of phytosanitary barriers can lead to economic losses and market access risks. Similarly, Kapur[11] examines the impact of phytosanitary regulations on agri-food trade between India and the United States, showing that regulatory differences and lack of harmonization hinder bilateral trade. Despite the above, there was an increase in US agricultural exports to India, rising from USD 971,33 million in 2013 to USD 2,34 billion in 2022, with an average annual growth of 9,2 %. According to Lederman et al.[17], exports are an indicator of a country's productive potential and a reflection of its ability to meet international standards. They also argue that the key to export success lies not in the quantity exported but in the quality of production processes, which are influenced by appropriate industrial and trade policies. Finally, the influence of these regulations implies questioning not only their immediate economic impact, such as rejection costs but also their long-term effect on the sustainability of the agro-export sector. Improving compliance infrastructure, such as laboratories and monitoring systems, could

be a key strategy to overcome these barriers and position Peru as a competitive leader in international markets.

The specific objective 2 of this study is to analyze how phytosanitary barriers influenced Peruvian asparagus exports between 2012 and 2019. The results indicated that phytosanitary barriers have a limited influence on the FOB value (0,02 %) and percentage variation (0,1 %) of exports. Still, they show a moderate relationship with the volume exported (55,4 %), highlighting their importance in product quality and safety. The null hypothesis (H0) was confirmed, as the significance values (0,954, 0,971, and 0,256) exceeded 0,05, indicating that barriers do not significantly influence exports. This result contrasts with previous studies such as Liu et al.[9], who found that phytosanitary barriers negatively affect quality and increase transaction costs, with quality improvements of only 0,031 in non-diversified and 0,011 in diversified firms in Chinese exports to the United States. Zúñiga[15] also notes that properly implementing phytosanitary measures could improve Peru's competitiveness. However, in the case of Peruvian asparagus, despite phytosanitary barriers, the high quality of the product and its compliance with international standards have allowed for stability in exports, minimizing the impact of the measures. Krugman et al.[19] stress that product competitiveness and production efficiency are key factors in international trade. In this sense, the results indicate that these factors have a greater impact than phytosanitary regulations on Peruvian asparagus exports. Phytosanitary barriers have a moderate influence on the volume exported. Still, their effect on FOB value and percentage variation is minimal, highlighting the importance of competitiveness and product quality in export decisions. In this sense, under those mentioned above and when analyzing the results, it is essential to recognize that although phytosanitary barriers are relevant for the quality and safety of agricultural products, the results of this analysis indicate that Peruvian asparagus producers have managed to adapt efficiently to these regulations.

Specific objective 3 of this study is to analyze how phytosanitary barriers influence Peruvian avocado agricultural exports between 2012 and 2019. The results reveal that phytosanitary obstacles do not have a significant impact on the FOB value (0,257) nor the percentage changes (0,377) of exports, although they do marginally influence the volume exported (0,049). With these results, the null hypothesis (H0), which holds that phytosanitary barriers do not positively influence exports, is partially rejected. While there is no statistical significance in FOB value and percentage changes, there is marginal significance in volume exported, indicating a limited but present impact of phytosanitary barriers on this aspect. These findings are consistent with Liu et al.[9], who identified that heterogeneous sanitary and phytosanitary (SPS) measures have varied impacts on the quality of Chinese agricultural exports, with differences in diversified (0,011) versus non-diversified (0,031) firms. They also partially align with Lima[12], who found that non-tariff barriers in Brazil marginally affect oats trade, reflected in a 14,06 % tariff equivalent. Mankiw[20] explains comparative advantage that although phytosanitary barriers generate additional costs, exporters can adapt to them to maintain competitiveness in international markets. In this context, based on the above and by examining the results, it is reflected that although phytosanitary barriers affect the competitiveness of exports, Peruvian companies have managed to adapt to international requirements, which contributes to the improvement of the quality of exported products without a significant affectation of the total value of exports.

CONCLUSIONS

The analysis concludes that 93,6 % of the variation in Peruvian agricultural exports, expressed in thousands of metric tons, is due to phytosanitary barriers. Although seen as obstacles, these regulations have a positive impact by encouraging improvements in product quality, compliance with international standards, and access to competitive markets. They also strengthen the sustainability of the agricultural sector by encouraging innovation in production processes and the adoption of biological control methods. This improves competitiveness and positions Peru as a reliable exporter in the global market.

The analysis concludes that phytosanitary barriers only explain 1,6 % of the variation in the FOB value of Peruvian grape exports, reflecting a minimal influence compared to other agricultural products. This is because grapes are better adapted to international standards and have robust production processes, facing fewer regulatory restrictions. The findings underline the importance of strengthening quality and sustainability practices in other crops, promoting technology transfer and compliance with international standards. Furthermore, the low incidence represents an opportunity to diversify markets and increase the global competitiveness of the product.

It is concluded that phytosanitary barriers had a limited influence on agricultural exports of Peruvian asparagus between 2012 and 2019. They had a minimal impact on FOB value (0,02 %) and percentage variation (0,1 %), but a moderate influence on the volume exported (55,4 %), highlighting their relevance in guaranteeing the quality and safety of the product. This result highlights that high quality and producers' compliance with international standards were key factors in maintaining export stability and minimizing the impact of regulations.

Finally, phytosanitary barriers have a limited influence on agricultural exports of Peruvian avocados between 2012 and 2019, with a marginal impact on the volume exported (0,049) but no significant effect on FOB value (0,257) and percentage changes (0,377). The most relevant part of achieving the objective was identifying that phytosanitary barriers explain a considerable proportion of the variability in the volume exported (90 %), highlighting their importance for compliance with international standards.

RECOMMENDATIONS

To improve the impact of phytosanitary barriers on Peruvian agricultural exports, it is recommended that products from the departments of Ica, La Libertad, and Lima implement policies that strengthen technology transfer, promote innovation, and improve the infrastructure for phytosanitary compliance, such as laboratories and monitoring systems. These actions should be led by government institutions in collaboration with the private sector and carried out in the central agro-exporting regions of Peru. Their implementation should begin in the short term to guarantee adaptation to international requirements. These measures are necessary because they enable compliance with global standards, reduce product rejections, and increase the country's competitiveness. The

primary beneficiaries will be agricultural producers, exporters, and the national economy by optimizing access to international markets and strengthening the trade balance.

To address the influence of phytosanitary barriers on agricultural exports of Peruvian grapes, it is recommended that Peruvian grape producers in the departments of Ica and Lima implement a comprehensive system to improve phytosanitary management, including producer training, investment in monitoring and control infrastructure, and promotion of sustainable practices. These actions should be led by the government in collaboration with farmers' and exporters' associations, focusing on the central producing regions of the country. It is crucial to initiate these measures in the short term to ensure compliance with international standards, reduce rejection risks, and enhance competitiveness. This will primarily benefit producers, exporters, and the country by strengthening its position in global markets and fostering sustainable agricultural development.

It is recommended that Peruvian asparagus producers in the departments of Ica and Lima strengthen the continuous training of Peruvian producers on best practices for compliance with international phytosanitary regulations to optimize product quality and safety further. This training should be led by the Ministry of Agriculture in collaboration with producer and exporter associations regularly, at least once a year. This action should be taken because, although phytosanitary barriers have not shown a significant impact on the FOB value and percentage change of exports, continuous training of producers would strengthen the agricultural sector's competitiveness and contribute to reducing any potential future impact of phytosanitary barriers. In addition, improving the management of phytosanitary measures will enable producers to ensure consistent quality that meets the expectations of international markets. This strategy will benefit both asparagus producers and exporters, improving their positioning in global markets and ensuring the sustainability of Peruvian exports.

It is recommended that Peruvian avocado producers in Lima and La Libertad departments implement a program to strengthen and adapt phytosanitary practices in Peruvian avocado producers to improve compliance with international regulations and optimize production processes. This program should be promoted by the Ministry of Agriculture in collaboration with producers' and exporters' associations, with a continuous approach and with training sessions held annually. This program must be implemented, as phytosanitary barriers, although with a marginal impact on the volume exported, remain essential in ensuring the competitiveness and quality of exports. Training should cover both cultivation techniques and best practices to meet the phytosanitary standards of the main international markets. This effort will benefit producers, who can maintain their competitiveness, reduce risks, and improve their positioning in global markets, ensuring the sustainability of Peruvian avocado exports.

FINANCING

None.

CONFLICT OF INTEREST

None.

AUTHORSHIP CONTRIBUTION

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