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Enhancing International Trade Security: Real-Time Risk Assessment in Brazilian Customs with Blockchain Technology

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Abstract

This study introduces an innovative approach by integrating blockchain technology with risk analysis methods for international trade. The practical application and tangible improvements observed in a real case study highlight the originality and value of this approach, offering a robust framework for future research and practical implementation. The security of exports presents a challenge for customs authorities, requiring the analysis of vast volumes of data from diverse sources and stakeholders. Blockchain technology offers a viable solution by facilitating the sharing of reliable and secure data among participants in the international supply chain. This study proposes a distributed risk analysis method based on Blockchain to detect and prevent fraud and irregularities in Brazilian exports. The technique aims to enhance efficiency and protection in customs clearance, providing real-time risk analysis feedback at various supply chain stages. The method includes four stages: data collection, risk classification, validation, and feedback. It employs a Model Form for Insertion into the Blockchain, the DBSCAN algorithm to identify out-of-pattern transactions (outliers) at the manufacturing stage, and a Monte Carlo simulation to analyze the volume and specific products exported from Rio Grande do Sul. We applied this method in a case study of beef exports from Brazil. Using this method led to significant improvements in processing times, operational costs, transparency, and security in the supply chain. The blockchain-based approach identified fraudulent activities, such as value tampering and undeclared goods, enhancing compliance and trust among trade partners. Implementing this method can significantly reduce operational costs and processing times in international trade while increasing security and transparency. This approach benefits customs authorities and private operators, promoting a more reliable and efficient commercial environment. Adopting blockchain technology in international trade can reduce fraudulent and illicit practices, promoting greater fairness and equity in commercial transactions. Increased transparency strengthens trust among various actors in the supply chain, fostering a sense of social responsibility.

Keywords: blockchain, export, security, customs, risk analysis

1. Introduction

The Fourth Industrial Revolution, spotlighted at the 2016 World Economic Forum, has underscored the profound impact of technologies such as Artificial Intelligence (AI), blockchain, and big data across the globe. To remain competitive in an increasingly demanding, connected, and dynamic global market, businesses and professionals must embrace these disruptive technologies. As automation and AI take over repetitive and predictable tasks, the human workforce must evolve, fostering creativity, complex problem-solving abilities, emotional intelligence, and critical thinking as core competencies. In this context, adaptability becomes a crucial competitive edge. Leveraging technology goes beyond merely enhancing production and operational efficiency; it involves seizing new business opportunities and innovative service models that emerge at the intersection of various technological domains. Preparing for this new era demands technical proficiency and strategic foresight, requiring a mindset geared towards continuous learning, reinvention, experimentation, and interdisciplinary collaboration on a global scale.

International trade, a cornerstone of the global economy, generated over 25 trillion dollars in 2023, providing employment and income for millions. However, exporting and importing goods presents numerous challenges and risks for private operators and public authorities. These risks include fraud, irregularities, sanitary and environmental regulations violations, smuggling, terrorism, and organized crime. Such factors compromise the security, efficiency, and competitiveness of international trade, underscoring the urgent need for coordinated and integrated actions among various stakeholders in the supply chain.

Customs agencies play a pivotal role in the international trade landscape, controlling and supervising the entry and exit of goods in countries (Howse & Trebilcock, 2005). They ensure compliance with national and international laws and regulations, collect taxes, and prevent and suppress illicit activities (Tacconi & Brack, 2003). To fulfill these responsibilities, customs officials analyze vast volumes of data from diverse sources, including documents, declarations, computerized systems, physical inspections, scanner images, and cameras. Additionally, customs agencies communicate and cooperate with other public bodies, such as regulatory agencies, police forces, intelligence services, and private operators, including exporters, importers, carriers, customs agents, and banks.

Efficiency and innovation hold paramount importance in the contemporary landscape of customs operations. Stakeholders dealing with a vast array of information and numerous participants require robust support to manage their activities effectively (Huria, 2019). The rapid and secure data processing and analysis are crucial for surveillance, tax collection, and combating illegal activities. Within this framework, blockchain technology emerges as a transformative tool, significantly enhancing the efficiency and security of international trade. It facilitates the exchange of reliable and secure data among supply chain participants, creating distributed, verifiable, and immutable records that multiple authorized parties can update and access without needing a central intermediary.

Blockchain technology's role in enhancing efficiency provides a promising outlook for the future of customs operations. It facilitates the tracking and transparency of trade operations, reduces costs and processing times, increases security and trust among agents, and introduces new methods for payments and financing. Additionally, blockchain aids in export risk analysis by identifying and preventing potential fraud and irregularities, such as value manipulation and undeclared products. In the corporate context, technology plays a crucial role in financial procedures and contract management, which have evolved into the "smart contract" model, as described by Lima, Hitomi, and Oliveira (2018, p. 6). These contracts, known for their efficiency, are part of a broader distributed ledger system, with transparency and immutability ensured by blockchain technology. Calixto (2019) highlights that blockchain extends further, possessing the capability to securely share and transfer digital assets, thereby eliminating risks of duplication or fraud in transactions. This efficient 'smart contract' model instills confidence in the future of financial procedures and contract management.

This article proposes a distributed risk analysis method for customs based on blockchain, aiming to detect and prevent export fraud and irregularities. The method involves four stages: data collection, risk classification, data validation, and feedback. Data collection entails recording relevant information about export operations on the blockchain through smart contracts, which are self-executing codes defining the transactions' rules and conditions. Risk classification uses machine learning algorithms to assign risk levels to operations based on pre-established criteria, such as the operators' history, the origin and destination of products, and the value and weight of the goods, among others. Data validation involves verifying the authenticity and consistency of the data recorded on the blockchain through consensus mechanisms and protocols, ensuring all network participants have the same data version. Feedback provides information on the risk analysis outcome to involved parties, such as customs, exporters, and importers, allowing for appropriate decision-making and actions.

The proposed method was applied to a case of beef exports from Brazil, demonstrating its potential effectiveness and benefits. Beef is a high-value product with significant commercial interest but is also subject to sanitary and phytosanitary risks, which can affect public health and the environment (Abdis et al., 2023). Applying the method to Brazilian beef exports illustrates how technology can adapt to meet specific sector challenges. Additionally, the method presented in this article can be adapted and applied to other products and trade routes, improving efficiency and protection in international trade. The potential of blockchain can also be used for other products and across various products simultaneously, thereby highlighting its capacity to significantly optimize global supply chains and strengthen international trade relations.

This article contributes to the field of customs risk assessment by introducing a novel methodology that integrates advanced clustering algorithms with blockchain technology, specifically tailored for the complex landscape of international trade. By leveraging the DBSCAN algorithm, this approach effectively identifies outlier transactions within customs data, addressing the critical need for robust anomaly detection in trade operations. The methodology's application to Brazilian beef exports exemplifies its practicality. It demonstrates how it can enhance decision-making processes by providing a data-driven risk score incorporating historical export behaviors and market dynamics. This integration strengthens the transparency and traceability of transactions through blockchain and offers a scalable solution adaptable to various commodities and trade environments. Theoretical foundations support this method through established principles of risk assessment, utilizing statistical measures such as deviation from the mean and standard deviation, which are widely recognized in finance and supply chain management. This approach empowers customs authorities to manage and mitigate risks proactively, ensuring compliance and safeguarding economic interests. By bridging the gap between theoretical models and real-world applications, this study provides a comprehensive framework that advances the efficacy and reliability of customs risk management systems.

Additionally, this article presents a method for integrating customs information into blockchain systems through a simplified pseudocode approach. By detailing a structured model for data insertion, the paper provides a practical framework that enhances the transparency and security of customs transactions. The pseudocode outlines a step-by-step process for encoding critical shipment details—such as order identification, manufacturer location, product specifications, and shipping terms—into blockchain entries. Using blockchain's immutable ledger, the proposed system protects data integrity and streamlines the risk assessment by enabling efficient tracking and analysis of goods throughout the supply chain. This innovative approach bridges the gap between theoretical blockchain applications and practical implementation in customs operations, offering a robust solution to modernize and fortify international trade practices.

Moreover, applying this method to Brazilian beef exports demonstrates its practical utility and adaptability to sector-specific challenges. The study highlights the potential of blockchain technology to optimize global supply chains and strengthen international trade relations, offering a robust solution to modernize and fortify trade practices. By integrating theoretical and practical insights, this research provides a comprehensive framework that advances the efficacy and reliability of customs risk management systems, positioning customs administrations at the forefront of innovation in the digital era.

This article, comprising eight sections, addresses various aspects of customs risk analysis using blockchain technology. In "Blockchain Technology," section two, we explore the characteristics and advantages of blockchain, emphasizing its applicability in managing customs risks. The "Proposed Method for Customs Risk Assessment" section details the developed methodology, including data collection, risk classification, data validation, and feedback. Following this, the "Manufacturer Risk Assessment" and "Logistics Agent Risk Assessment," sections 4 and 5, present specific case studies to illustrate the practical application of the method. The "Classification and Integration with Blockchain," section six, discusses the methodology implementation within the blockchain environment, highlighting the security and efficiency benefits. Finally, the "Final Considerations" section synthesizes the study's main conclusions. It suggests future directions for research and practical applications, instilling confidence in the proposed methodology's potential.

2. Blockchain Technology

One potential application of Blockchain technology is in managing customs risks, aiming to ensure the security and compliance of foreign trade operations. Customs risks can range from non-compliance with tax, tariff, and sanitary regulations to practices like smuggling, counterfeiting, and terrorism (Nikoofal et al., 2023). Customs risk analysis involves identifying and assessing potential import and export operations risks and defining appropriate control and inspection measures to mitigate them.

According to Haque et al. (2024), blockchain technology is a decentralized database that operates without a central authority or third-party verification. It consists of a series of interconnected blocks containing a hash of the previous one, forming a continuous chain from the initial or "genesis" block to the most recent one. Blockchain technology monitors, controls, and secures Internet of Things (IoT) devices, using decentralization and encryption for protection. Blockchain transactions do not require intermediaries, making them trustworthy, and the technology offers features like decentralization, immutability, and transparency, which provide significant benefits in terms of increased security and data protection.

Blockchain also serves as a verification system that, among other things, records the sale/purchase (ownership) of cryptocurrencies like Bitcoin, Ethereum, and Ripple. For this reason, distributed ledgers in the form of Blockchain promise to be a transformative technology that will revolutionize the business world as we know it. This technology allows for cryptocurrency ownership records and running different types of applications, platforms, information storage, and distribution systems (Haile, 2024). At the governmental level, Blockchain can monitor and control specific tasks, such as voting systems, tax collection, passport issuance, real estate registration, delivery of grants, and other benefits (Santos, 2023). Blockchain is a distributed network of multiple computers in different locations. They can exchange, receive, and store value or information with each other. Each transaction is shared across the entire network and is recorded in a "block" when the whole network confirms that the transaction (information) is valid, using the transactions (past information) from previous blocks.

Permissioned Blockchain is a technology where only authorized agents can participate. According to Rizzardi et al. (2022), permissioned Blockchain is the technology that allows only authorized agents to join, creating a network environment where an entity or consortium strictly controls access and permissions. The restrictive nature of permissioned Blockchains brings privacy and operational efficiency benefits, making them particularly interesting for business and governmental organizations that require high levels of security and control over their transactions and data. The public Blockchain operates as a decentralized network comprising Blockchain storage entities. Each of these entities has a comprehensive replica of the entire system. This approach ensures the system's resilience if many network nodes become inaccessible and data is lost. The entire system can be reconstructed using a single node that maintains a complete copy of the Blockchain (Haque et al., 2024).

Blockchain technology-based networks generally fall into two main types: private (permissioned) and public (non-permissioned). However, beyond these two types, there is also a third type, called hybrid or consortium blockchain, which mixes features of both private and public blockchains. In this variant, access is controlled, and the network's distributed access is restricted to a limited number of participants. It is also worth noting that the governance of a consortium blockchain is shared among the founding members, allowing for a more democratic and efficient network management. This contrasts with public blockchains, where governance is decentralized, and with private blockchains, where governance is centralized in the entity operating the network.

Blockchain technology offers an innovative approach to managing customs risks, providing a secure, transparent, decentralized platform for monitoring and controlling foreign trade operations. Blockchain operates without intermediaries and, combined with its features of immutability and distributed verification, ensures greater security and reliability in transactions. Additionally, the distinction between permission and public blockchains and introducing hybrid or consortium blockchains allows for application flexibility. This flexibility can meet the security and privacy needs of business and governmental organizations while also addressing the resilience and transparency required by decentralized networks.

3. Enhancing Customs Risk Management through Blockchain Integration

Customs risk assessment, a critical element in safeguarding the integrity of international trade operations, is on the brink of a transformation. Traditionally, customs risk assessment methods rely on statistical analyses and predictive models that utilize historical data to identify risk patterns, Berk e Bleich (2013). While effective in certain aspects, these methods face significant challenges, such as managing large volumes of real-time data and integrating information from multiple sources. However, the future holds promise with the potential of more transparent and efficient customs risk assessment techniques, Okazaki, (2017). These techniques could not only overcome the current challenges but also foster trust and collaboration between trade partners and customs authorities.

Recent literature underscores the transformative potential of emerging technologies like blockchain in customs risk assessment. Gao et al. (2018) highlight blockchain's ability to address the challenges of traditional methods by providing a decentralized and secure platform for information sharing. Blockchain technology enables the creation of immutable and auditable records accessible in real time by all stakeholders. This plays a crucial role in enhancing transparency and trust, thereby reassuring the audience about the benefits of blockchain in customs risk assessment. It also facilitates the early detection of risks such as fraud and discrepancies in customs documentation. Therefore, applying blockchain in customs risk assessment represents not merely a technological innovation but a necessary evolution to tackle the challenges of modern global trade.

In the Results section, summarize the collected data and the analysis performed on those data relevant to the discourse that is to follow. Report the data in sufficient detail to justify your conclusions. Mention all applicable results, including those that run counter to expectation; be sure to include small effect sizes (or statistically nonsignificant findings) when theory predicts large (or statistically significant) ones. Do not hide uncomfortable results by omission. Do not include individual scores or raw data, except for single-case designs or illustrative examples. In the spirit of data sharing (encouraged by APA and other professional associations and sometimes required by funding agencies), raw data, including study characteristics and individual effect sizes used in a meta-analysis, can be available on supplemental online archives.

Customs risk, a term encompassing potential threats and vulnerabilities in international trade and customs processes, has far-reaching implications. These risks, including illicit practices and procedural deviations, can compromise the integrity of cross-border commercial operations, posing threats to national security, public health, and economic stability. For instance, manipulating goods' value in customs documents, a common strategy to evade taxes, generates significant government revenue losses. Similarly, the smuggling of prohibited goods without declaration poses imminent risks to national security, public health, and the economy, given their ability to illegally cross borders (Juma et al., 2019).

Customs administrations are essential to reducing the risk associated with customs, Karklina-Admine et al. (2024). However, the effectiveness of international trade is harmed by obstacles they must overcome, such as documented fraud and non-compliance with customs regulations, which can lead to fines, delays in customs clearance, and supply chain disruptions. Import or export of goods that pose security risks, such as weapons or hazardous materials, also constitute significant dangers to public safety and national protection. In response, customs administrations implement risk assessment methods and advanced technologies to detect and mitigate such risks, ensuring compliance with trade regulations, protecting national interests, and facilitating legitimate trade activities.

The proposed method's customs risk assessment consists of two main steps: transaction representation and subsequent classification. This process is executed simultaneously in two different phases of the supply chain: first, in the goods' manufacturing phase and then in the transportation phase.

The procedure is initially activated in the production phase, at which point the risk assessment process begins immediately after the importer uploads the order details into the Blockchain system. The uploaded information includes, but is not limited to, the manufacturer's location, invoice details, and the product's country of origin. This step primarily aims to identify potential risks of value manipulation, such as under- or over-invoicing, through careful analysis of the submitted transactions, which will be discussed in the next section.

Table 1. Model Form for Insertion into the Blockchain (Phase 1)

Information Field	Detailed Description
Order ID	A unique identifier for each order, facilitating traceability and cross-referencing.
Order Date	The date the order was placed, including day, month, and year.
Manufacturer Location	The complete address of the manufacturing location, including city, country, and, if applicable, industrial zone.
Invoice Details	Invoice number, date, detailed description of items, quantities, and unit prices.
Country of Origin	The country where the products were manufactured or produced.
Product Description	A complete description of the products, including categories, technical specifications, and HS codes.
Declared Value	The total declared value of the products, as stated on the invoice.
Shipping Terms	Shipping conditions, including, for example, FOB, CIF, and carrier information.
Estimated Date of Arrival	The expected date for the products to arrive at the final destination.
Associated Documentation	References to associated documents, such as certificates of origin, export/import licenses.

Source. Own Elaboration.

Once completed, this model form (Table 1) would be encoded in JSON (JavaScript et al.), for example, and inserted into the Blockchain chosen by customs as a transaction. Each field in Table 1 serves as a crucial piece of information that contributes to the transparency, security, and efficiency of the import/export process, allowing all stakeholders to verify the authenticity and compliance of the information without compromising data confidentiality.

Moving forward in the supply chain, the second phase is the transportation phase of the goods, where the transport agent begins their risk assessment as soon as the relevant information becomes available on the Blockchain. It is important to note that Blockchain technology can significantly benefit the supply chain in various ways: Enhanced transparency, improved traceability, efficiency, intelligent contracts, security, cost reduction, and real-time tracking (Casado-Vara et al., 2018). According to the authors, Blockchain technology can potentially revolutionize the supply chain industry by improving transparency, traceability, security, efficiency, and cost-effectiveness (Deshpande, 2012).

According to Dujak and Sajter (2019), Blockchain technology promises to overcome trust issues by enabling a trustless, secure, and authenticated system for exchanging logistics and supply chain information in supply networks. New implementations in the supply chain are evolving from Blockchain to a broader notion of distributed ledger technologies. Blockchain introduces an innovative trust mechanism based on advanced cryptographic technology and a decentralized network, eliminating the need for trust in intermediaries. This revolutionary feature of Blockchain radically transforms relationships within the supply chain, which significantly depend on mutual trust between partners. Furthermore, the blockchain network facilitates the secure and transparent sharing of information among all supply chain partners, enhancing relationship improvement and operational efficiency (Wang et al., 2020).

The second phase uses data such as the shipping route and specific details of the commercial transaction to identify risks associated with undeclared goods. Table 2 presents a model for inserting information related to the supply chain part into the Blockchain.

Table 2. Model Form for Insertion into the Blockchain (Phase 2)

Information Field	Detailed Description
Transportation ID	A unique identifier for the transportation operation, facilitating traceability and cross-referencing.
Order ID	A unique identifier is associated with the original order, linking the transportation operation to the specific order.
Start Date of Transportation	The date when the transportation of the goods begins is formatted as YYYY-MM-DD.
Transportation Agent	Information about the logistics company responsible for the transportation, including name, contact, and address.
Shipping Route	Details about the origin and destination of the goods, including cities, countries, and specific ports or airports.
Estimated Time	Estimated time for the delivery of the goods, expressed in days, weeks, etc.
Transaction Details	Information about the shipping terms (e.g., CIF, FOB), declared value, and insurance details.
Packing List	A detailed list of all transported items, including identification, description, quantity, weight, and dimensions.
Transportation Documentation	References to key documents for transportation, such as the Bill of Lading and the Packing List.
Safety Observations	Notes on safety requirements, hazard classifications of the products, and any required inspections.
Company Route Frequency	Information on the volume of contracts of the company responsible for the movement of the goods. Example, whether it is an entering or continuing company. Regularity information can be added to the form.
Insurance	Details about the insurance policy covering the goods, including insured value, insurance company, and policy number.

Source. Own Elaboration.

The analysis conducted at each of these phases is carried out on two distinct levels: an individual and a global level. At the individual level, the method examines the shipment under review, using the historical transactions of the same importer for comparison purposes. At the global level, the total set of available transactions, covering all importers, is used as a basis for comparison. The evaluation combines the results obtained at both levels in each phase to determine if the current shipment presents risks. This process involves modeling the history of shipments as points in a multidimensional space, with each phase of the evaluation divided into risk and safe subspaces. The risk subspace encompasses the shipments where risk is confirmed, while the safe subspace includes those without identified issues.

To illustrate the practical application of the risk assessment process in the logistics industry, let's consider a real-world example. Imagine a logistics company that uses a data-based risk assessment system to monitor and manage international shipments. This system collects data from various sources, including information about the sender, the recipient, the nature of the goods, the history of previous shipments, transport routes, and transit times. This data is then used in the evaluation phase (Data Collection and Risk Analysis), which is followed by the evaluation process and the decision-making based on the assessment. Additional verification measures are recommended if the goods fall into Group A - a group with initially assessed risk. This could include a more detailed inspection of the goods and documentation or the consideration of additional insurance or alternative transport routes. On the other hand, if the goods fall into Group B – a group without initially assessed risk, the shipping process proceeds without the need for extra interventions, as it is classified as safe based on historical analyses.

At each evaluation step, the results of the two levels of analysis are represented as sets of discrepant factors, individual and global. These factors are then processed to determine the current shipment's risk classification, considering the specific perspective of the evaluation phase in question. Besides the safe and risky classifications, a shipment can also be categorized as indeterminate. Shipments with this classification require a reevaluation through a centralized risk assessment process conducted by the customs administration. The introduction of the classification of shipments as indeterminate aims to enhance the accuracy of the proposed classification method. For this, a threshold is introduced that establishes the minimum difference required between the discrepant factors for the classification of the shipments. This threshold is of utmost importance, as shipments with a small gap between outliers do not present distinct characteristics enough for a direct classification, requiring further investigation by the customs authorities.

Figure 1 illustrates the phases of the life cycle of a customs risk assessment. Each phase involves different activities and decisions. This study proposes applying a risk assessment methodology in phases 1 (manufacturing) and 2 (transporting goods) of the export process. After classifying the risk level A or B of the shipment on the Blockchain, a message would be sent to the customs authorities. The customs authorities, as key stakeholders in the risk assessment process, would then act according to the risk level of the goods. This highlights the practical implications of the proposed methodology and its potential to enhance the accuracy of the classification method.

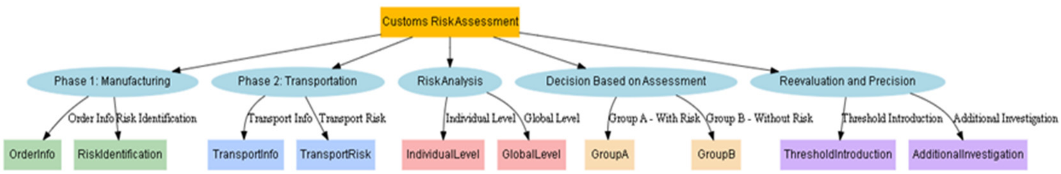

Figure 1 - Customs Risk Assessment: Proposed Process

Source. Own Elaboration.

The proposed method for customs risk assessment, rooted in blockchain technology, represents a groundbreaking innovation in risk management for international trade in the digital era. The integration of blockchain enhances data transparency and security and fosters a collaborative environment among various economic agents in the supply chain, including manufacturers, logistics agents, and customs authorities. This method significantly improves operational efficiency and accuracy in risk identification and strengthens the integrity and reliability of cross-border commercial operations. Ultimately, adopting this technological approach positions customs administrations at the forefront of innovation, enabling them to confront the complex challenges of contemporary global trade with greater resilience and effectiveness.

Integrating blockchain into the customs risk assessment process significantly advances over traditional methods. By enhancing data transparency, improving security, and fostering collaboration among supply chain agents, the proposed method directly addresses the limitations of current systems. The method's validity and reliability gain reinforcement from blockchain's ability to provide immutable and auditable records, which are crucial for trust and efficiency in customs operations, Rouhani e Deters (2021). As international trade continues to evolve, innovative methods like this are essential to ensure customs administrations can effectively respond to the increasing complexities of the global trade environment. Embracing this technological approach positions customs administrations at the forefront of innovation, enabling them to confront contemporary challenges with greater resilience and efficacy.

4. Manufacturer Risk Analysis in the Export Industry

The proposed method relies on a robust dataset on the export of beef (including offal, preparations, and preserves) from various cities in the State of Rio Grande do Sul, Brazil, for 2018 (Note 1). This experiment utilized data from 23 large-scale companies that exported an average of USD 3.74 per kilogram of beef. The data collected from Funcexdata in April 2024 is a reliable source. The companies are located in nineteen cities: Santo Ângelo, Santa Rosa, Porto Alegre, São Luiz Gonzaga, Marau, Rio Grande, São Sebastião do Caí, Pelotas, Encantado, Caxias do Sul, Passo Fundo, Garibaldi, Montenegro, Trindade do Sul, Estância Velha, São Gabriel, Bagé, Alegrete, Estação, and Frederico Westphalen.

Graph 1 illustrates the volume and average price data for beef (including offal, preparations, and preserves) exported from Rio Grande do Sul from 2010 to March 2024 (HS 0201). This comprehensive analysis, which includes significant fluctuations in both value (USD FOB) and average price (USD FOB/Kg), provides a detailed understanding of the beef trade evolution. The data shows a trajectory marked by significant fluctuations in value (USD FOB) and average price (USD FOB/Kg). Starting in 2010 with an export value of USD 198,817,790 and an average price of USD 3.36 per kilogram, a considerable increase was noted in 2011, reaching an export value of USD 247,254,609 and an average price of USD 4.42 per kilogram. After this peak, the value and average price experienced variations, with periods of decline and recovery reflecting global market fluctuations and internal production conditions. From 2016 onwards, a trend of recovery and continuous growth is observed until 2022, with a notable peak in 2022, where the export value reached USD 442,962,338 and the average price hit USD 5.34 per kilogram, the highest recorded in the analyzed period. However, in 2023, a significant reduction in export value and average price is observed, indicating possible challenges in the international market or changes in production and export conditions.

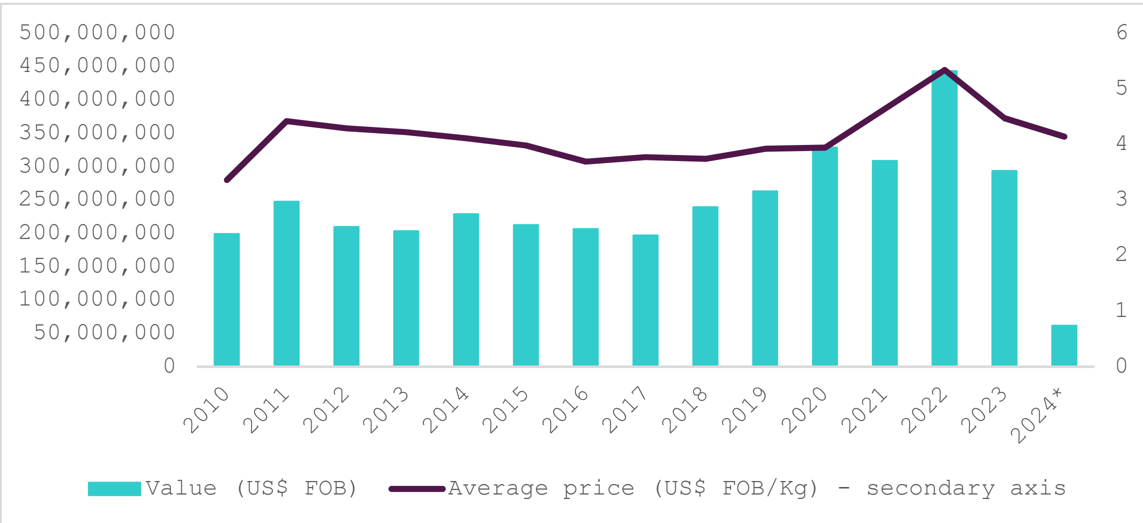

Figure 2. Beef Export (including offal, preparations, and preserves) from Rio Grande do Sul, Brazil, between 2010 and March 2024

Source: Own elaboration based on Funcex data.

To evaluate the risk of changes in import values, previous shipments are placed in a three-dimensional space, where each shipment represents a point with cost and manufacturer location coordinates. All companies exported beef (including offal, preparations, and preserves) in 2018. Graph 2 illustrates the dispersion of these shipments.

The export trade flow data for beef (including offal, preparations, and preserves) from the Rio Grande do Sul in 2018 appears in Table 3, which details the contribution of companies of various sizes to the total export value (USD FOB) and the number of participating companies. The microenterprise segment contributes a small share, with an export value of USD 84,598, involving only two companies. Small companies contribute a larger share, with 26 companies exporting USD 328,731. Medium-sized companies also make a significant contribution, with five companies exporting a total of USD 2,853,180.

Table 3. Export from Rio Grande do Sul – Brazil of Beef (including offal, preparations, and preserves) – Most recent public data

DESCRIPTIONS	2018
Companies classified by size or firm size	Value (USD FOB)
Micro company	84,598
Small	328,731
Special	8,122,678
Medium	2,853,180
Large	227,577,594
Not Classified	235

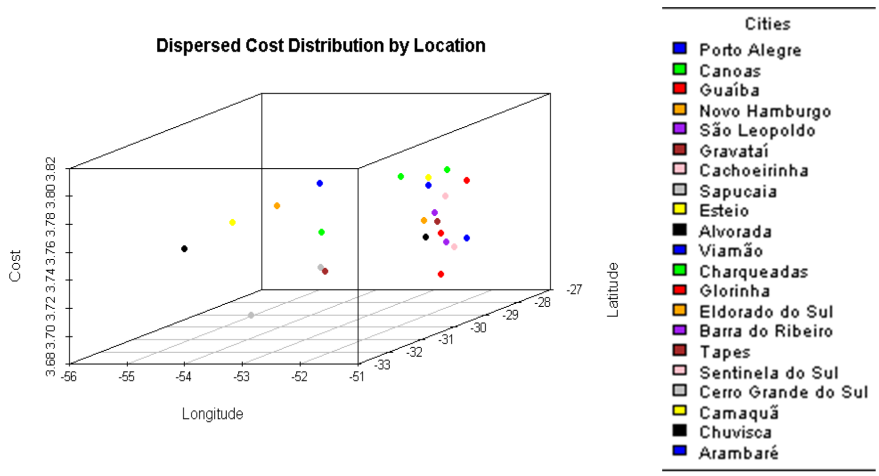

Figure 3. Previous Shipments in Three-Dimensional Space

Source. Own elaboration.

The risk analysis strategically uses these coordinates to check for inconsistencies or changes in declared values that might suggest an intention to reduce the amount of taxes owed. By analyzing the relationship between the cost of the goods, the location of the manufacturer, and the code referring to beef (including offal, preparations, and preserves), it is possible to verify if there have been changes in the information provided by the importer, which could compromise the integrity and legality of the commercial transaction.

4.1 Identification of Outlier Transactions at the Manufacturer Stage

It is important to note that a deviation can be, for example, the correct payment of taxes. Customs duties are an important source of revenue for the country, and sellers who do not pay them cause several problems. When sellers do not pay customs duties, the government loses a significant source of revenue for the country. Sellers who evade customs duties can offer their products at a lower price than their competitors who follow customs regulations. This harms companies that comply with the rules and creates unfair competition. When sellers do not pay customs duties, goods take longer to be cleared, which disrupts trade. Sellers not paying customs duties may encourage illegal trade, further affecting the country's economy. In summary, sellers' non-payment of customs duties significantly impacts the country's economy and trade (Dangsawang & Nuchitprasitchai, 2024).

Graph 3 presents all previous shipments in three-dimensional space with an outlier (Average price of USD 2.5 FOB/Kg). One of the objectives of this article is to present a methodology capable of identifying potential outliers (information that deviates from the rest) and serving as supporting information for customs to carefully investigate this information recorded on the Blockchain via form number 1 (Declared Export Value).

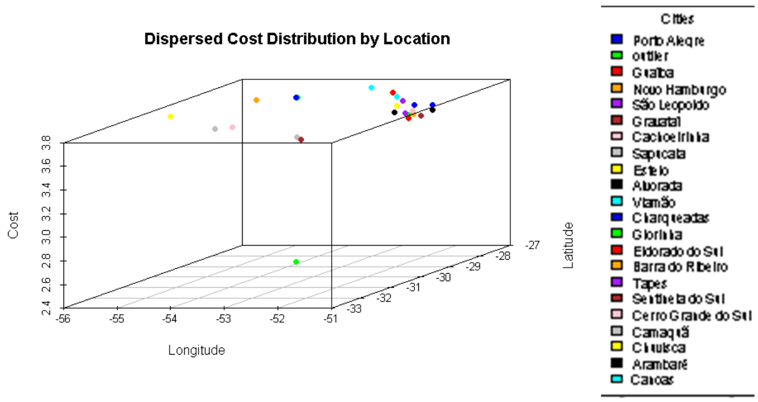

Figure 4. Previous Shipments in Three-Dimensional Space with Outlier (lower cost than the others)

Source. Own elaboration.

The figure 4 illustrates the cost distribution associated with beef shipments from various locations near Porto Alegre, represented in a three-dimensional graph that combines geographic coordinates (longitude and latitude) with the declared costs of each shipment. Among the colored points, which indicate regular shipments with cost variations within an expected range, one point stands out as an outlier. This point symbolizes a shipment with a declared cost significantly lower than the other points (average price of $2.5 FOB/Kg), marking it as a clear outlier in cost distribution. Identifying this point is crucial for customs and risk analysis, as it suggests a possible discrepancy or irregularity, such as under-invoicing or fraud in value declaration. Compared to what other shipments regularly declared, the much lower cost highlights the importance of a detailed investigation into this specific shipment to understand the reasons behind the discrepancy in declared costs and take the necessary corrective measures to ensure compliance and protect economic and regulatory interests.

To detect points like the one presented in Graph 3, this article proposes an algorithm based on point distance, DBSCAN (Density-Based Spatial Clustering of Applications with Noise). This algorithm is particularly suitable for identifying outliers in datasets with a spatial structure, as demonstrated by Birant and Kut (2007), Pavlis et al. (2018), and Jiang et al. (2019). The points represented in the three-dimensional space of location and cost in Graph 3 exemplify such a structure.

4.2 Use of DBSCAN in Identifying Out-of-Pattern Transactions (Outliers) at the Manufacturer Stage

The DBSCAN model employs a density-based spatial clustering technique for noise applications, as Uncu et al. (2006) and Si (2024) discussed. The density of points in a specific region determines the formation of clusters. A point cannot join a cluster if it does not meet the density or distance criteria, as Birant and Alp (2007) and Hanafi and Saadatfar (2022) noted. It is essential to highlight that, unlike centroid-based algorithms such as K-Means, DBSCAN can identify clusters of arbitrary shapes, making it efficient for complex and heterogeneous datasets. The function that obtains all the neighbors of element p, Epsilon-neighborhood ($N_{\varepsilon}(p)$) is defined as follows:

$$N_{\varepsilon}(p) = \{q \in D | dist(p, q) \leq \varepsilon\} \quad (1)$$

Where: (p) and (q) are points in the dataset (D), ($dist(p, q)$) is the distance between (p) and (q), (ε) is the specified neighborhood radius. A point is considered a core point (Core Point) if the number of points in (N_{ε}) is greater than or equal to (MinPts).

As a second definition, we have the concept of directly density-reachable, which states that an element p is directly density-reachable from an element q if:

$$p \ \in \ N\varepsilon(q) \quad (2)$$

$$|N_{\varepsilon}(p)| \geq minPTS \quad (3)$$

The Border Point is a point that is not a core point but is within the (ε) region of a core point. The Noise Point is considered noise if it is neither a core point nor a border point. According to Ventorim (2021), the algorithm was developed to discover clusters and noise from a dataset based on its spatial coverage. DBSCAN uses density to perform clustering, which enables the algorithm to perform clustering of arbitrary shapes.

The core elements and the border elements are the two types of elements present in a cluster. There are elements in an ε-neighborhood of a core element, based on its definition, at least minPTS. But this does not apply to border elements. Thus, a core element can be directly reachable from a border element; however, the reverse is not true. A core element has more ε-neighborhood elements than a border element. In the directly density-reachable criterion, pairs of core elements have symmetry. This means that if p is a core element and q is also, and if p is directly density-reachable from q, the reverse is also true.

The third concept to be presented uses the previous concept in its definition, given that it is an extension of directly density-reachable, being called density-reachable and defined as: An element p is density-reachable from an element q, if there is a chain of elements $p_1, p_2, \ldots,\ p_n$, given that$p_1\ =\ p$ and $p_n\ =\ q$ such that $p(i+1)$ is directly density-reachable from pi. In the fourth definition, we have the concept of density connected. An element p is density-connected to an element q if there is an element in which both p and q are density-reachable. When considering two border elements in a cluster, there is at least one core element from which both border elements are density reachable.

If there is a dataset D, a cluster C is a non-empty subset of D if it satisfies the following properties:

I. $\forall p, q$: $Se\ p\ \in\ C\ e\ q$ If q is density-reachable from p, then q ∈ C. (Maximality).

II. $\forall p, q\ \in\ C$: p is density-connected to q. (Connectivity).

This is the density-based cluster concept. The DBSCAN algorithm can divide the dataset into clusters and identify the members belonging to each cluster, as long as all elements of the same cluster are density-connected.

Figure 5 shows the clustering via DBSCAN. In this figure, the outlier transaction is identified in the manufacturer's stage. Cluster zero contains 1 observation (cost 2.4).

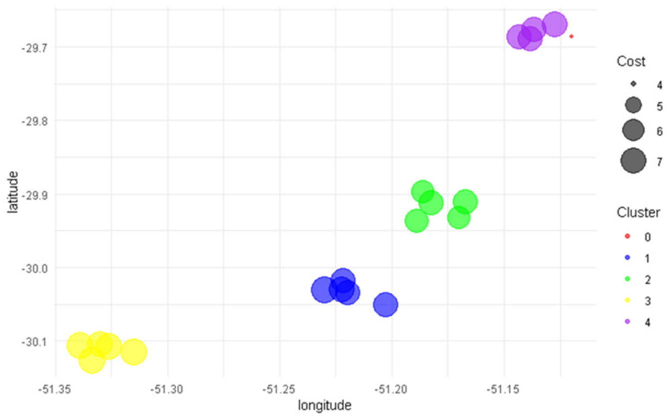

Figure 5. Clustering via DBSCAN

Source. Own elaboration.

Figure 5 visually represents the clusters identified by the DBSCAN algorithm. These clusters offer valuable insights into each cluster's geographical distribution and cost values. Cluster zero, which contains only the outlier, signifies a shipment that warrants deeper scrutiny. This outlier, deviating from the pattern found in the other four clusters, underscores the DBSCAN algorithm's unique ability to identify elements that do not fit well into any cluster. The cost scale, ranging from 1 to 10, was designed to accentuate the difference between the average costs of the 23 shipments and the outlier. The DBSCAN results reveal the formation of five clusters, with one being the noise point (outlier), further demonstrating the algorithm's proficiency in grouping points based on density.

The Silhouette Coefficient served as a tool to validate the accuracy of the estimation. This coefficient gauges how well a point has been clustered with other points in the same cluster, considering the proximity of points within a cluster and the distance to points in the nearest clusters. The K-means algorithm was used as a benchmark to compare the accuracy of the DBSCAN algorithm. The Silhouette Coefficient value for the DBSCAN algorithm was 0.711246, while for the K-means algorithm, it was 0.5749625. The higher Silhouette value indicates that the DBSCAN algorithm outperformed K-means in effective clustering, as evidenced by the analysis of the Silhouette Coefficient values. A higher Silhouette Coefficient for DBSCAN suggests that points within each cluster are closer to each other, while points in different clusters are relatively farther apart, indicating that the clusters are separated from each other.

Notably, including more variables can significantly enrich cluster analysis, especially in contexts such as customs dispatch, where multiple data dimensions can capture the complexity of operations, and the diversity of goods involved. Adding more variables allows for a more nuanced understanding of patterns and relationships in the data, which can lead to more precise identification of clusters and outliers and provide deeper insights into international trade behavior. Additional variables might include trade volume, which can indicate risk, especially for shipments that do not match usual patterns for specific products or trade routes. Transaction frequency can also indicate risk, with less frequent operators representing a higher risk. Compliance history, including information on previous violations or irregularities, can provide further insights. The destination country may present varying levels of risk based on economic, political, and regulatory factors. Another additional information could be the classification according to exporter frequency, which includes newcomer companies, continuous and discontinuous companies, and dropouts. These are some of the variables that can significantly enrich cluster analysis.

Clustering algorithms, as essential tools for enhancing risk assessment processes, automatically group data points based on inherent similarities. This allows customs authorities to detect unusual patterns that may indicate fraudulent or non-compliant activities, Steenari, e Nurminen(2023). By analyzing large volumes of transaction data, clustering algorithms uncover hidden structures and relationships that might not be immediately apparent through manual inspection. This efficient process reassures customs officials that they are equipped with the best tools for the job. Consequently, clustering algorithms facilitate the efficient processing of data and empower customs officials to proactively identify and address potential risks (Galindo González,2024), thereby safeguarding national security and economic interests.

5. Logistics Agent Risk Assessment Stage

The logistics (or distribution) agent's space is formed by four dimensions that indicate the agent's identification number, the HS code of the merchandise, the state, and the commercial volume. These parameters (coordinates) aim to show whether the choice of a particular agent for the shipment in question is appropriate. Additionally, they indicate whether the merchandise can be shipped through the declared port. It is possible to analyze the relationship between two of the mentioned parameters (for example, commercial volume and the agent's experience with the HS code), assuming an export dataset of (i) green coffee, roasted coffee, soluble coffee, and coffee extracts, (ii) beef (including offal, preparations, and preserves), and (iii) paper and pulp. The data are for exports via land from Rio Grande do Sul, Brazil. In Graph 5, it can be observed that it is possible to group land shipments that are out of the region's standard or even the average value associated with the merchandise in question (beef, paper, and pulp, or green coffee, roasted coffee, soluble coffee, and coffee extracts). In this stage, a score (risky or safe) can be created for each shipment generated in the blockchain with information such as those in the Model Insertion Form (Table 2).

The methodology for risk classification in this study involves a systematic approach to assess the risk of logistics agents based on historical export data. The first step is to calculate the mean (μ_i) and standard deviation (σ_i) of historical export volumes (X_i) for each product (i). This provides a baseline for understanding typical export volumes. Next, for each shipment volume (V_i), we compute the deviation from the mean (Eq. 4). This deviation metric quantifies how much a particular shipment volume deviates from the historical average. To provide a normalized measure of risk, we define the risk score ((R_i) based on the deviation from the mean, normalized by the standard deviation (Eg. 5). This risk score helps identify shipments that significantly deviate from the norm. A predefined threshold (e.g., two standard deviations) is used to classify shipments as “Risky” in equation 6. This threshold-based classification ensures that only those shipments with substantial deviations are flagged as risky.

Deviation from Historical Average:

For each product (i), calculate the mean μ_i and standard deviation (σ_i) of historical export volumes (X_i).

Compute the deviation from the mean for each shipment volume

$$(V_i): [\text{Deviation} = |V_i - \mu_i|] \quad (4)$$

Risk Score Calculation:

Define the risk score (R_i) based on the deviation from the mean, normalized by the standard deviation:

$$R_i = \frac{|V_i - \mu_i|}{\sigma_i} \quad (5)$$

Threshold for Risk Classification:

Classify shipments as "Risky" if the risk score (R_i) exceeds a predefined threshold (e.g., 2 standard deviations):

$$\text{Risky if } R_i > 2 \quad (6)$$

The use of deviation from the mean and standard deviation as metrics for risk assessment is well-established in various fields, including finance, quality control, and supply chain management. For more information, see Alexander et al. (2005), Montgomery (2009), Silver and Thomas (2016), Chopra and Meindl (2015), and Hubbard (2020).

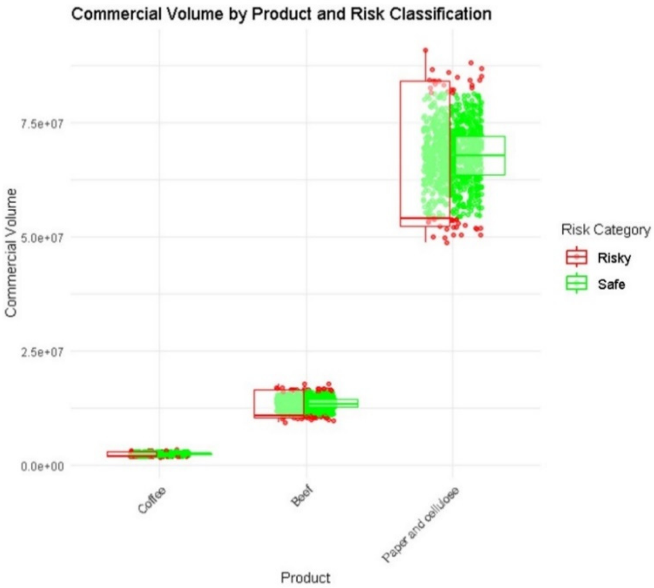

Figure 6. Previous land shipments – Monte Carlo simulation for the volume and specific product shipped from Rio Grande do Sul

Source: Own elaboration based on Funcex data.

The risk score for evaluating exports results from an analysis that combines the historical behavior of exported volumes and their relationship with the general market. Initially, the study considers how much the exported values deviate from the product's historical average (Figure 6). Values significantly exceeding this average, specifically by more than ±2 standard deviations, classify as potentially risky. A significant percentage variation, such as growth exceeding 50% compared to the average of the last six months, signals risk. This quantitative method effectively detects anomalies that may indicate anything from unusual seasonal variations to potential irregularities in export operations. Furthermore, the analysis delves deeper by considering specific product trends and seasonality, as well as the growth of the exported value relative to the overall market performance. Products with clear seasonal patterns that show abnormally high volumes outside these periods are flagged as risky. The long-term trend of export data helps discern whether an increase in values forms part of a sustainable growth trajectory or an unexpected spike. Cluster analysis groups shipments by similar characteristics, identifying those significantly deviating from established commercial norms. Through these analyses, a comprehensive risk-scoring model is developed that synthesizes these various factors, allowing for the classification of shipments into risk categories. Figure 5 displays the simulation of 1,000 values for each product using Monte Carlo Simulation. Values significantly deviating from the mean (e.g., ±2 standard deviations) appear as risky.

Additionally, a significant percentage change compared to the previous period (e.g., more than 50% growth relative to the average of the last six months) signals risk. The risk-scoring model for exports is designed to be adaptable, incorporating additional criteria beyond those already mentioned, such as deviation from the mean, percentage variation, trend analysis, seasonality, market growth comparison, and cluster analysis. Other dimensions that add value to the model include Regulatory Compliance and Compliance History. An essential aspect of international trade involves adhering to global and local regulations. An assessment of the regulatory compliance of exports and the exporter's compliance history will also provide relevant risk information. For example, exports made by companies with a history of irregularities or regulatory violations appear riskier. This criterion considers the frequency and severity of past non-compliances, adjusting the risk score to indicate the likelihood of regulatory or compliance issues. Another essential aspect to believe in in the Commercial Risk and Market Diversification analysis is the stability and diversity of commercial relationships. Exports concentrated in a single market or client may be more susceptible to economic or political variations. Additionally, a sudden change in commercial relationship patterns, such as unexpected entry into a new market or the abrupt termination of long-standing commercial relationships without a clear explanation, indicates risk. Incorporating an analysis of market diversification and the stability of commercial relationships into the risk-scoring model helps detect risks related to excessive dependence or instability in commercial relationships.

5. Classification Stage

The classification stage is initiated when the transactions from the manufacturer and the transport agent are sent to the blockchain (Raja Santhi & Muthuswamy, 2022). The submission of the commercial invoice details by the manufacturer triggers the manufacturer's risk assessment stage. In contrast, the transport agent's transaction submission to the blockchain triggers the transport agent's risk assessment stage. This article primarily focuses on presenting a classification method to mitigate the risk associated with these two agents involved in the customs process. After each risk assessment, the result is promptly sent to the customs administration through the blockchain system, providing customs with a real-time shipment assessment during the international trade supply chain stages.

For each stage, the risk of a point (shipment) is obtained by analyzing its location in the "risky" and "non-risky" subspaces. The evaluation process for each subspace (producer, transport, and logistics agent) determines whether the new point can be categorized as a normal point or an outlier (risky).

A continuous improvement and feedback loop is established to ensure the ongoing effectiveness of the risk classification process. The performance of the risk classification models is regularly monitored and adjusted based on new data and feedback from customs authorities. Input from all stakeholders, including manufacturers, transport agents, and customs authorities, is collected to identify areas for improvement. By implementing a robust and dynamic risk classification process, customs authorities can enhance the efficiency and security of the international trade supply chain. This is achieved by ensuring that shipments are more accurately assessed, reducing the risk of delays due to unnecessary inspections, and appropriately managed, thereby minimizing the potential for security breaches.

As mentioned above, the classification criteria rely on quantitative and qualitative factors. Regarding Quantitative Factors, for example, the Declared Value involves comparing the declared value of goods with historical data and market trends to identify discrepancies. The Shipping Route evaluation also analyzes the shipping route for unusual patterns or deviations from standard practices. Furthermore, the Volume and Weight assessment evaluates the shipment's volume and weight against historical averages and industry standards.

Regarding Qualitative Factors, for example, the Compliance History involves evaluating the compliance history of the manufacturer and the transport agent, including any past violations or irregularities. The Country Risk considers the risk associated with the origin and destination countries, including political stability, regulatory environment, and economic conditions. Additionally, the Product Type assessment evaluates the risk based on the type of product being shipped, with higher scrutiny for sensitive or high-value goods.

There are numerous possibilities for evaluating the risk of goods in international trade. The process is adaptable to the objectives of the involved economic agent, whether it be customs, the financing bank, the buyer, or even the agency providing insurance for the exported cargo. Your role in this process is crucial and significant. Your unique objectives and expertise are integral to the risk evaluation, making it a collaborative and comprehensive process.

The classification criteria rely on quantitative and qualitative factors. Table 4 presents Some Possible Criteria

Table 4. Quantitative and Qualitative Risk Factors

Quantitative Factors	Description
Declared Value	Comparing the declared value of goods with historical data and market trends to identify discrepancies.
Shipping Route	Analyzing the shipping route for any unusual patterns or deviations from standard practices.
Volume and Weight	Evaluating the shipment's volume and weight against historical averages and industry standards.
Qualitative Factors	Description
Compliance History	Evaluating the compliance history of the manufacturer and the transport agent, including any past violations or irregularities.
Country Risk	I am considering the risks associated with the origin and destination countries, including political stability, regulatory environment, and economic conditions.
Product Type	We are evaluating the risk based on the type of product being shipped, with higher scrutiny for sensitive or high-value goods.

Source. Own elaboration.

6. Integration of the Proposed Method with Blockchain

The proposed method for risk assessment in customs is significantly enhanced by its integration with blockchain (Nguyen et al., 2022). This integration revolutionizes the efficiency, transparency, and reliability of the risk assessment process. Blockchain's secure data storage capabilities provide an immutable environment for storing shipment transaction data, including manufacturer information, shipping agent, invoice details, and importer transaction history. This immutability ensures the reliability of the information used in the risk assessment, as the data cannot be manipulated or tampered with.

Blockchain enhances product traceability by tracking how shipments move along the supply chain, from the manufacturer to the final recipient. This improvement in traceability helps identify potentially risky shipments and facilitates the investigation of fraudulent activities. Blockchain can automate the risk assessment process by intelligently executing the steps of the method suggested in the previous sections (Dzhaparov, 2020). This reduces the need for manual intervention, speeds up the process, and reduces the likelihood of human errors.

Furthermore, the process becomes more transparent and collaborative. Blockchain promotes transparency by allowing all parties involved in the supply chain, such as manufacturers, shipping agents, customs authorities, and importers, to access and view transaction data. This transparency helps stakeholders work together and makes them feel included and part of a team, united in the fight against trade fraud.

Integrating blockchain with the proposed risk assessment method enhances data security and privacy. Blockchain's decentralized nature ensures that no single entity controls the entire data set, reducing the risk of data breaches and unauthorized access. Each transaction is encrypted and linked to the previous one, creating a secure chain of information that is highly resistant to hacking and cyber-attacks. This robust security framework instills trust and confidence among stakeholders, encouraging them to share accurate and complete data, which further improves the effectiveness of the risk assessment process.

Integrating the proposed method with blockchain technology extends beyond security and transparency, opening new avenues for innovation and operational efficiency. Blockchain eliminates the need for intermediaries and enables process automation through smart contracts, significantly reducing operational costs and processing times, thereby ensuring financial security and efficiency. Smart contracts, self-executing codes operating within the blockchain, can automate document verification, goods release, and payment execution, ensuring all parties fulfill their obligations accurately and promptly, McKinney et al. (2017). This automation accelerates processes and minimizes the risk of human errors and fraud, creating a more secure and reliable commercial environment.

Blockchain's ability to provide an immutable and verifiable record of all transactions is a game-changer in modernizing customs practices. It facilitates auditing and regulatory compliance, allowing for more efficient and precise oversight of foreign trade operations. This improves governance and compliance and strengthens trust between trade partners and regulatory authorities. Implementing this technology sets a new standard of excellence and innovation in international trade, empowering customs administrations to tackle the challenges of the 21st century with greater agility and effectiveness.

Some countries have already integrated blockchain technology into international trade. Singapore launched the TradeTrust (Note 2) project, which uses blockchain to digitize and authenticate commercial documents such as invoices and certificates of origin. This helps reduce fraud and speeds up the customs clearance process, bringing a new level of efficiency to international trade. TradeTrust was developed to meet the requirements of the UNCITRAL Model Law on Electronic Transferable Records (MLETR), which was adopted into Singapore legislation - the Electronic Transactions Act (ETA) in 2021. TradeTrust enables adopters to quickly implement ETRs as an electronic Bill of Lading that meets the requirements of the MLETR, Singapore ETA, UK Electronic Trade Documents Act (ETDA), and US (New York and Delaware) laws, and, therefore, they are legally valid across multiple platforms and systems. TradeTrust's open-source code is freely available. It can be easily integrated into any enterprise and solution provider's systems to create and verify documents supporting viable use cases.

The Korea Customs Service (KCS) (Note 3) has launched an initiative to use blockchain to digitize customs documents, improve the traceability of goods, reduce fraud, and enhance operational efficiency. Korea Customs has been enhancing its global customs network and striving to create a mutually beneficial trade environment while offering traders the latest news and trends. A dedicated team has been organized and dispatched to support our traders further to minimize clearance errors and assist businesses in clearance disputes. This team is a testament to our commitment to providing comprehensive support. Additionally, Korea Customs is actively working with the World Customs Organization to secure trade facilitation and security, conducting ODA projects and delivering various programs through cooperation funds. This includes modernization projects for customs administration and e-clearance systems in developing countries and capacity-building activities for customs officers to contribute to mutual growth and advancement of the global society.

7. Final Considerations

The Fourth Industrial Revolution has shown the revolutionary effects of technologies such as Artificial Intelligence (AI), blockchain, and big data on the world. To remain competitive in an increasingly demanding, connected, and dynamic market, companies and experts must adapt to the changes brought about by these innovations. The transition to this new technological era requires more than just technical improvements. It necessitates a strategic approach that values continuous learning, reinvention, and collaboration among people. Customs, which play an essential role in international trade, face the challenge of properly managing and overseeing the entry and exit of goods, requiring the analysis of a large volume of data and collaboration with various governmental and private organizations.

Amidst the challenges customs activities face, blockchain technology emerges as a pivotal solution, promising to enhance efficiency and security in international trade. By providing a secure and immutable data storage environment, blockchain facilitates shipment tracking, fosters transparency in commercial operations, and automates risk assessment. This not only aids in preventing fraud and irregularities but also improves data management and collaboration among international trade agents. The integration of blockchain into the customs process not only optimizes operations but also opens doors to new business opportunities and innovative service models, underscoring the importance of adaptation and continuous innovation in the face of global trade challenges.

This study introduces a blockchain-based risk classification method that offers significant advantages to customs risk management and international trade security. With this method, shipments can be evaluated in real-time at the manufacturer and carrier stages, leveraging securely and immutably stored data on the blockchain. This not only enhances the efficiency of the customs procedure but also boosts the transparency and trust of commercial operations. The automation of risk assessment, made possible by blockchain technology, reduces the need for manual intervention, thereby minimizing the possibility of human errors and accelerating the customs clearance process.

The logistics agent's risk analysis, incorporating multiple dimensions such as the agent's identification number, the HS code of the goods, the state, and the trade volume, provides a comprehensive view of the agent's suitability for the shipment in question. This multidimensional approach ensures a more accurate assessment of the risk associated with each shipment, facilitating the identification of potentially risky operations and informed decision-making by customs authorities. The Monte Carlo simulation, applied to estimate the volume and specific product shipped from the State of Rio Grande do Sul, exemplifies the practical applicability of this method in identifying out-of-pattern shipments, contributing to the effectiveness of the risk scoring model.

Nonetheless, developing a risk-scoring model that synthesizes factors such as deviation from the mean, percentage variation, trend analysis, seasonality, and comparison with market growth offers a robust tool for classifying shipments into risk categories. Including additional criteria, such as regulatory compliance and compliance history, as well as the analysis of market diversification and the stability of commercial relationships, further enriches the analysis, allowing for a more holistic and informed risk assessment.

This article presented a risk-scoring model for Brazilian exports, considering economic and financial criteria. The model aimed to provide a tool to support customs agents' decision-making. Notably, the suggested model can be helpful in various agents related to foreign trade, not only customs agents but also exporters, banks, insurers, government agencies, and international organizations. The model can assist in risk assessment objectively and transparently, reducing information asymmetry and transaction costs. The methodologies presented in this article establish a starting point for a more in-depth and refined analysis of export risks. The model can be enhanced with more criteria, data, and methods, depending on the availability and quality of information.

Integrating the proposed risk assessment method with blockchain can transform risk management in international trade, offering customs authorities a powerful tool for identifying and mitigating risks efficiently and transparently. This study contributes to the body of knowledge in customs security and international trade, highlighting the crucial role of blockchain technology in facilitating safer and more regulated trade.

This method can improve processing times, operational costs, transparency, and supply chain security. The blockchain-based approach effectively identified fraudulent activities, such as value manipulation and undeclared goods, thereby enhancing compliance and trust among trade partners. However, the study encountered data availability and quality limitations and the need to adapt the method for various products and trade routes. Future research should apply this technique to other industries and commercial contexts. Implementing this method can significantly reduce operational costs and processing times in international trade while boosting security and transparency. This approach benefits customs authorities and private operators, fostering a more reliable and efficient commercial environment.

One major limitation involves the availability and quality of data used in the risk analysis model. Inconsistent or incomplete data can undermine the accuracy of analyses and the effectiveness of the risk classification system. To address this issue, implementing rigorous data verification and validation protocols before inserting information into the blockchain proves essential, ensuring the use of only accurate and complete data. Additionally, adapting the method for various products and trade routes may require machine learning algorithms and risk classification criteria adjustments, as each context presents unique characteristics and challenges. Developing specific modules for each product type or route can overcome this limitation, allowing for system customization that accounts for the particularities of each scenario. Finally, resistance to adopting new technologies among some stakeholders may pose an obstacle. Thus, it becomes crucial to promote training sessions and workshops demonstrating the proposed method's benefits and efficacy, facilitating its implementation and acceptance within the international trade sector.

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The Publication Ethics Committee of the Canadian Center of Science and Education.

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The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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Notes

Note 1. Due to the General Data Protection Law (LGPD - Lei Geral de Proteção de Dados, Law No. 13.709), since 2018, the federal government no longer discloses results (sales volume) by company.

Note 2. https://www.imda.gov.sg/how-we-can-help/international-trade-and-logistics/tradetrust

Note 3. https://www.customs.go.kr/kcs/main.do

Appendix A - Coding of the Model Sheet for Blockchain Insertion (JSON, JavaScript Object Notation)

Figure 2 - Pseudo Code for Coding of the Model Sheet for Blockchain Insertion


```
{
  "Order_ID": "123456789",
  "Order_Date": "2023-09-15",
  "Manufacturer_Location": {
    "Address": "Rua Exemplo 123, Zona Industrial",
    "City": "São Paulo",
    "Country": "Brazil"
  },
  "Invoice_Details": {
    "Invoice_Number": "FAT-001234",
    "Date": "2023-09-15",
    "Items": [
      {
        "Description": "Product A",
        "Quantity": 100,
        "Unit_Price": 10.00
      },
      {
        "Description": "Product B",
        "Quantity": 200,
        "Unit_Price": 5.00
      }
    ],
    "Total_Value": 2000.00
```

  },
  "Country_of_Origin": "Brazil",
  "Product_Description": [
    {
      "Product": "Product A",
      "Specifications": "Technical specifications of Product A",
      "HS_Code": "123456"
    },
    {
      "Product": "Product B",
      "Specifications": "Technical specifications of Product B",
      "HS_Code": "789012"
    }
  ],
  "Declared_Value": 2000.00,
  "Shipping_Terms": {
    "Incoterms": "FOB",
    "Carrier": "XYZ Transport Company"
  },
  "Estimated_Arrival_Date": "2023-10-05",
  "Associated_Documentation": {
    "Certificates_of_Origin": ["Certificate123.pdf"],
    "Licenses": ["ExportLicense456.pdf"]
  }
}

Source: Own elaboration

Once prepared, this JSON can be sent to a blockchain system, where it will be stored immutably. Each field within the JSON serves a specific purpose, ensuring that all necessary information for risk assessment, compliance, and traceability is present and easily accessible (Figure 2).

Appendix 2 – Pseudo Code for Data Modeling via DBSCAN for Identifying Possible Outliers

Figure 3 shows the pseudo-code for data modeling via DBSCAN to identify possible outliers. The R-Project, specifically the dbscan() function available in the dbscan package, was used.

Figure 3 - Pseudo code for data modeling via DBSCAN for identifying possible outliers

```
# Load the dbscan package
if (!requireNamespace("dbscan", quietly = TRUE)) install.packages("dbscan")
library(dbscan)
data <- data.frame(
  longitude = c(.) ,
  latitude = c(.) ,
  cost = c(.) ,
  HScode = rep("SH0201", 24),
```

```
    city = c(.)
)
# Data normalization
data_norm <- scale(data)

# Apply DBSCAN to the normalized data
set.seed(123) # For reproducibility
dbscan_result <- dbscan(data_norm, eps = "", minPts = "")
# View the results
print(dbscan_result)
```

Source. Own elaboration.

The pseudo-code performs the following steps: For each point in the dataset, the number of neighbors within a distance (ε) is calculated. A point is then marked as a core point if it has a number of neighbors greater than or equal to (MinPts). Points that are not core put are within the distance (ε) of a core point are marked as border points. Points that are neither core nor border points are considered outliers. Therefore, to detect the outlier point through the distance between regular points, you would configure DBSCAN with an appropriate value of (ε)and (MinPts) based on the spatial distribution of your dataset. The point termed an outlier, having a significantly different (lower) cost than other points and possibly being isolated in three-dimensional space (considering longitude, latitude, and price), would be identified as an outlier by the algorithm due to its low neighbor density.