Exploring the Inhibitory Effect of RASFF on China-EU Trade of Rice-Based Products
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ABSTRACT
Rice-based products exported from China to Europe have repeatedly encountered technical trade barriers. Using panel data from 24 states of the European Union during 2001–2017, this study builds a theoretical model to investigate the impact of implementation, intensity and structure of the Rapid Alert System for Food and Feed (RASFF) on China-EU rice-based product trade. The study found that RASFF has a serious inhibitory effect on the trade of traditional rice-based products because of detecting GM ingredients, showing an obvious lag effect, diffusion effect and structure effect. The negative effect occurs in entry process, and the inhibitory effect of border rejection and information notifications results in time lag, but the marginal effect of alerts for market links is insignificant. Moreover, the positive information disclosure effect of technical barriers implemented by individual members is much smaller than the negative diffusion effect. Finally, countermeasures and suggestions are proposed, including the source supervision of the test, the supervision of GM variety approval and GM seed production, the establishment of an early-warning and rapid-response mechanism to technical barriers of agricultural products, and food enterprise information.

1. Introduction
China is the European Union (EU) ’s the largest trading partner, largest source country for imports and its third-largest export market. China is the second-largest export market for EU agricultural products and the third largest agricultural export country to the EU. China is also one of the potential core markets of European geographical indications for agricultural products. The China-EU Comprehensive Investment Agreement (CAI) was completed in December 2020 and further promoted China-EU investment cooperation in the field of agricultural economy and trade. According to the Food and Agriculture Organization of the United Nations (FAO), the total value of imports of rice-based products from EU member states has increased since 2001. It increased to more than $380 million in 2020. China’s total value of exports of rice-based products increased at an average annual growth rate of 10.77%. However, China’s total export value of rice-based products to the EU has declined since 2008. The trade value of Chinese exported rice-based products dropped from 6,159 thousand of US dollars in 2001 to 4,773 thousand of US dollars in 2017, with an average annual growth rate of −1.488%. The value in 2020 was less than 7% of the total import value of EU rice-based products. The demand for EU rice-based products is high, and China’s rice-based product supply capacity is increasing, while the proportion of China’s exports of rice-based products to the EU is very small. The direct cause may be that since 2006, the EU’s Rapid Alert System for Food and Feed (RASFF) has detected unlicensed genetically modified ingredients in China’s exports of rice-based products. For instance, unauthorized Bt63, Kefeng 6 and KMD1 were detected by the EU in rice-based products imported from China in March 2010.
Moreover, RASFF reported the export situation of Chinese rice-based products in the 51st week of 2020. The data showed that three types of rice-based products were returned by the UK because of containing unapproved GM ingredients – – 35S promoter of the Cauliflower Mosaic Virus. Compared with the previously returned products, in addition to rice noodles, black rice flour has been added. RASFF notifications have taken the form of border rejection, information, alerts and news. From 2006 to 2017, RASFF reported 235 records of China’s exports of rice-based products due to the presence of unlicensed GM ingredients. The records included information (69 records), border rejections (53 records) and alerts (113 records). RASFF has become the main technical barriers to trade (TBT) in rice-based products exported from China to Europe. According to a report by the General Administration of Customs (PRC) in 2019, Chinese enterprises incurred 2336 million of US dollars (6.8985 RMB = 1 USD) in additional costs in response to foreign TBTs. This has led to a serious obstacle to normal foreign trade. For food and agricultural trade, nontariff measures such as sanitary and phytosanitary measures (SPS) are significant barriers. Scholars in the field do not have a unified explanation for TBTs. TBTs mainly include technical regulations, standards and conformity assessment procedures, as well as animal health and food safety measures. TBT is generally defined as a comprehensive and far-reaching sanction that is different from traditional tariffs. The introduction of legitimate regulations and standards within TBTs are expected to improve market efficiencies. Technical trade measures described by the Conference on Trade and Development (UNCTAD), as one of three major obstacles to international trade, have gradually transformed into disguised barriers to trade instead of sanitary and phytosanitary measures or correction of market failures. TBTs have been used to shelter emerging industrial sectors from the rigors of highly competitive foreign exporters. TBTs, particularly sanitary and phytosanitary measures and tariff-rate quotas, are two critical policy barriers that impede agricultural trade. There are obvious differences in the GM food labeling systems between China and Europe. China requires mandatory labeling for all products included in the catalog which includes 17 products in 5 categories. The EU has adopted the precautionary principle and mandatory quantitative labeling of GM foods. It has established an EU list containing information and data on GM foods. Member states carry out control measures, including sample checks and testing according to the list. The EU strengthens supervision through risk assessment, post market monitoring and a framework for traceability. Traceability and labeling requirements for products consisting of or containing genetically modified organisms (GMOs) will not be applied if the proportion of GMO traces is no higher than the threshold of 0.9%, provided that these traces are adventitious or technically unavoidable. This is also the most stringent labeling system in the world. Indeed, China has not yet approved the commercialization of GM rice or GM maize. It does not rule out the possibility of some developers illegally carrying out field trials (intermediate in trials, environmental release and productivity tests), the application for trial approval of GM varieties as nontransgenic varieties, or even illegal GM seed acquisition and commercial cultivation by some growers. For instance, the illegal cultivation and sale of GM rice were found in Hubei in 2014. Traditional crops may mingle with low levels of hybrid GM components. However, the crop in mature, in the harvest, storage and transportation process is not completely cleaned, resulting in the mixing of different products, which contains LLP of non-target transgenic components. For example, the United States organized on a batch of MON810 GM corn to be exported to China, and the GM product obtained import license of China. When organizing the export of the product, a small amount of insect-resistant MIR162 maize was mixed in. Although the transformants are approved for production in the United States, China has not approved import product containing GM ingredients. Additionally, the safety evaluation of GMOs in China emphasizes the production link before listing, ignoring the circulation link after listing. Under the framework of the existing labeling system between China and Europe, it is of great theoretical and practical significance to examine the mechanism of how EU RASFF affects the import of rice-based products from China. (Figure 1)
To break through the existing research on insufficient attention to RASFF technical trade measures, this study considers the implementation, intensity, structure and diffusion effect of technical trade measures on China’s exports of rice-based products. This paper reveals its mechanism using panel data from 24 states of the EU from 2001 to 2017. The study not only expands the theoretical model of the impact of TBTs on agricultural trade and provides method support but also has important reference value for relevant government departments on how to deal with increasingly stringent TBTs.

2. Literature Review

With the weakening of traditional trade barriers such as tariffs, TBTs predominating in technical trade measures are widely used by countries. Technical trade measures have a far-reaching impact on international trade, but their impact on agricultural export trade is uncertain.

Theoretically speaking, if the products of an export company do not meet the requirements established by the importing country, the company will be prohibited from entering the importing country’s market (Traoré & Tamini, 2022; Kinzius
et. al, 2019), and the export volume will be reduced (Zhang & Zhu, 2020). TBTs also increase additional export costs, including variable costs and fixed costs, with a negative impact on export trade (Fontagné & Oreife, 2018). For instance, reducing the probability of exporting for these companies leads to low-productivity firms dropping out of the market. Tian and Chai (2019) found that restrictive technical trade measures have significant negative effects on the volume and value of exports. This negative impact is exacerbated by the higher costs of agricultural products. Zhang and Zhu (2020) found that TBTs significantly inhibited China’s agricultural exports. Yang and Li (2020) pointed out that the reduction of TBTs decreases the production and circulation costs of agricultural products, as well as promotes the growth of China’s total import and export volume. Hejazi et. al (2022) indicate that stricter importer maximum residue limits reduce bilateral trade to the tune of 8.8%.

The implementation of technical trade measures can alleviate the problem of information asymmetry in the market. The reduction of consumers’ search costs for information will force companies to improve product quality to avoid export risks. These reductions enhance consumers’ confidence and stimulate consumers’ demand. Second, the TBTs implemented by importing countries will create an “anti-driving mechanism” for export companies. To maintain their original market positions and profit levels, export companies will actively carry out technological innovation and export market structural adjustment to break through the restrictions of technical trade measures. Technological innovation improves production efficiency and reduces the marginal cost of firms, thereby enhancing the competitiveness of agricultural products and ultimately promoting export trade. Third, under the influence of “learning-by-exporting,” TBTs promote information exchange in the markets of China and importing countries, promote economies of scale and reduce transaction costs. Enterprises will introduce a series of fixed-cost investments, such as equipment investment, and the new fixed costs will be apportioned among more export products while complying with the technical trade measures of importing countries. After reaching a certain empirical threshold of cost, the cost and technology will no longer hinder the export of enterprise products. TBTs formulated by Japan, the United States, the EU, and South Korea have positive effects on the development of China’s agricultural export trade. Rabádán and Triguero found that the United States and Iran benefit from stricter food safety standards imposed by importing countries in the trade of pistachios. Song and Zang (2016) considered the time dimension and the time point dimension. They found that the impact of Japan’s TBTs on China’s agricultural exports shows significant negative effects in the short term but promotes positive effects in the medium term and long term. The uncertain impact of TBTs on the export trade of products may depend not only on the differences in product attributes but also on the different measurements of technical trade measures. There are some differences between narrowly and broadly defined technical trade measures, and their characteristics and intensity are difficult to clarify. To overcome these shortcomings, this study uses the number and types of RASFF notifications to measure the strength and structure of EU technical trade measures. These can distinguish the characteristics of technical trade measures. Using descriptive statistics, analyzed the effect of RASFF on the fish trade. Most of the existing research on RASFF by Chinese scholars has focused on the statistical level of the number and type of notifications; they have rarely carried out in-depth empirical research, except for. They used RASFF to carry out food safety risk predictions.

Aiming at specific agricultural products export trade, Peng et. al (2020) took fresh pear as an example and found that if the commodity scope limited by technical trade measures was focused more on fresh pear products, the negative effect will be more significant. Taking apple and garlic as the example, Xie and Zhu (2019) found that foreign pesticide maximum residue limits standards have marked inhibitory effects on the export of apples and garlic in China. Zhang et. al (2013) took vegetables as an example to find that the formulation of standards and regulations of importing countries had an inhibitory effect on vegetable exports in China. Li (2013) took tea as an example and found that the gradual strengthening of the positive list system in Japan led to the continuous
3. Status of RASFF Notifications on China’s Export of Rice-based Products

The EU began using early warning systems for food safety management as early as 1979. In 2000, the Food Safety White Paper pointed out the need to establish a rapid early warning system, whose scope should be extended to the entire food and feed industry and that should be able to publish information about food safety emergencies to ensure that consumers and trade organizations are appropriately informed. In 2002, Regulation No. 178/2002 Basic Food Law issued by the EU formally established the RASFF. RASFF has implemented four types of technical trade measures for imported food and feed, including border rejection, information, alerts, and news. Border rejection is a notification added in 2008, which entails the rejection of entry when a product is found to have health risks during port inspections. Such notifications are intended to strengthen controls and ensure that rejected products do not enter EU member states through other ports. Information notification is aimed at products that are identified as risky but have not yet entered the market, mainly including information on how food or feed of concern is detected and rejected at EU ports, so there is no need to take immediate measures. Alerts are pushed by member countries that have found problems; when harmful food and feed is found in the market, it is necessary to take immediate measures and issue alert notifications. News is information related to the safety of food or feed involving concerns by the regulatory agencies of member states; however, such notifications do not rise to the level of alerts or information notifications and are transmitted to the member states in the form of news. It follows that border rejection notifications and information notifications are for products entering ports, while alert notifications and news notifications are for products that have entered the market.

Italy issued an information notification on corn seeds imported from the United States on 6 June 2002. This was the first batch of agricultural products that contained GM ingredients notified by RASFF. Spain and Italy revealed that rice-based products imported from Argentina contained GM ingredients and implemented border controls in 2004. France issued an alert notification on rice-based products exported from China on September 7, 2006. This is the first time that rice-based products exported from China to the EU were notified of the presence of GM ingredients. Unauthorized Bt63, Kefeng 6 and KMD1 were detected by the EU in rice-based products imported from China in March 2010. China has still not allowed the commercialization of GM rice by 2022. The EU issued its first decision, the Commission Implementing Decision 2011/884/EU of 22 Dec 2011 on emergency measures regarding unauthorized GM rice in rice-based products originating from China (2011/884/EU), in December 2011. According to 2011/884/EU, the EU will carry out a mandatory analysis of GM ingredients in 25 types of rice-based products from China (covering rice in the husk, husked (brown) rice, rice flour, semimilled or wholly milled rice, rice pellets, flaked rice grains, rice starch and preparations for infant use). Then, the consignment shall be redispached to the country of origin or destroyed based on the test results. The EU’s latest control system has a high level of precision that can detect 26 kinds of GM substances in rice-based products. Thus, the EU requires that Chinese authorities approve the ratification by submitting an analytical report of rice-based products before exporting to demonstrate whether exported the products contain GM ingredients. The decision is implemented by the RASFF, and the results are notified to member states. RASFF will also increase the frequency of sampling and analysis to include all imported rice-based products. Since the implementation of 2011/884/EU, RASFF has notified 56 batches of GM rice-based products from China. Emergency measures for China’s rice-based products would continue to be implemented to ensure that no unauthorized GM food or feed is
to enter the EU market. The EU took further restrictive measures to extend the scope of products suitable for the detection of transgenics in imported rice-based products in June 2013. The EU included sesame balls and other products of the scope of detection of transgenic and correspondingly raised the requirements for such products to enter the EU market. This led to a general disruption of Zhangzhou’s sesame ball exports to the EU. Additionally, the EU has lifted restrictions on the production base of imported rice-based products. The EU required that the rice farms of imported rice-based product companies have local customs for records. It is concluded that China’s exports of rice-based products to Europe faces some of the toughest immigration checks in history.

4. Methods

4.1 Theoretical Model

The trade gravity equation can be used to estimate the trade effects of nontariff measures, including technical trade measures. The metrological model has the theoretical basis of Krugman’s monopolistic competition model, the constant elasticity of substitution demand and the Iceberg Cost model. Under the assumption of increasing returns to scale, national producers produce and trade differentiated products, which are shipped to consumers in other countries at a certain cost. When exploring the total value of trade exported from country \( i \) to country \( j \), the general form of the gravity model is:

\[
x_{ij} = n_i p_i^{1-\sigma} (T_{ij})^{1-\sigma} E_j G_j^{\sigma-1}
\]

where \( n_i \) and \( p_i \) respectively denote the quantity and price of product varieties of country \( i \). \( E_j \) and \( G_j \) indicate the expenditure and price index of country \( j \), respectively; \( T_{ij} \) denotes iceberg transport costs, and \( \sigma \) denotes substitution elasticity. Focusing on international agricultural trade, the general form of the gravity model with a multilateral trade resistance term is:

\[
y_{ijt} = f(TBT_{ijt}, Distance_{ijt}, GDP_i, GDP_j, Ccul_i, f_c, f_e, \epsilon_{ijt})
\]

where \( y_{ijt} \) indicates the volume of exports from country \( i \) to country \( j \) at time \( t \) and \( TBT_{ijt} \) indicates the technical trade measures imposed by importing country \( j \) against exporting country \( i \) for a particular product at time \( t \). \( \text{Distance}_{ijt} \) indicates the distance on bilateral trade between trading partners \( i \) and \( j \) to measure the transportation cost. If the distance is further, transportation costs will be higher, and profitability and the value of bilateral trade will be smaller. \( GDP_i \) and \( GDP_j \) respectively denote the gross domestic product per capita of countries \( i \) and \( j \) to measure the economic aggregates of importing and exporting countries. Economic aggregates of the importing country reflect the country’s required capacity for imported goods; if the gross domestic product per capita of the importing country is higher, the required capacity will be stronger. \( Ccul_{ij} \) indicates whether trading partners belong to the common cultural circle. Within the common cultural sphere, consumer preferences for goods are highly similar, which will increase the demand for exported goods. \( TBT_{ijt} \) and \( \epsilon_{ijt} \) indicate importing country fixed effects and time fixed effects, respectively. \( \epsilon_{ijt} \) is a stochastic error term.

4.2 Gravity Model and Estimation Procedures

Based on the theoretical model, this paper constructs the following metrological model to test the impact of RASFF on China’s export of rice-based products.

\[
\ln Value_{it} = \beta_0 + \beta_1 (TBT_{i, t}) + \beta_2 (TBT_{i, t-1}) + \beta_3 GDP _{EU} + \beta_4 GDP _{CHN} + \beta_5 \text{Distance} + \beta_6 B & R + \beta_7 \text{Distance} \times B & R + \beta_8 \text{Regulate}_t + \beta_9 \text{Regulate}_{t-1} + \mu_i + \lambda_t + \epsilon_{it}
\]

where \( i \) and \( t \) indicate EU member states and years respectively. \( \ln Value_{it} \) denotes the export value of rice-based products from China to EU member state \( i \) in year \( t \). The core factors are the technical trade...
measures of EU member states. Differences in the measurement methods of technical trade measures may have a direct impact on the estimated results. Measuring by standard numbers is one way of trade-oriented measurement technology, and it can also be expanded. However, the data used in the literature to measure traditional technical trade measures are mainly obtained from TRANS, the Perinorm database or WTO-notified data. The data cannot distinguish the structure of technical trade measures, nor can they reflect the degree of limitation (Tian & Chai, 2019). Technical trade measures implemented by RASFF, including border rejection, information, alerts and news, have the advantage of distinguishing the structure and degree of limitation. Specific information about the goods at border crossings or in the market can be traced back to the official website. In this study, RASFF is measured by whether to implement technical trade measures that inspect GM ingredients (Barriers), strength (Times) and structure (Border Rejection, Alert, Information). The EU integration has increasingly made the markets of EU countries inextricably linked with one another. If the potential benefits of multiple parties are influenced by a tough technical trade measure, these countries tend to take joint action. Once technical trade measures come into effect, they may have an extreme diffusion effect. If the technical trade measures implemented by one country are easily emulated by others, they could be easily extended from one country to other countries or regions. Therefore, this study considers the diffusion effect of technical trade measures in the EU regions on China’s rice-based product exports. TBT\textsubscript{1} represents a series of technical trade measures of RASFF. It includes five variables. Intraregional Barriers\textsubscript{it} denotes whether the EU member state has implemented RASFF in year \( t \). This variable is a dummy variable taking a value of 0 if none of the EU member countries have implemented RASFF; otherwise, it is 1. Intraregional Times\textsubscript{it} is used to measure the intensity of technical trade measures within the region. It can be calculated by the number of aggregations of RASFF. Intraregional Border rejection, Intraregional Alert and Intraregional Information are used to measure the structure of technical trade measures within the region. They are calculated by the aggregation of the number of border rejections, alerts and information.

Considering the time lag effect of TBTs, the technical trade measures in the EU are lagged by one period in the econometric model in this study. TBT\textsubscript{i,t-1} denotes the lagging items of these five variables.

\( GDP-EU_{it} \) is the GDP per capita of the \( i \)-th EU member state in year \( t \). \( GDP-CHN_{it} \) is the Chinese annual per capita GDP in year \( t \). \( Distance \) is the relative geographic distance between China and the EU member states \( i \). It is the relative value of weighted absolute geographic distance, which is weighted by the population distribution within a country. B&R is whether EU member state \( i \) is a country along the Belt and Road. This variable is a dummy variable taking a value of 1 if the EU member country is a country along the Belt and Road; otherwise, it is 0. \( Distance \times B&R \) is an interaction item between relative geographic distance and countries along the Belt and Road. The continuous expansion of the relative economic scale between China and the countries along the Belt and Road, as well as the infrastructure connectivity with an increasing number of countries along the Belt and Road, are conducive to stimulating the formation of more diversified consumer demand for agricultural products. These promote in-depth cooperation between the two sides in the intraindustry labor division of agricultural products and trade in more similar categories of agricultural products. Rugualte\textsubscript{it} denotes the number of regulations on GM rice-based products implemented by Chinese authorities in year \( t \). It is used to reflect the intensity of Chinese regulations. The Chinese regulations are lagged by one period in the econometric model, due to a lag in trade policy. Additionally, this study also controls the importing country fixed effect (\( \mu_{i} \)) and time fixed effect (\( \lambda_{t} \), and \( \epsilon_{it} \) is a random disturbance term.

5. Data

5.1 Data Source

Taking data availability and integrity into consideration, the sample used in this paper is the EU member states that imported Chinese rice-based products from 2001 to 2017. The value of trade in rice-based products is from the Food and Agriculture Organization of the United
Nations’ (FAO) database. The export destinations in the sample only included EU member states. RASFF is an information exchange platform for food safety that is primarily targeted at EU member states. The EU had 28 member states in 2017. A sample of 24 countries was selected. Estonia, Latvia, Lithuania and Luxembourg were excluded due to very few imports of Chinese rice-based products. The EU includes the 10 Central and Eastern European countries of the Czech Republic, Cyprus, Hungary, Estonia, Latvia, Lithuania, Poland, Slovakia, Malta and Slovenia that joined in 2004, Romania and Bulgaria that officially joined the EU in 2007, and Croatia that officially joined in 2013. For rice-based products, the sample selects the accumulated value of export of flour, millet and rice as the export trade value of rice-based products. Among them, rice is the cumulative value of brown rice, milled rice, paddy rice, husked rice and broken rice. Existing research has mainly used trade value and trade volume to measure export trade. Studying the export trade of agricultural products between China and Russia under the green barrier, adopted the value of agricultural trade. Wang adopted the volume of soybean when exploring the impact of Sino-US trade frictions on the import cost of Chinese soybean. Rice-based products are a kind of processed food with paddy, millet and flour as the main raw materials, and rice-based products have various types and complex structures. They also involve product diversification and have obvious price differences. The total export volume of rice-based products cannot directly measure its total export value. In this study, the export value of rice-based products is chosen as the explanatory variable in US dollars. This economic indicator reflects the scale of Chinese foreign trade of rice-based products.

TBT data are collected from the RASFF’s notifications on rice-based products. The data on notifications are from China Trade Remedies Information. RASFF summarizes and analyses large amounts of early warning information. Then, RASFF implements timely risk ranking and screening. This is followed by issuing notifications of all types of food safety risks. It can provide information to support the European Commission and the EU Member States for rapid and effective regulatory measures. Notifications can be classified into four types: alerts, border rejections, news and information. Thus far, the EU member states have not yet adopted news notifications about China’s exported goods. The remaining three types of notifications have all revealed that rice-based products imported from China have contained GM ingredients. Data on whether an importing country is an EU member state are from an overview of the EU countries of the Ministry of Foreign Affairs of the People’s Republic of China.

The gross domestic product per capita of importing countries and China data and the urban population size data at the country level are all collected from the Penn World Table (PTW). Absolute geographical distance data are collected from the CEPII-GeoDist database. Countries along the Belt and Road data are collected from *Vision and Actions on Jointly Building Silk Road Economic Belt and 21st-Century Maritime Silk Road* which is jointly released by the National Development and Reform Commission, the Ministry of Foreign Affairs and the Ministry of Commerce of the People’s Republic of China. The data on the regulation of rice-based products are collated from the Ministry of Agriculture and Rural Affairs of the People’s Republic of China. These data are collected from the regulatory news of GM rice-based products on the website from 2001 to 2017 by the authors. Information was searched and screened using the keywords “GM” and “Rice.” The whole year cumulative number of times measures the Chinese regulation strength of rice-based products in year t.

However, the RASFF window lacks data on GM-related TBTs from 2018 to 2019. Using balanced panel data of 24 countries from 2001 to 2017, this paper estimates the econometric model.

Table 1 provides descriptive statistics of the main variables in the metrological model. The results reveal that the independent variables obey the observed change hypothesis.

### 5.2 Characteristic Facts

#### 5.2.1 China-EU Trade Situation for Rice-based Products

The total imports of rice-based products from the EU member states were 3,803,557 thousand U.S. dollars in 2020, approximately 3.47 times more than in 2001. The total exports of rice-
based products from China showed a fluctuating growth trend, with an average annual growth rate of 10.77% from 2001 to 2020. The total export value was 922,894 thousand U.S. dollars by 2020, accounting for approximately 24.3% of the total imports of rice-based products from the EU member states in the same year. China’s rice-based product export share to the EU shows a declining trend. Ranked by the total import value of rice-based products by 2020, the value of rice-based products imported from China to the top 5, 6–10 and 11–20 countries accounts for less than 2.5% of total import of rice-based products. For the member states ranked 21st to 28th, the proportion is even lower.

### 5.2.2 The Relationship between Trade of China-EU Rice-based Products and RASFF’s Technical Trade Measures

The China-EU trade situation of rice-based products and technical trade measures are reported in Fig. 2. Rice-based products exported from China to the EU peaked in 2003. Then, the value of trade showed large fluctuations. The export value of rice-based products was 4,773 thousand U.S. dollars by 2017, accounting for 19.93% of the value in 2003. Order Agricultural No. 38 of 2004 amended the safety management measures for the import of agricultural GMOs. RASFF has notified imported rice-based products containing unauthorized GMO Bt63, GMO Kefeng and Kemingdao 1 (KMD1) since 2002. For instance, Italy notified rice-based

![Figure 2](image-url)  
**Figure 2.** China-EU trade situation for rice-based products. Note: The unit of trade value is thousands of US dollars. The principal coordinate (left coordinate) is used to reflect the change in trade value. The sub-coordinate (right coordinate) is used to reflect the number of technical trade measures implemented by the EU member states.

| Variable          | Description                                                                 | Mean  | Std. dev. | Min  | Max  |
|-------------------|------------------------------------------------------------------------------|-------|-----------|------|------|
| InValue           | The logarithmic value of rice-based trade (USD) exported to the i-th EU member state in the t year |       |           |      |      |
| Border Intrasregional | An interaction item between whether the EU region has implemented RASFF and whether the country is the member of the EU in the year t | 0.684 | 0.466     | 0    | 1    |
| Times Intraregional | An interaction item between the number of aggregations of RASFF implemented by the i-th EU member state in the t year and whether the country is the member of the EU in the year t | 13.373 | 13.926    | 0    | 46   |
| Border rejection Intraregional | An interaction item between the number of aggregations of border rejection implemented by the i-th EU member state in the t year and whether the country is the member of the EU in the year t | 6.480 | 8.661     | 0    | 32   |
| Alert Intraregional | An interaction item between the number of aggregations of alert implemented by the i-th EU member state in the t year and whether the country is the member of the EU in the year t | 2.949 | 5.226     | 0    | 20   |
| Information Intraregional | An interaction item between the number of aggregations of information implemented by the i-th EU member state in the t year and whether the country is the member of the EU in the year t | 3.944 | 6.116     | 0    | 24   |
| Dist. Regulate | The number of regulations adopted in China in year t | 1.824 | 2.752     | 0    | 10   |
| Distance InD | The logarithmic value of the opposite distance of China to EU member states | 8.991 | 0.088     | 8.807 | 9.211 |
| GDP-EU | Whether the EU member states in the year t is countries along the “Belt and Road” | 0.417 | 0.494     | 0    | 1    |
| GDP-CHN | The logarithmic value of GDP per capita (USD) of the i-th EU member states in year t | 10.280 | 0.372     | 8.958 | 11.176 |
| GDP-CHN | The logarithmic value of per capita GDP (USD) in year t | 9.006 | 0.330     | 8.416 | 9.430 |
products imported from the US containing GM ingredients in 2002. Spain and Italy reported rice-based products imported from Argentina containing GM ingredients in 2004. The EU member states have taken technical trade measures to impose barriers on Chinese exported rice-based products since 2006. The frequency of the RASFF system implementing technical trade measures on rice-based products exported from China showed fluctuating growth from 2006 to 2014. The possible reason for this trend is the promulgation of Decision 2011/884/EU during this period. According to RASFF’s official data, RASFF issued a total of 235 notifications of GM rice-based products in China exported to Europe from 2006 through the end of 2017. There were 113 alert notifications, 53 border rejection notifications and 69 information notifications. Germany was the country with the highest number of notifications for the presence of GM ingredients in rice-based products exported from China, with 59 notifications, followed by the UK and France, with 38 and 23 notifications, respectively.

Looking at the trade value and technical trade measure trends of rice-based products between China and Europe, the export value of China’s rice-based products to the EU showed a correlation with RASFF. Compared with the period 2006–2009, the export trade value of China-EU rice-based products decreased from 2010 to 2014. However, the EU RASFF on rice-based products increased during the same period. Furthermore, compared with the period 2012–2014, the export trade value of rice-based products from China to the EU increased from 2015 to 2017. EU RASFF on rice-based products decreased, while the frequency of domestic regulations increased during the same period. However, whether RASFF on rice-based products affects China’s exports and the degree of impact remains to be empirically tested.

6. Results and Discussion

6.1 Basic Regression Results

A least squares dummy variable was used to estimate the marginal impact of the implementation of RASFF within the EU region. A correlation coefficient of less than 0.8 between independent variables and a variance inflation factor of 2.71 (less than 5) indicate that there is no serious multicollinearity in the model. The likelihood ratio test was used to test the validity of the model. The results of the estimates are shown in Table 2. Model (4) based on Models (2) – (3), considers the current effect of both intraregional RASFF, Chinese regulation and their 1-period lagged effect. The model has a high

| Variables | Export value of rice-based products |
|-----------|-----------------------------------|
|           | (1) | (2) | (3) | (4) |
| Intraregional Barriers | −4.543*** | −2.770*** | −2.770*** | −2.770*** |
|  | (0.740) | (0.801) | (0.801) | (0.801) |
| 1-period lag Intraregional Barriers | −4.106*** | −4.106*** | −4.106*** | −4.106*** |
|  | (1.127) | (1.127) | (1.127) |
| Regulate | 0.089 | 0.406* | 0.222 |
| 1-period lagRegulate | | | | 0.545 |
| Relative Distance | 88.414*** | 90.805*** | 90.805*** | 90.805*** |
|  | (6.001) | (6.942) | (6.942) |
| B&R | 990.059*** | 1,060.657*** | 1,060.657*** | 1,060.657*** |
|  | (174.549) | (189.412) | (189.412) |
| Interaction item between Relative Distance and B&R | −110.997*** | −118.885*** | −118.885*** | −118.885*** |
|  | (19.275) | (20.912) | (20.912) | (20.912) |
| GDP-EU | −8.101** | −7.816** | −7.816** | −7.816** |
|  | (2.318) | (3.615) | (3.615) |
| GDP-CN | 6.327*** | 13.574 | 19.714 | −46.308 |
|  | (1.409) | (20.824) | (16.341) | (55.541) |
| Constant | −775.220*** | −845.828*** | −904.357*** | −289.419 |
|  | (80.973) | (209.177) | (183.695) | (545.011) |
| Country fixed | yes | yes | yes | yes |
| Time fixed | yes | yes | yes | yes |
| R² | 0.631 | 0.655 | 0.655 | 0.655 |
| LR | 2.190*** | 2.230*** | 1.760*** | 1.480*** |

*ap < 0.01; **p < 0.05; *p < 0.1
goodness of fit. This study uses the estimation results of Model (4) to carry out in-depth analysis.

6.1.1 Marginal Impact of Intraregional RASFF
The marginal effect of the 1-period lagged intraregional barriers and intraregional barriers are negative, and the original hypothesis is rejected at a significance level of 1%. The results indicated that RASFF has a significant negative impact on the export value of China’s rice-based products with a significant lagged effect. The results are in line with theoretical expectations; RASFF may lead to export companies dropping out of the market (e.g., significant crowding-out effects). This result is similar to the findings of.\textsuperscript{35,36} They found that import refusals decrease exports to the United States. The negative effects of the 1-period lag are more significant than those of the current period. This may be the time lag between the issuance and formal implementation of technical trade measures, and its negative impact on trade occurs gradually over time. Tian and Chai (2019) produced similar results.

6.1.2 The Marginal Impact of Domestic Regulation
The marginal impact of domestic regulation is positive and significant at the 10% level. The results indicate that domestic regulation has a positive effect on the export of China’s rice-based products. With the improvement of the management level of the Chinese government, China’s response capacity for technical trade measures improved gradually, so the overall restriction effect of RASFF on trade from China was reduced;\textsuperscript{37} produced similar results. They pointed out that domestic regulations represent the government management level of exporting countries. With the improvement of the management level, exporting countries’ ability to deal with technical trade measures gradually increases, while the overall restriction effect of importing countries’ technical trade measures on exporting countries’ trade will be significantly reduced. Zhang Qi et al. (2013) found that the formulation of Chinese standards, regulations and the amount of external TBT-SPS notifications had significant effects on promoting vegetable exports in China.

Furthermore, China has introduced a series of regulatory measures for the cultivation and import and export trade of GM crops. For example, in 2010, the Ministry of Agriculture and Rural Affairs of the People’s Republic of China enjoined the agriculture department together with the relevant departments of Hunan and Hubei provinces to investigate and verify information on the sale of illegal GM rice-based products in individual supermarkets exposed by the network and announced the results of the investigation in a timely manner. The Ministry of Agriculture carried out supervision and spot checks on GM seeds in 2011. Emphasis was again placed on the nonuse of GM technologies in staple foods without approval in 2012. Regulatory intensity has been increasing since 2014.

Additionally, the marginal effects of the four variables, relative geographical distance, countries along the Belt and Road, an interaction item between relative geographic distance and countries along the Belt and Road, and the GDP per capita of the \textit{i}-th EU member state, were positive, positive, negative and negative, respectively. The null hypothesis was rejected at a 1% or 5% significance level. The results suggest that the Belt and Road initiative has a positive effect on rice-based products for export and that the collaboration network among countries along the Belt and Road initiative has significantly boosted the rice-based products trade between China and Europe, similar to that by.\textsuperscript{38} However, the interaction item between relative geographic distance and countries along the Belt and Road has negative marginal effects. The results show that the relative geographical distance weakens the positive effect of the Belt and Road policy on rice-based products in export trade from China to Europe. If the relative economic scale of EU member states is larger, rice-based product imports from China will be smaller.\textsuperscript{39} This finding can be explained by the high income-driven the optimization for upgrading the food consumption of households, which may generate rigid demand for organic rice products and reduce demand for rice-based products that are possibly related to GM ingredients. This also indicates that rice-based products will have greater trade potential for development in the high-end market.

6.2 Extension Analysis of RASFF Intensity
Table 3 indicates the impact of the number of RASFF notifications on rice-based product exports from China to Europe. Because the number of technical trade measures has been most widely used in the
Table 3. Extension analysis of RASFF intensity.

| Variables                      | Export value of rice-based products |
|--------------------------------|-------------------------------------|
|                                | (1)       | (2)       | (3)       | (4)       |
| Intraregional Times            | −0.161*** | −0.093*** | −0.093*** | −0.093*** |
|                                | (0.019)   | (0.018)   | (0.018)   | (0.018)   |
| 1-period lag Intraregional Times| −0.141*** | −0.141*** | −0.141*** | −0.141*** |
|                                | (0.021)   | (0.021)   | (0.021)   | (0.021)   |
| Regulate                       | −0.313*** | −0.407    |           | −0.162    |
|                                | (0.156)   | (0.253)   |           | (0.412)   |
| 1-period lag Regulate          |           |           |           | −0.162    |
|                                |           |           |           | (0.412)   |
| Other Control Variables        | yes       | yes       | yes       | yes       |
| Country Fixed                  | yes       | yes       | yes       | yes       |
| Time Fixed                     | yes       | yes       | yes       | yes       |
| R²                             | 0.628     | 0.650     | 0.650     | 0.650     |
| LR                             | 2.09***   | 2.49***   | 3.41***   | 2.82***   |

*p < 0.1; **p < 0.05; ***p < 0.01

In the existing literature,27 we use it to measure the strength of RASFF. Similar to the basic regression, the extension Model (4) considers the number of RASFF notifications within the region, the current effect of the domestic regulation and the lag effect based on the Models (1)–(3). Consistent with the basic regression, this study carries out an in-depth analysis using the estimated results of the extended Model (4).

The number of RASFF notifications and its 1-period lag both have a negative marginal impact, and the null hypothesis was rejected at a significance level of 1%. Stricter import standards are indeed trade-restrictive.40 The estimates show that if RASFF notifications increase in the EU region, China’s rice-based exports to the EU would face greater resistance. This result is consistent with the result of the investigation by,41 which found that less stringent measures would promote trade. The adverse effect demonstrates a significant lag effect.

The marginal influence of domestic regulation is not remarkable. At present China has introduced a series of regulatory measures for the cultivation of GM crops, such as investigating and verifying the information of illegal GM rice in supermarkets, launching the supervision and spot inspection of GM seeds and emphasizing that GM technology cannot be used as principal food without approval. Ghodsi pointed out that the introduction of regulations requires a certain amount of time to investigate and demonstrate before the final implementation as well as the effectiveness of role-play.42 This study believes the effectiveness of regulations depends not only on their strict comprehensive and systematic implementation but also on continuity and nonrandomness. Therefore, relevant departments urgently need to strengthen the importance of China’s exports of rice-based products. In addition, the direction of action and significance of the control variables in the extension model are consistent with the basic regression (Table 2) and will not be described here.

6.3 Extension Analysis of the RASFF Structure

Table 4 presents the impact of the structure of RASFF on rice-based products in export trade from China to Europe. Similar to the basic regression, extension Model (4) considers the structure of RASFF, the current effect of domestic regulation and the lag effect based on Models (1)–(3). Consistent with the basic regression and extension analysis of the intensity of RASFF, this study carried out an in-depth analysis using the estimated results of the extended Model (4).

Intraregional border rejection, intraregional information and its 1-period lag both have negative marginal impacts, and the null hypothesis was rejected at a significance level of 1% and 5%, respectively. One possible explanation is that border rejection is used to strengthen the control of imported rice-based products and ensure that these prohibited products will not enter the EU market through other border stations. All border stations in the EU Exclusive Economic Zone (EEZ) will be notified of a border rejection imposed by a member state of the EU. Additionally, policy changes significantly affect the frequency of border
controls. However, the marginal effect of intraregional border rejection is delayed, and this inhibitory effect will start to appear over the subsequent 1-year period. The information notifications mainly include the reasons for why the food or feed of concern was detected and rejected in EU ports. The goods did not enter the EU market, so the information does not command a rapid response. The lagging measures taken by EU member states make the negative effect of the information over the subsequent 1-year period more significant. The information has prevented the entry of GM rice-based products into the EU market, leading to an increase in the fixed and variable costs of export enterprises, affecting the internal and external margins of export and reducing the export trade value.

Furthermore, the marginal impact of warnings was not significant. This can be explained by saying that the EU implements a strict quantitative mandatory labeling system, with the threshold set to 0.9%. If GM rice-based products account for more than 0.9% of the rice ingredients, they will be identified as GM food. Once detected, such products will face border rejection and information notifications. Therefore, it is almost impossible for GM food to enter EU ports or appear on the EU food market. The purpose of the warning is to provide information for all RASFF members to confirm whether related products have entered their markets and to take the necessary measures.

### 6.4 Robustness Test: Ignoring the Diffusion Effect of RASFF

Once technical trade measures come into effect, they have a strong diffusion effect, one of which is horizontal diffusion among sponsors. This study considers the intraregional diffusion effect of RASFF in the basic regression. To verify this diffusion effect in reverse, the following section ignores the diffusion effect and directly estimates the impact of RASFF imposed by a country on China’s export of rice-based products. The estimated results are shown in Table 5. Contrary to the estimated results of the basic regression, the 1-period lag in implementation, intensity, border rejection, warning and information of RASFF in importing countries all showed a positive marginal effect. This means that the positive effect of information disclosure in technical trade measures for the exporting countries is far less
than the negative diffusion effect, and increases trade costs.

7. Conclusion

The study found that RASFF has a negative impact on the trade in rice-based products exported to Europe and that it has a significant lag effect. The intensity of RASFF increases trade resistance to rice-based products exported to Europe. It also has a significant lag effect. The negative effect of RASFF is mainly shown in the entry links instead of the market links. Border rejection notifications and information notifications are the main means of notification at the entry links. The inhibition of these two measures on the export of rice-based products to Europe showed a time lag effect. However, the marginal effect of alert notifications at the market links was not significant. Furthermore, the positive effect of information disclosure of the technical trade measures implemented by individual EU member states is far less than the negative diffusion effect on Chinese corporations. The positive effect of domestic regulation on the trade in rice-based products exported to Europe is only significant at the 10% level.

This study constructs a theoretical model to reveal the influence mechanism of RASFF’s implementation, intensity and structure on exports of rice-based products to Europe. This study extends the theoretical model of the impact of technical trade measures on agricultural products. It also provided method support. The conclusion of the study has important implications for the promotion of relevant government departments to deal with more stringent technical trade measures. First, RASFF technical trade measures implemented by EU member states that adhere to the precautionary principle in relation to GM food will have a serious inhibitory effect on trade in agricultural products that contain of GM ingredients.

A general plan for crisis management in the field of the safety of food and feed established in 2019 by the EU will exacerbate this negative impact,

Table 5. The robustness test of ignoring the diffusion effect of RASFF.

| Variables | Export value of rice-based products |
|-----------|------------------------------------|
|           | (1)      | (2)      | (3)      |
| RASFF of importing countries | −0.259   |          |          |
| 1-period lag RASFF of importing countries | 0.698    | (0.499)  |          |
| the number of RASFF of importing countries | 0.021    | (0.069)  |          |
| 1-period lag the number of RASFF of importing countries | 0.172**  | (0.074)  |          |
| Border rejection of importing countries |          | 0.037    |          |
| 1-period lag Border rejection of importing countries | 0.315*** | (0.117)  |          |
| Alert of importing countries |          | −0.067   | (0.098)  |
| 1-period lag Alert of importing countries | −0.400*  | (0.227)  |          |
| information of importing countries | 0.181    | (0.220)  |          |
| 1-period lag Information of importing countries | 0.491*** | (0.165)  |          |
| Regulate | 0.381*   | 0.420*   | 0.449*   |
| 1-period lag Regulate | 0.471    | 0.536    | 0.524    |
| Other Control variables | yes      | yes      | yes      |
| Constant | −401.826 | −286.559 | −242.710 |
| (564.332) | (557.183) | (634.484) |          |
| Country Fixed | yes      | yes      | yes      |
| Time Fixed | yes      | yes      | yes      |
| R² | 0.637    | 0.637    | 0.645    |

***p < 0.01; **p < 0.05; *p < 0.1
which would, in turn, drive companies to exit the EU market. Second, RASFF technical trade measures indicate that Chinese rice-based products exported to Europe contain GM ingredients. China has not yet allowed the commercialization of GM rice, GM corn or other rice-based products. Therefore, some developers may be illegally conducting field trials, resulting in the intentional or unintentional release of GM ingredients into the environment at one stage of the intermediate test, environmental release and productive test. The developers apply for trial accreditation by passing off transgenic varieties as nontransgenic; and some growers illegally obtain GM seeds and grow them commercially.

The following recommendations are made. First, supervision should start from the source and should be strengthened throughout the entire process of GM organism testing including the control conditions of the intermediate test before filing, institutional development after approval, the implementation of control measures, and the storage and treatment of test materials, and the whole test can be managed with traceability. Second, the supervision of trial examination and the areas of variety approval should be strengthened, and the GM varieties that have not obtained safety certificates should not be allowed to perform regional testing. Third, the supervision of seed production and operation links should be strengthened, and a system of open and secret investigations should be implemented, relevant personnel should carry out surprise biological inspections of seed enterprises and bases for breeding, and testing before seeds fall to the ground and during the seedling should be implemented. Fourth, related business departments also need to establish technical trade measures and early warning mechanisms for agricultural products and long-effect rapid response mechanisms in the case of emergencies. China’s agricultural trade with the EU, which involves the risk of GM ingredients, should be comprehensively evaluated. In addition to rice-based products, it is also essential to determine what other foods may inevitably lead to a low level of mixing due to the technicalities and provide enterprises with lists to reduce sunk costs in the process of export trade agricultural products toward the EU. Fifth, relevant enterprises should pay constant attention to the development trends and information disclosures of relevant technical standards in importing countries, check whether their products comply with relevant regulations, minimize the probability of blocked exports of agricultural products, and calmly deal with the adverse impact of technical trade measures. The research framework and method of this paper have important reference value for countries engaged in the trade of rice-based products involving GM ingredients and for the study of other agricultural trade products (papaya, etc.).

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This project was funded by the Talent Training Project of Yunnan Province (KKSY201408035), the Hot Frontier Project of Faculty of Management and Economics of Kunming University of Science and Technology (QY2014003).

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