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The Welfare Impact of India's Rice Tariff from a Global Perspective

—Research on Computable Local Equilibrium Model

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Abstract

Based on the literature of Francois and Hall (1997, 2003, 2007), this article constructs a computable partial equilibrium model and data on rice production and trade in countries related to India's rice export tariffs in 2022. The empirical analysis is conducted from the industry level on the impact of India's rice export tariffs on rice trade, production, prices, and producer and consumer welfare in relevant countries or regions. The following conclusions are drawn: Firstly, the trade disruption effect of India's imposition of rice export tariffs is significant, with exports to other countries (regions) decreasing by over 80%; Secondly, the imposition of rice export tariffs by India has only increased consumer prices for rice in India and China by 7.9% and 3.9%, and the cost of export tariffs will be borne by importers; Thirdly, imposing rice export tariffs in India does not provide substantive protection for Indian rice consumers, as the price of Indian rice consumers has increased by 7.9%; Fourthly, from the perspective of social net welfare indicators, India's imposition of rice export tariffs resulted in an increase of $471 million in India's social net welfare and a loss of $93.1 million in China's social net welfare. However, from the perspective of individual group welfare, Indian rice producers and consumers will become the biggest victims, losing $7.04 billion and $4.10 billion, respectively; Fifthly, looking at the entire data, India's imposition of rice export tariffs has a relatively small impact on China's rice supply and consumption, with only 3.9% change in prices for both Chinese producers and consumers.

Keywords

Export Tariffs, Indian Rice, Computable Local Equilibrium Model, Welfare Effect

1. Introduction

Since the onset of COVID-19, global food supply has shrunk and stocks have decreased. At the same time, driven by insufficient rainfall in major rice-producing areas and the Russia-Ukraine conflict, global food prices have reached a record high in recent months. In order to ensure its domestic food supply, India has adopted export restrictions, announcing that it will impose a 20% export duty on certain varieties of rice on September 9, 2022. Among them, an export tariff of 20% will be imposed on unrolled rice, hulled brown rice, and semi- or full-milled rice starting from September 9th. As the world's largest rice exporter, India provides over 40% of its rice to the international market, surpassing the total exports of Thailand, Vietnam, Pakistan, and the United States last year. In addition, Vietnam and Thailand are also major global rice exporters and major competitors of Indian rice. The white and brown rice that has been subject to tariffs, this time accounts for over 60% of India's exports, which will weaken India's competitiveness in the world market. During the 2007 food price crisis, India also took similar actions to ban rice exports, which pushed global rice prices to new heights. There are various types of export restrictions, including minimum export prices, general export licenses, special export licenses, export tariffs, and absolute export bans. The adoption of such export restrictions, known as food protectionism, is contrary to the concepts of globalization and free trade, but it is in line with the expectations of the country to protect its food sovereignty. Food protectionism is aimed at preventing international food prices from affecting domestic food prices, which is closely related to the high integration of national and international markets, the large import and export volume of food, and the susceptibility of food prices to pass from the international market to the local market; it is also to avoid domestic food shortages, which are mainly related to food exporting countries. High international food prices may lead to a large amount of food flowing from the local market to the international market, which will also create a situation of food shortage in the local market.

In order to explore the welfare impact of India's rice tariff, this paper will analyze from the following aspects. First of all, this paper summarizes the domestic and foreign scholars' research on food security and the welfare impact of tariff policies. Then, it makes a detailed analysis of the current situation of global rice production, trade and consumption, and combines the GSIM model to analyze the impact of India's tariff on global rice production, trade, price, and producer and consumer welfare. This paper can not only deepen the understanding of the economic and welfare impact of India's rice tariff increase, but also provide a certain reference for China's rice import and export.

2. Literature Review

Headey and Martin (2016) and Headey (2013) believe that the implementation of food protectionism measures by major food exporting countries has a negative impact on food importing countries and has an upward impact on glob-

al food prices. Yuan (2013) conducted an in-depth analysis of the evolution process, influencing factors, and interrelationships between the international grain market and China's grain import and export trade. He concluded that grain exporting countries restrict grain exports, while grain importing countries rush to purchase or hoard grain, resulting in a superimposed negative effect on the international grain market, causing high grain prices, and ultimately threatening global food security, especially seriously harming poor countries in food shortages. Sun (2011) used time series data to empirically analyze the impact of export restrictions from major grain-producing countries on international grain prices during the 2007-2008 food crisis. The study proved that the trade volume of major rice-producing countries has a significant negative impact on international grain prices. Li and Ma (2015) used cointegration tests and VAR models to analyze the interrelationships between domestic and international grain prices.

Some literature empirically examines the welfare impact of tariff policies. Sheng (1995) used the General Equilibrium Model (CGE) to measure and analyze the welfare effects of China's trade liberalization. Ye et al. (2008) established a GSEM model to simulate and compare the impact of different policy adjustments on the social welfare of the grain sector. The results showed that the tariff quota system and ecological return policy would reduce the social welfare of the grain sector, while the grain subsidy policy could improve the welfare of the grain sector and compensate for the loss of producer welfare caused by market opening. You and Fan (2009) analyzed the impact of embargo policies on the welfare of various countries, stating that export embargoes will inevitably cause welfare losses in the domestic food industry and have adverse effects on food and agriculture or grain enterprises. Huang et al. (2010) constructed an agricultural CGE model to analyze food security issues under the conditions of increasing agricultural subsidies. The simulation results showed that the increase in agricultural subsidies is conducive to promoting household consumption and government consumption, and the overall macroeconomic development shows a good trend. Liu and Chen (2014) used the GTAP simulation method to quantitatively examine the changes in economic effects brought about by reducing technical trade barriers under the RCEP framework. The research results showed that achieving zero tariffs within the RCEP region has a significant positive change effect on the economic aggregate, welfare level, and trade scale of member countries. Miao (2014) used the Minot welfare effect model to test and decompose the changes in farmers' welfare during grain price fluctuations based on the estimation of grain supply and demand elasticity and grain yield. Zheng and Pu (2015) used wheat as an example to analyze the social welfare impact of the current minimum purchase price policy for grain from multiple perspectives. They believed that the minimum purchase price policy for grain achieved a win-win situation between social benefits and the benefits of participating entities in the initial stage. However, as the domestic situation changed, producers,

private grain enterprises, and overall social welfare were affected. Under the background of agricultural subsidy policy reform, Wang et al. (2018) conducted field research data on 353 small wheat planting households in Qitai County, Xinjiang. From the perspective of micro welfare, a logistic binary regression model analysis showed that after the agricultural subsidy policy reform, the willingness to operate the scale of grain, agriculture, and food in Qitai County was not obvious. Guo and Chen (2019) used the CGE model to dynamically simulate the economic effects of trade frictions between China and the United States. The research results showed that trade frictions between China and the United States will have a profound impact on the global macro economy, and the imposition of tariffs will have adverse effects on GDP growth and residents' welfare of both China and the United States. Su and Huo (2019) constructed an equivalent model of tariffs for state-owned trade in China's major grain imports. The results showed that pursuing the goal of maximizing profits can effectively correct and reduce trade distortions and welfare losses in the three major grain import state-owned trade. Zhong et al. (2021) analyzed the domestic performance of grain export restrictions in Russia and Ukraine under the recent three fluctuations in the international grain market, and found that the role of grain export restrictions in isolating foreign grain prices and stabilizing domestic grain prices is very limited. Its effect may be offset by further increases in international prices and increased inventory.

Due to the difficulties in collecting a large amount of data in the CGE model, a computable local equilibrium model has emerged to overcome this limitation. Francois and Hall constructed the "Commercial Trade Policy Analysis System" (referred to as the COMPAS model), and later expanded the bilateral perspective of the COMPAS model to a global perspective of the "Global Simulation Model" (referred to as the GSIM model). In addition, the Agricultural Trade Policy Simulation Model (ATPSM) developed by the Food and Agriculture Organization of the United Nations and the Single Market Local Equilibrium Simulation Tool (SMART) developed by the World Bank are both computable local equilibrium models. Compared with the CGE model, the computable local equilibrium model has the following advantages: Firstly, due to only examining the clearance of a single product market, the number of equations required to be solved is greatly reduced, and the model has high operability, flexibility, and transparency; Secondly, simply collecting industry level relevant data not only reduces the difficulty of data collection, but also effectively avoids "aggregation errors" in data aggregation, improving the accuracy of simulation results.

Much research has been done on the topic of grain export restrictions. However, most of the existing studies show that the impact of export restrictions on international markets is mostly, and the impact on local welfare in food exporting countries is relatively small. In view of this, this paper hopes to make some contributions to the analysis of the welfare impact on food exporting countries. Based on Francois and Hall (2003, 2007) and other literatures, this paper con-

structs a computable partial equilibrium model. Firstly, it theoretically analyzes the impact of tariff increase on the local economy and welfare of grain exporting countries, and then computationally and programmatically applies the partial equilibrium model to the data of global rice trade, production and consumption in 2021. The welfare effects of India's rice tariff policy on different subjects were simulated.

3. Research Design and Data Collection

3.1. Research Design

GSIM simulation analysis belongs to comparative static analysis, which analyzes the impact of relevant policies by comparing indicators of changes before and after implementation. The main steps are: Firstly, to determine a base period for inspection, collect and calculate data on the output, import and export trade volume, market share, and other specific products of the country during the base period; Secondly, assuming that all other conditions remain unchanged except for a certain trade policy (excluding the influence of other factors), the model is used to simulate the output, price, import and export trade and other indicator values of specific products in each country when the market is cleared again; finally, by comparing simulated values with base period values, the economic and welfare impacts of trade policy changes at the industry level are identified.

Although the GSIM model is a local equilibrium model, it belongs to multilateral analysis and can flexibly select the number of countries according to research needs. This article balances the global rice trade and production situation using a 12 country model. Specifically, in addition to the six major rice exporting countries of India, Thailand, Vietnam, Pakistan, the United States, and Myanmar, we also selected five major rice importing countries based on the 2021 rice export trade situation, including China, the Philippines (PH), the European Union (EU), Nigeria, and Iraq, and then regarded the other countries as a whole.

3.2. Data Collection

The data required for the GSIM model mainly includes the following three categories: 1) the import and export trade volume of rice between selected countries (regions) in 2021; 2) The parameters of rice demand elasticity, supply elasticity, substitution elasticity, etc. in the selected country (region); 3) Import tariffs for rice in the selected country (region).

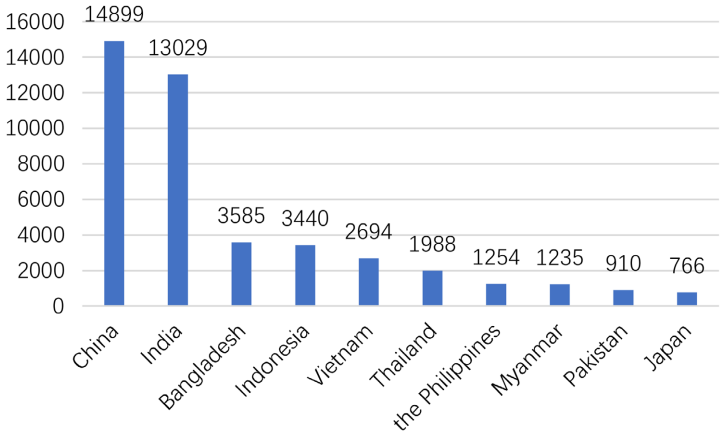
3.2.1. Global Rice Production, Trade, and Consumption Status

1) Global rice production and domestic sales situation. According to statistics from the US Department of Agriculture, China is currently the world's largest rice producer, with an annual output of 149 million tons, accounting for 28.9% of the global production that year. India, which ranks second, produced 130 million tons of rice in 2021, accounting for 25.3% of the global total production.

Therefore, China and India's total rice production accounts for more than half of the global rice production (Figure 1).

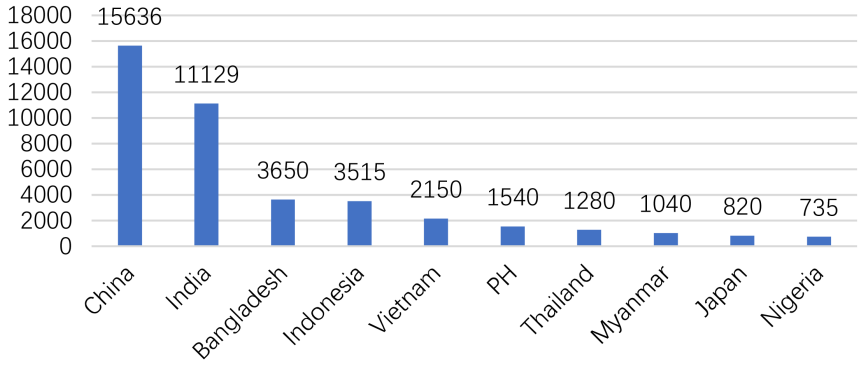
In addition, China is also the world's largest domestic rice producer, consuming 160 million tons of rice in 2021 (Figure 1). Compared to its production volume, China still needs to import a large amount of rice. India, ranked second, had a total domestic consumption of 110 million tons in 2021. Similarly, the total domestic consumption of rice in China and India exceeds half of the world. It can be seen that China and India play a crucial role in the import and export of rice (Figure 2).

2) China's rice import situation. China is not only the world's largest producer and domestic seller of rice, but also the world's largest importer of rice. According to statistics from the United Nations Commodity Trade Database, the overall import volume of rice in China had not changed much before 2012, with an annual total import volume ranging from 230,000 to 750,000 tons. In 2012, China's import volume experienced a significant increase, reaching 2.344 million tons, and then maintained a relatively high level. In 2021, the import reached a



Data source: The authors collated according to the United Nations Commodity Trade Database.

Figure 1. Top 10 global rice producers in 2021 (Unit: 10,000 tons).



Data source: The authors collated according to the United Nations Commodity Trade Database.

Figure 2. Top 10 global rice domestic sales countries in 2021 (Unit: 10,000 tons).

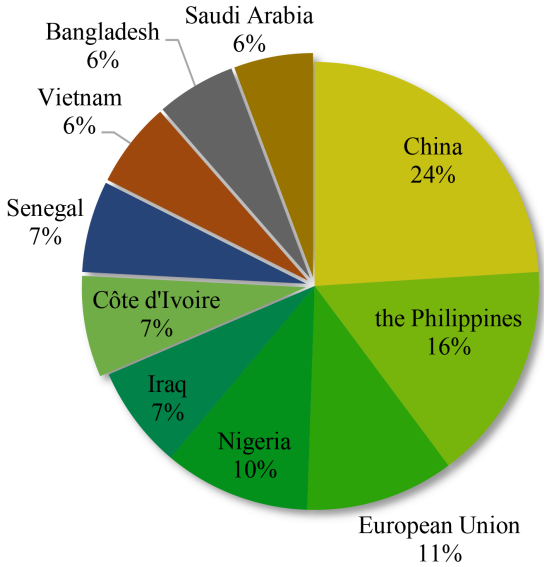
historic high of 4.924 million tons. India is China's largest importer of rice. In 2021, China imported 1.089 million tons of rice from India, accounting for 22.1% of China's total rice imports that year. Vietnam and Pakistan are the second and third largest countries for China to import rice. In addition, among the top ten countries in the world that import rice, except for China accounting for 10.9% of the world and the Philippines accounting for 6.6% of the world, the proportion of other countries is relatively stable, ranging from 2% to 4% (Figure 3).

India is the world's largest exporter of rice. According to statistics from the US Department of Agriculture, India's total rice exports in 2021 were 22 million tons, accounting for 39.3% of global exports. Ranked second, third, and third are Thailand, Vietnam, and Pakistan, with a total export of only 19.4 million tons of rice, accounting for 34.7% of global exports. In 2021, India's rice exports were higher than the total exports of Thailand, Vietnam, and Pakistan that year. Obviously, India holds an important position in world rice exports (Figure 4).

3) The amount of rice trade between the selected countries (regions). The author compiled the rice import and export trade volume between the selected countries (regions) in 2021 based on data from the United Nations Commodity Trade Database and the United States Department of Agriculture. The bold values in Table 1 represent the domestic sales of rice in the corresponding country (region), which are obtained by subtracting the total output value of rice in that country (region) from its export value.

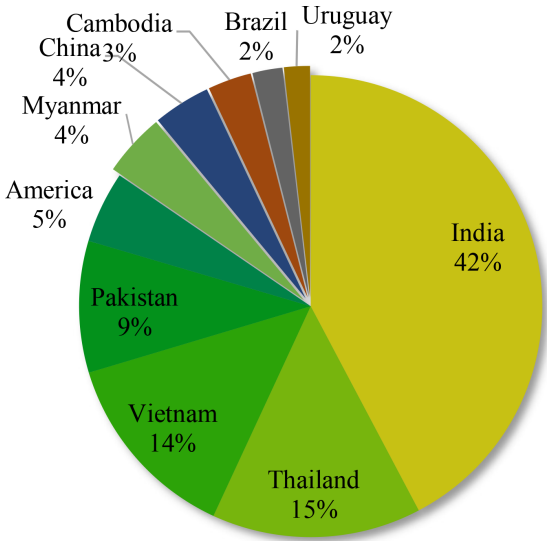
3.2.2. Elasticity Parameter

Elastic parameters are the most critical parameters in the GSIM model and have a direct impact on the simulation results. There are three different elasticity



Data source: The authors collated according to the United Nations Commodity Trade Database.

Figure 3. Top 10 global rice importers in 2021.



Data source: The authors collated according to the United Nations Commodity Trade Database.

Figure 4. Top 10 global rice exporters in 2021.

Table 1. Selected countries (regions) import, export, and domestic sales of rice in 2021 (in millions of US dollars).

Exporter (Region)	Importing Country (Region)											
	India	Thailand	Vietnam	Pakistan	America	Myanmar	China	PH	EU	Nigeria	Iraq	Others
India	49173.4	2.3	262.3	0.1	210.7	0.2	369.4	38.7	148.4	5.9	522.0	8063.6
Thailand	1.0	5575.3	7.8	0.0	512.3	0.8	327.6	60.6	167.2	0.9	113.4	2150.1
Vietnam	0.0	1.4	9056.4	0.0	15.2	0.0	522.8	1252.1	44.6	0.6	0.0	1173.0
Pakistan	0.0	1.4	0.0	1952.6	25.1	0.0	381.2	15.8	350.1	0.0	12.7	1366.0
America	1.1	2.2	0.0	0.1	1580.7	0.0	0.0	0.1	27.0	0.7	45.8	1851.5
Myanmar	0.1	3.9	3.9	0.0	0.0	4564.5	302.0	83.2	139.7	0.0	0.0	137.8
China	0.0	1	13.1	37.9	0.3	0.0	66,710.8	48.0	14.5	0.0	0.0	892.6
PH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5694.3	0.0	0.0	0.0	0.6
EU	1.3	0.2	0.0	0.0	32.6	0.0	0.2	0.2	590.8	0.1	0.0	385.3
Nigeria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2386.2	0.0	0.1
Iraq	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	113.5	0.0
Others	1.2	1.9	425.0	0.0	196.9	0.0	284.2	5.4	565.9	0.0	0.0	1654.2

Data source: The authors compiled it based on the United Nations Commodity Trade Database and other sources.

parameters in the GSIM model: supply elasticity, demand elasticity, and substitution elasticity. According to Wang et al. (2017), the long-term price elasticity of China's rice import demand is −3.8, and the short-term price elasticity is −1.53; Miao and Lu (2011) estimated that the price elasticity of demand for rice in China is −0.0542. According to Kumar et al. (2011), the price elasticity of demand for food in India is −1.29. According to Digal and Placencia (2019), the

price elasticity of Philippine rice is −1.528 (compensated) and −1.647 (uncompensated). Soe et al. (1994) estimated that the price elasticity of demand for general quality rice in Myanmar is −0.95, while the price elasticity of demand for high-quality rice is −0.96. Isvilanonda and Kongrith (2008) estimated that the price elasticity of demand for Thai rice is −0.392. Onyeneke et al. (2020) estimated that the elasticity of demand for rice in Nigeria is −0.233 (compensated) and −0.770 (uncompensated). Rani et al. (2020) estimated that the demand elasticity for rice in Pakistan is −0.739. Due to the lack of literature on direct estimation of national rice elasticity parameters, the author used the elasticity parameter values from GTAP 9.0 as a substitute (Table 2).

3.3.3. Rice Tariff Rate

The import tariff rate for rice in the selected country. This article collects data on rice import tariff rates (MFN rates) for selected countries in 2021 from the World Trade Organization (WTO) tariff inquiry system. In the simulation analysis, it is assumed that except for India, which imposes a 20% rice export tariff on all countries, the rice export tariff rates of other countries remain unchanged (Table 3).

Table 2. Size of demand, supply, and substitution elasticity of rice in selected countries.

	India	Thailand	Vietnam	Pakistan	America	Myanmar	China	PH	EU	Nigeria	Iraq	Others
Demand Elasticity	−1.29	−0.392	−0.971	−0.739	−0.58	−0.95	−0.0542	−1.528	−0.58	−0.233	−0.975	−0.95
Supply Elasticity	1.79	1.79	1.79	1.79	2.14	1.79	1.89	0.84	0.84	0.84	0.84	1.22
Substitution Elasticity	5.05	5.05	5.05	5.05	5.05	5.05	5.05	5.05	5.05	5.05	5.05	5.05

Data source: The authors collated and obtained according to relevant research results.

Table 3. Rice tariff rates for selected countries (regions) (Unit: %).

Exporter (Region)	Importing Country (Region)											
	India	Thailand	Vietnam	Pakistan	America	Myanmar	China	PH	EU	Nigeria	Iraq	Others
India	0.00	52.00	40.00	5.00	11.20	5.00	1.00	35.00	7.70	10.00	0.00	22.00
Thailand	70.00	0.00	40.00	11.00	11.20	5.00	1.00	50.00	7.70	10.00	0.00	22.00
Vietnam	70.00	0.00	0.00	11.00	11.20	5.00	1.00	50.00	7.70	10.00	0.00	22.00
Pakistan	70.00	52.00	40.00	0.00	11.20	5.00	1.00	35.00	7.70	10.00	0.00	22.00
America	70.00	52.00	40.00	11.00	0.00	5.00	1.00	35.00	7.70	10.00	0.00	22.00
Myanmar	70.00	0.00	40.00	11.00	11.20	0.00	1.00	50.00	0.00	10.00	0.00	22.00
China	70.00	52.00	40.00	8.00	11.20	5.00	0.00	50.00	7.70	10.00	0.00	22.00
PH	70.00	0.00	40.00	11.00	11.20	5.00	1.00	0.00	7.70	10.00	0.00	22.00
EU	70.00	52.00	40.00	11.00	11.20	5.00	1.00	35.00	0.00	10.00	0.00	22.00
Nigeria	70.00	52.00	40.00	11.00	11.20	5.00	1.00	35.00	7.70	0.00	0.00	22.00
Iraq	70.00	52.00	40.00	11.00	11.20	5.00	1.00	35.00	7.70	10.00	0.00	22.00
Others	70.00	52.00	40.00	11.00	11.20	5.00	1.00	35.00	7.70	10.00	0.00	22.00

Data source: The authors collated according to the World Trade Organization tariff database.

4. Impact of India's Imposition of Rice Export Tariffs on Global Rice Trade, Production, and Welfare Effects

This article simulates the economic and welfare impacts of India imposing a 20% export tariff on rice based on data from 2022. The output module of the GSIM model mainly includes four parts: Firstly, the changes in the volume of rice trade and trade (including domestic sales and domestic sales) between countries; Secondly, changes in rice production in relevant countries; Thirdly, changes in producer and consumer prices of rice in relevant countries; Fourthly, regarding changes in the surplus of national rice producers and consumers, changes in government tax revenue, and changes in social net welfare.

4.1. Size of Trade Effects

Regarding the trade effects of tariff changes, the GSIM model outputs both the magnitude of changes in trade volume among countries and the simulation of changes in trade volume between countries. Based on relevant research, Bown et al. comprehensively summarized the trade effects of anti-dumping measures and summarized four main trade effects of anti-dumping measures: trade restriction effect, trade diversion effect, trade inhibition effect, and trade diversion effect. According to Bown et al.'s research, this article categorizes the trade effects of India's export tariffs into four different types.

Table 4 shows the changes in rice trade volume between selected countries (regions) in 2022, simulated by the GSIM model. According to the ranking of

Table 4. Impact of India's 20% export tariff on rice trade between selected countries (regions) (Unit: %).

Exporter (Region)	Importing Country (Region)											
	India	Thailand	Vietnam	Pakistan	America	Myanmar	China	PH	EU	Nigeria	Iraq	Others
India	**−10.2**	−162.2	−160.2	−137.1	−154.4	−157.9	−155.8	−156.0	−131.3	−88.3	−81.9	−101.0
Thailand	14.6	**−1.1**	0.9	0.0	6.7	3.2	5.3	5.1	29.9	72.9	79.3	60.1
Vietnam	0.0	1.4	**3.4**	0.0	9.2	0.0	7.8	7.6	32.3	75.3	0.0	62.6
Pakistan	0.0	−32.3	0.0	**−7.3**	−24.5	0.0	−25.9	−26.2	−1.4	0.0	48.0	28.8
America	26.4	10.7	0.0	35.7	**18.5**	0.0	0.0	16.8	41.6	84.6	91.0	71.8
Myanmar	7.2	−8.5	−6.5	0.0	0.0	**−4.3**	−2.1	−2.4	22.4	0.0	0.0	52.6
China	0.0	−5.6	−3.6	19.4	2.2	0.0	**0.8**	0.5	25.3	0.0	0.0	55.5
PH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**−13.3**	0.0	0.0	0.0	41.7
EU	−31.8	−47.4	0.0	0.0	−39.6	0.0	−41.0	−41.3	**−16.5**	26.5	0.0	13.7
Nigeria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**−4.1**	0.0	−16.9
Iraq	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**94.5**	0.0
Others	−3.8	−19.5	−17.5	0.0	−11.6	0.0	−13.0	−13.3	11.5	0.0	0.0	**41.7**

Note: The bold values in the table indicate the change in rice sales within the country (region). Data source: Based on GSIM model simulation.

rice exporting and importing countries, the simulation results in Table 4 can be divided into four parts: the upper left corner represents the changes in trade volume between rice exporting countries, the upper right corner represents the changes in rice trade volume between exporting countries and importing countries, the lower left corner represents the changes in rice trade volume between importing countries and exporting countries, and the lower right corner represents the changes in trade volume between rice importing countries.

1) Trade disruption effects. The simulation results in Table 4 indicate that imposing a 20% export tariff on rice in India will result in an average decrease of 101% in Indian rice exports compared to 2022. Meanwhile, Chinese rice exports to Thailand decreased by 5.6% and exports to Vietnam decreased by 6.5%. This indicates that the imposition of tariffs by India has a significant trade damaging effect on Pakistan's rice exports to Thailand. There are two main reasons for this: Firstly, imposing tariffs will lead to an increase in the cost of China's rice imports from India, resulting in a decrease in the import volume of China's rice imports from India; Secondly, countries such as Thailand, Vietnam, and Pakistan are all major rice exporting countries, making China's rice imports selective in the international market.

2) Trade transfer effect. The simulation results in Table 4 indicate that while India's rice export volume has significantly decreased, other countries or regions such as Thailand, Vietnam, and the United States have significantly increased their rice export volume to importing countries. This indicates that the imposition of export tariffs by India will lead to an increase in the export value of rice from countries or regions such as Thailand, Vietnam, and the United States to the international market, indicating a significant trade transfer effect.

3) Trade deflection effect. The phenomenon of China's rice imports from India being hindered and turning to third-party markets. According to the simulation results in Column 8 of Table 4, it can be seen that when India imposes a 20% rice export tariff, China's imports from Thailand and Vietnam both increase by more than 5%. This indicates that there is indeed a so-called trade bias effect in India's imposition of rice export tariffs. It is precisely the existence of this trade deflection effect that partially offsets the loss of India's import share.

4) Changes in domestic sales of rice in China and India. The values on the diagonal in Table 4 represent the magnitude of changes in domestic rice sales in the corresponding countries. Obviously, when India imposed a 20% export tariff on rice, China's domestic rice sales only increased by 0.8%, indicating that the impact of India's rice export tariff on China's domestic market sales is very limited. The main reason is that China is the world's largest rice producer, with sufficient food supply and a market adjustment for imported rice. From the simulation results in Table 4, it can also be seen that under the 20% export tariff imposed by India, the domestic sales of rice in India decreased by 10.2%.

In summary, due to the existence of trade deflection effects and trade transfer effects, the adverse impact of India's 20% export tariff on China's rice imports is

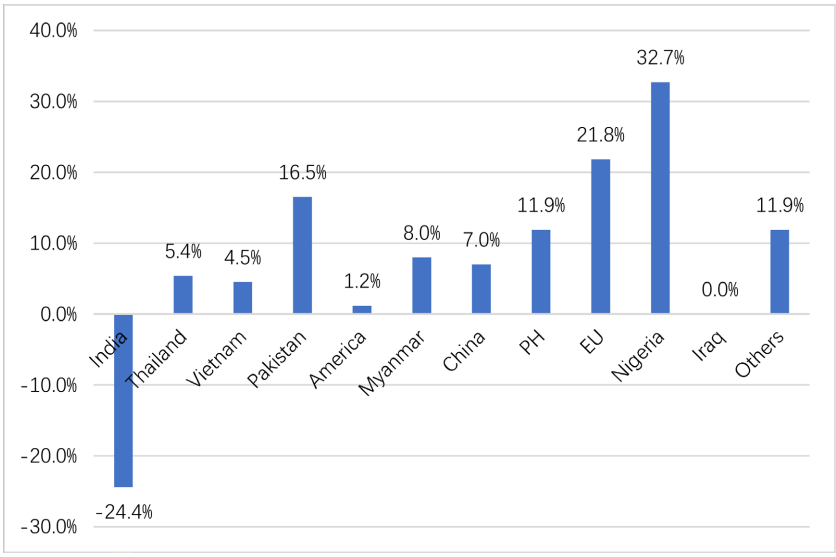
relatively limited.

4.2. Rice Yield and Price Effect

4.2.1. Changes in Rice Yield

Another noteworthy issue is the impact of India's imposition of export tariffs on rice output in selected countries (regions). Figure 5 shows the simulation results of the GSIM model. Overall, India's imposition of rice export tariffs will lead to varying degrees of increase in rice production in countries such as Thailand, Vietnam, and Pakistan. Among them, the EU and Nigeria have the largest increases in rice production, with increases of 21.8% and 32.7%, respectively. The reason is that the European Union and Nigeria are major rice importers, with a relatively high degree of dependence on foreign rice. India, Thailand, Vietnam, and Pakistan are all important rice importers, so the imposition of rice export tariffs by India has a significant beneficial impact on its rice production. Figure 5 also indicates that the imposition of rice export tariffs by India will have a positive impact on China's rice production, with an annual increase of approximately 7.0%. Considering the large production base of China's Big Secret, the annual increase is the largest among the selected countries (regions).

From Figure 5, it can also be seen that the imposition of rice export tariffs by India has no impact on Iraq's rice production. The main reason is that Iraq is a major importer of rice, and its domestically produced rice does not circulate in the international market and is sold entirely domestically. Therefore, India's imposition of rice export tariffs limits its rice production. Overall, the imposition of rice export tariffs by India has a positive impact on rice production in most countries (regions). The reason for this is: Firstly, this article only simulated the impact of India's imposition of rice export tariffs, without considering the impact of non-tariff barriers between countries; Secondly, due to the impact of



Data source: Based on GSIM model simulation.

Figure 5. Changes in rice production in major countries (regions).

natural factors such as land and climate on rice production, it is difficult to see significant changes in rice production in the short term.

4.2.2. Price Changes of Rice

Table 5 shows the impact of India's imposition of rice export tariffs on rice prices in selected countries (regions). It can be seen that the impact of India's imposition of rice export tariffs on rice prices varies greatly among different countries (regions). Rice prices in countries (regions) such as Thailand, Vietnam, and Pakistan will increase to a certain extent, with Nigeria having the largest increase in producer and consumer prices, and the price of rice in India will decrease. However, overall, the impact of India's imposition of rice export tariffs on rice prices in exporting countries is relatively limited, while the price range of rice in importing countries is relatively large.

The simulation results in Table 5 indicate that consumer prices of rice in the Indian market have increased by 7.9%, while producer prices have decreased by 13.6%. In addition, the consumer price of rice in the Chinese market has only increased by 3.9%, much lower than the increase in Indian consumer prices. This indicates that the imposition of rice export tariffs by India has harmed both domestic producers and consumers, while the impact on rice prices in the Chinese market is relatively low.

4.3. Welfare Effect

The welfare effect of this article mainly includes four aspects: producer surplus, consumer surplus, government tax revenue, and government subsidy revenue. Add up the four benefits mentioned above to obtain the net change in the corresponding country's social welfare. The welfare changes of the selected countries (regions) under the 20% export tariff on rice imposed by India are shown in Table 6.

1) The welfare impact on China. Table 6 shows that India's imposition of rice export tariffs will increase the welfare level of Chinese rice producers, with an annual increase of approximately $2.755 billion from 2022. The reason is that China is also a major exporter of rice, and India's imposition of rice export tariffs has increased import costs, inevitably leading to a significant increase in Chinese rice exports, thereby improving the welfare level of Chinese rice producers. Meanwhile, the imposition of rice export tariffs by India will lead to a decrease in the welfare level of Chinese rice consumers, resulting in an annual

Table 5. Impact of rice export tariff imposed by India on rice prices in selected countries (regions) (Unit: %).

Country/Region	India	Thailand	Vietnam	Pakistan	America	Myanmar	China	PH	EU	Nigeria	Iraq	Others
Producer Price Changes	−13.6	3.0	2.5	9.2	0.7	4.5	3.9	6.7	12.2	18.3	0.0	6.7
Consumer Price Changes	7.9	3.0	2.5	9.2	0.7	4.5	3.9	6.7	12.2	18.3	0.0	6.7

Data source: Based on GSIM model simulation.

welfare loss of approximately $2.842 billion. A possible economic explanation is that although India's imposition of rice export tariffs is beneficial for China to export rice to the international market, it will also greatly reduce China's import of rice from the international market, leading to a decrease in the supply of Chinese rice to the domestic market and an increase in domestic rice market prices, which will have a negative impact on the welfare of Chinese consumers. In addition, the imposition of rice export tariffs by India will result in a reduction of approximately $6 million in China's rice tariff revenue annually. Finally, let's take a look at the impact of India's imposition of rice export tariffs on China's net welfare. Table 6 shows the changes in net welfare of countries (regions), and simulation results show that China's social net welfare has decreased, with an annual loss of approximately 93.1 million US dollars.

2) The welfare impact on India. From Table 6, it can be seen that the imposition of rice export tariffs by India is very detrimental to both domestic producers and consumers, with a significant decrease in producer and consumer surplus. The surplus of Indian producers will decrease by approximately $7.044 billion annually, while the surplus of consumers will decrease by approximately $4.106 billion annually. However, with India imposing a 20% export tariff on rice, its subsidy income will increase by $11.62 billion, and the tariff income will only increase by $200,000. Ultimately, the net social welfare will increase by approximately $471 million. A possible economic explanation is that as India is the world's largest rice exporter, when India imposes rice export tariffs, the demand for Indian rice in the international market decreases, resulting in losses for Indian rice producers. Although India's rice exports have decreased, domestic

Table 6. Welfare changes at the food level in selected countries (regions) (in millions of US dollars).

Country/Region	A Producer Surplus	B Consumer Surplus	C Tariff Changes	D Subsidy Changes	E = A + B + C + D Change in Net Benefits
India	−7044.0	−4105.5	0.2	11，620.4	471.1
Thailand	276.2	−171.1	−2.3	0.0	102.8
Vietnam	312.4	−406.1	−193.3	0.0	−287.1
Pakistan	409.2	−187.6	0.7	0.0	222.4
America	24.6	−133.9	−34.5	0.0	−143.8
Myanmar	244.7	−209.6	0.0	0.0	35.1
China	2754.9	−2842.0	−6.0	0.0	−93.1
PH	389.7	−478.8	45.8	0.0	−43.3
EU	129.6	−223.3	1.8	0.0	−91.8
Nigeria	469.2	−447.5	−0.3	0.0	21.4
Iraq	0.0	−208.4	0.0	0.0	−208.4
Others	217.2	−4308.4	−546.1	0.0	−4637.3

Data source: Based on GSIM model simulation.

market prices have risen, causing a certain degree of loss to consumer welfare. Overall, India's net social welfare level will experience a significant increase. Therefore, from the perspective of social net welfare indicators, India will be the biggest beneficiary.

5. Conclusion and Suggestions

5.1. Conclusion

This article uses a computable partial equilibrium model to empirically examine the impact of India's imposition of rice export tariffs on rice trade, production, prices, producer surplus, consumer surplus, and subsidy changes in other countries (regions). The following conclusions are drawn.

Firstly, the trade disruption effect of India's imposition of rice export tariffs is significant. From the simulation results, it can be seen that India's trade volume in rice exports to other countries (regions) has decreased by over 80%. The trade volume of rice imported by China from India has decreased by 155.8%, but the trade deflection effect will lead to an increase in China's imports from third-party markets such as Thailand and Vietnam, which are 5.3% and 7.8%, respectively.

Secondly, the imposition of rice export tariffs by India has little impact on consumer prices of rice in India and China, only increasing by 7.9% and 3.9%. The cost of export tariffs is mainly borne by importers.

Thirdly, imposing export tariffs on rice in India does not provide substantive protection for Indian rice consumers. The simulation results show that the price of Indian rice consumers has increased by 7.9%, indicating a decrease of 24.4% in Indian rice production. This also indicates that imposing export tariffs has adverse effects on both domestic rice producers and consumers.

Fourthly, from the perspective of social net welfare indicators, India's imposition of rice export tariffs resulted in an increase of $471 million in India's social net welfare and a loss of $93.1 million in China's social net welfare. However, from the perspective of individual group welfare, Indian rice producers and consumers will become the biggest victims, losing $7.04 billion and $4.10 billion, respectively.

Finally, looking at the entire data, the impact of India's imposition of rice export tariffs on China's rice supply and consumption is relatively small, with only 3.9% changes in prices for both Chinese producers and consumers.

In short, India's imposition of rice export tariffs has a significant inhibitory effect on India's rice exports to other countries (regions), and also has adverse effects on domestic rice producers and consumers. In addition, the net welfare of Indian society has increased, but from the perspective of the welfare of individual groups, the welfare of Indian rice producers and consumers has been greatly reduced. However, the impact of India's rice tariffs on China is not large, and China's social net welfare is lost, but it has little impact on Chinese producers and consumers.

5.2. Suggestions

1) Rice is the most important grain ration in our country, and we should ensure the absolute security of our food. The simulation results indicate that due to the existence of trade transfer effects and trade deflection effects, China's rice imports and social net welfare effects have decreased, with a significant decrease in consumer surplus. Therefore, it is necessary to ensure that domestic food supply is not significantly affected by international food and that domestic consumer prices do not change significantly.

2) Stabilize the domestic rice market price. From the simulation results, it can be seen that although India's imposition of rice export tariffs has reduced China's social net welfare from the perspective of social net welfare indicators, from the perspective of individual group welfare, Chinese rice producers have significant benefits, with producer surplus increasing by $2.75 billion, but consumer surplus losing $2.84 billion. In addition, changes in consumer prices in China increased by 3.9%.

3) Strengthen the diversification of rice trade and maximize the stability of rice sources. From the simulation results, it can be seen that China's rice imports from India decreased by 155.8%, while rice imports from Thailand and Vietnam only increased by 5.3% and 7.8%, indicating unstable import channels.

4) Deepen agricultural structural adjustment, improve agricultural subsidy policies, and increase the basic production capacity of rice. In addition, it is necessary to establish a comprehensive agricultural insurance system, increase rice production through large-scale and mechanized production, and increase land use efficiency.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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