

# Impact of Indian Rice Export Restrictions on Global Indica and Japonica Rice Markets and Food Security

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## Abstract

India has frequently imposed rice export restrictions since the 2000s. These restrictions have posed a significant risk to the global rice market and food security. Therefore, we examined the impact of India's restrictions on rice exports on the global indica and japonica rice markets, as well as food security, using a partial equilibrium model and several food security indicators. The results of our simulations revealed that the restrictions affect the global indica and japonica rice markets through a substitution effect based on changes in relative prices. Furthermore, domestic indica rice prices for many net indica rice importers and exporters were expected to increase in 2023/24, leading to medium-term volatility. Our comprehensive assessment demonstrated that the restrictions pose a major risk to domestic food security for both net importers and exporters of indica rice in the short and medium term.

**Discipline:** Social Science

**Additional key words:** domestic rice prices, international rice prices, prevalence of undernourishment, price volatility, Rice Economy Climate Change model

## Introduction

India is the world's largest rice exporter, accounting for 34% of global rice exports in 2022/24 (USDA-FAS 2024b). As such, India's rice production and trade regulations affect global rice markets. Since the 2000s, it has often responded to soaring international rice prices by imposing export restrictions on rice (Ali et al. 2024). In September 2022, intending to secure the domestic rice supply and distribution and stabilize domestic rice prices, India banned the export of broken rice and imposed a 20% tariff on milled non-basmati and parboiled rice. Nevertheless, India has maintained high rice export levels and maintained its status as the top global rice exporter, resulting in a shortage in the supply of domestic rice. Moreover, domestic prices have increased by more than 30% since October 2022 (IFPRI 2023b). This has partly been attributed to heavy monsoon rains in June 2023, which severely damaged the country's main rice-producing areas. In response, in July 2023, the Indian government imposed an export ban on milled non-basmati and non-parboiled rice. Further, in August 2023, it imposed a 20% export tax on parboiled (milled)

rice and implemented a minimum export price of US\$1,200 per ton for basmati (milled) rice (MAFF 2023) to ensure domestic supply and avoid rice price hikes in the domestic market.

In September 2024, the government removed its ban on the export of non-basmati rice (USDA-FAS 2024c), despite having notified the World Trade Organization's Secretariat that these restrictions would remain in force until 31 December 2024. This change in export policy has been attributed to ample rainfall during the monsoon season (June to September 2024), as well as a large surplus of rice stockpiled by the Food Corporation of India, which reserved 32.3 million tons in September 2024, a 38.7% increase over the previous year (MAFF 2024). In addition, minimum rice export prices were eliminated in October 2024, and the international price of indica rice consequently dropped by 11.2% from September to October 2024 (World Bank 2024). While the Indian government removed the restriction on exporting non-basmati rice in September 2024, reimposing these restrictions would pose a significant risk to the international rice market and to local and global food security.

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Received 14 May 2025; accepted 1 September 2025; J-STAGE Advanced Epub 30 April 2026.

<https://doi.org/10.6090/jarq.25J03>

Sharma (2011) reviewed agricultural export restrictions in India and other major exporting countries. Glauber & Mamun (2024) reviewed the effects of India's restrictions on rice exports on global rice markets and concluded that the restrictions affected sub-Saharan African countries the most. They also concluded that *if reducing inflation were the goal, the evidence suggested that export restrictions were a relatively ineffective tool, in addition to their more detrimental impact in global markets*. Meanwhile, Mitra & Josling (2009) assessed the impact of Indian rice export restrictions on Indian and international rice prices by applying short-run demand and supply characteristics. Heady (2010) estimated that the international rice price would have decreased by 27.1% if India had not implemented export restrictions in 2008 using a cereal price transformation. However, no studies have evaluated the impact of India's restrictions on global indica and japonica rice markets using a partial equilibrium model. Further, no studies have examined the substitution effect from indica and japonica rice production and consumption. This study aims to fill this gap by developing a partial equilibrium model and the substitution effect. Furthermore, it comprehensively assesses the impact of domestic prices on food security at the national level using several food security indicators.

## Method and assumptions for the baseline and scenarios

To examine the global indica and japonica rice markets, we constructed the Rice Economy Climate Change (RECC) model, covering rice markets in 24 countries and regions, namely, Thailand, Vietnam, Indonesia, Malaysia, the Philippines, Cambodia, Laos, Myanmar, China, Japan, South Korea, India, the United States (US), the European Union (EU27), Bangladesh, Sri Lanka, Nepal, Pakistan, Brazil, Côte d'Ivoire, Egypt, Madagascar, Nigeria, and the rest of the world. The RECC model includes equations for projecting the rice yield and harvested areas affected by climate change and agricultural investments (Fig. 1). The base year for our projections and simulations was 2020/22 (a three-year average). We extended these to 2023/24 through 2045/46. Indicators for each country and regional market included production, consumption, exports, imports, and ending stocks for indica and japonica rice through 2045/46. For detailed model structures, please refer to Koizumi &

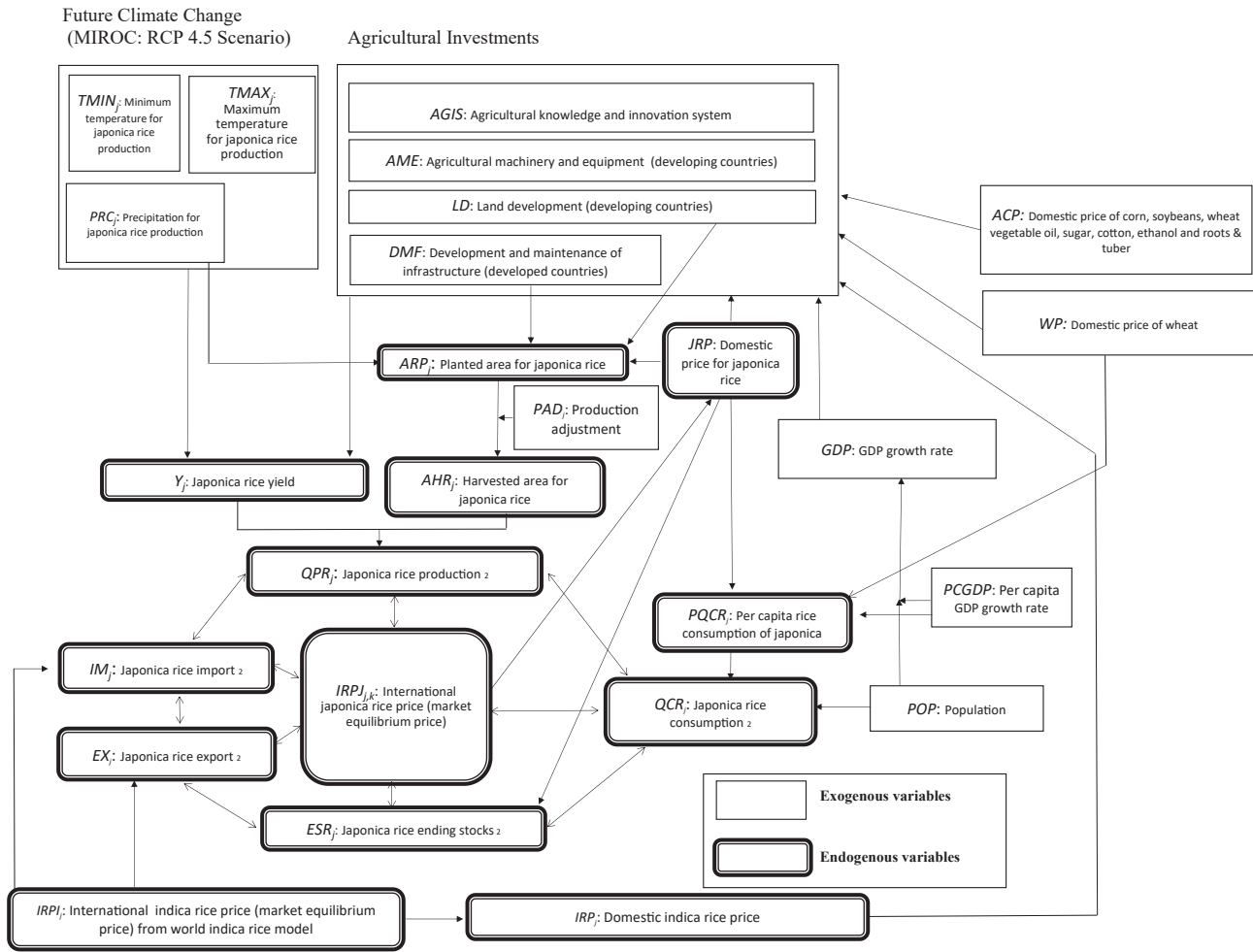
Furuhashi (2020, 2021, 2022). The Appendix presents global indica and japonica rice data.

For the baseline scenario, we made assumptions about the general economy, agricultural policies, and technological changes, excluding shocks induced by policy changes during the projection. The climate variables in each country and region (i.e., the minimum/maximum temperatures and precipitation) are exogenous to the model. In contrast, all climate variables for the baseline were derived from climate change projections by the Model for Interdisciplinary Research on Climate (MIROC) and applied Representative Concentration Pathway (RCP) 4.5 scenarios, which were input into MIROC. Population data for all countries were obtained from the 2024 revision (medium variant) of the World Population Prospects (United Nations, Department of Economics and Social Affairs 2024). In addition, we treated real gross domestic product (GDP) as an exogenous variable, and real GDP growth rate assumptions were based on the World Economic Outlook (IMF 2024). The growth rates of agricultural investments from 2023/24 to 2045/46 depend on lagging indica and japonica rice prices, other agricultural prices, and GDP. In addition, international and domestic prices of wheat, corn, soybeans, vegetable oils, sugar, cotton, ethanol, roots, and tubers were derived from the OECD-FAO Agricultural Outlook 2024-2033 (OECD-FAO 2024)<sup>1</sup>. We assumed that the present agricultural and trade policies, in effect until 2020/22, will continue for the projected period, so the baseline projection assumes that India will not impose export restrictions on rice after 2023/24. We conducted our baseline projection from 2023/24 to 2045/46 using these assumptions and exogenous variables for per capita GDP, population, and agricultural commodity prices.

The scenarios were applied for sensitivity analysis, assuming that India would impose export restrictions on rice in 2023/24 but not from 2024/25 onward. We set the volume of India's rice exports in 2023/24, when the restrictions were triggered, at 14,429,000 tons, based on the US Department of Agriculture's Foreign Agricultural Service (USDA-FAS 2024b).

Furthermore, we conducted a comprehensive assessment of the impact of the restrictions on each country's food security, applying the impacts on domestic indica and japonica rice prices derived from this study as the primary indicators. We employed four reference

<sup>1</sup> We assumed that international agricultural commodity prices in 2033 will remain constant from 2034 to 2045. In this model, the wheat price is an exogenous variable for the area planted and per capita consumption of indica and japonica rice. The prices of wheat, corn, soybeans, vegetable oil, sugar, cotton, ethanol, root, and tubers are exportable variables for the agricultural investment variables that affect the area planted and the yield exogenously.



**Fig. 1. Structure of the RECC model for the japonica rice market**

Notes:

1. " " represents mutual interactions.
2.  $QPR$ ,  $QCR$ ,  $EX$ ,  $IM$ , and  $ESR$  have mutual interactions.
3. "j" represents japonica rice or indica rice.
4. "k" represents integrated countries and regions.
5. This figure represents the japonica portion of the RECC model. The structure of the model is similar to that for indica rice.

indicators to evaluate the influence of export restrictions on country-level food security. To evaluate the access and utilization of food, we used the prevalence of undernourishment (POU) as the first reference indicator<sup>2</sup>. Export restrictions can severely undermine food security, including psychological impacts at the household and individual levels; therefore, we used the prevalence of moderate or severe food insecurity as the second reference indicator of the psychological impact of export

restrictions on food security<sup>3</sup>. As the third indicator, we applied the proportion of rice in the total food calories consumed. Finally, food safety net programs are crucial policy measures that address household and individual vulnerability to the availability and access to food security. As the fourth reference indicator, we applied the food safety net program index from the Global Food Security Index released by the Economist Impact (2022), with a lower index indicating less developed safety net

<sup>2</sup> POU is an estimate of the proportion of a population with habitual food consumption that is insufficient to provide the dietary energy required to maintain a normal, active, and healthy life (FAO et al. 2024).

<sup>3</sup> This indicator provides internationally comparable estimates of the proportion of the population facing moderate or severe food access difficulties. The FAO Food Insecurity Experience Scale provides a measure of the severity of food insecurity experienced by individuals and households based on direct interviews.

programs. These four indicators reflect the impact of factors beyond export restrictions; therefore, we used them as reference indicators to assess the impact of export restrictions on food security.

We integrated four supplementary indicators to complement the main and reference indicators. First, to evaluate the direct impact of export restrictions on access and utilization at the country level, we used the percentage of calories imported due to export restrictions released by the International Food Policy Research Institute (IFPRI) (2023a)<sup>4</sup>, which covers net food-importing and net-exporting countries. We applied the cereal import dependency ratio from FAOSTAT (FAO 2025) as a second complementary index to distinguish whether the evaluated country is a net importer. Third, country-level income indicators are required because household income is the most crucial element for ensuring access. Due to differences in data availability across countries, we used per capita GDP<sup>5</sup>, derived from the IMF, as a proxy variable for national income. Finally, to evaluate the direct, country-level impact of the restrictions on food retail prices in terms of stability, we used the rate of change in the food consumer price index (CPI) released by the World Bank (2025).

### Baseline and scenario projection results for global indica and japonica rice markets

From 2020/22 to 2045/46, the world's production of indica rice is expected to rise at a rate of 1.5%, consumption at 1.5%, exports at 1.8%, and imports at 2.0% per annum (Appendix Tables A1, A2). The international indica rice price (5% broken milled white rice, Thailand) is projected to increase by 3.6% per annum from 2020/22 to 2045/46. Meanwhile, global japonica rice production is expected to increase by 0.4%, consumption by 0.4%, exports by 5.7%, and imports by 6.6% per annum during the projection period (Appendix Tables A3, A4). Finally, the international japonica rice price (California, milled rice, average f.o.b. price) is projected to increase by 1.4% per annum from 2020/22 to 2045/46.

Our scenario settings indicate that indica rice exports in India are projected to decrease by 27.0% in 2023/24, while global indica rice exports are projected to decrease by 7.9% in 2023/24 compared with the baseline projection (Table 1). Furthermore, global indica rice

production is not projected to change<sup>6</sup>, whereas its consumption is predicted to decrease by 1.0%. Consequently, the international indica rice price is predicted to increase by 22.7% in 2023/24. From 2023/24 to 2026/27, it is projected to increase by 3.9% on average, and from 2023/24 to 2045/46, it is projected to increase by 0.6% on average. This setting scenario projects that Chinese indica rice consumption will decrease by 0.5%, and rising indica rice prices in China will increase japonica rice consumption by 0.02% compared with the baseline projection in 2023/24. This substitution effect from the change in the relative prices of indica and japonica rice is projected to cause a decrease in Chinese and global japonica rice exports by 2.1% and 0.2%, respectively, in 2023/24. Further, global japonica rice production is not projected to change; consumption is projected to increase by 0.01%, and imports are projected to decrease by 0.2% in 2023/24. Thus, the international price of japonica rice is projected to increase by 2.4% in 2023/24. From 2023/24 to 2026/27, the international price of japonica rice is projected to increase by an average of 0.2%. Meanwhile, from 2023/24 to 2045/46, it is expected to increase by 0.01% on average.

The coefficients of variation (CVs) of international indica and japonica rice prices during the baseline period from 2023/24 to 2034/35 are projected to be 0.0956 and 0.3397, respectively (Table 2). Furthermore, the CVs of international indica and japonica rice prices in the baseline projection period from 2035/36 to 2045/46 are 0.1199 and 0.2623. The CVs of international indica and japonica rice prices from 2023/24 to 2034/35 in the scenario are higher than those in the baseline projection, while the CVs of international indica and japonica rice prices from 2035/36 to 2045/46 in the scenario are almost the same as the baseline projection, as shown in Table 2.

### Indian rice export restrictions impact on the domestic rice market and food security

In response to increased international indica rice prices, domestic indica rice prices in net indica rice importing countries—Côte d'Ivoire, China, Nigeria, Sri Lanka, Nepal, Indonesia, and the Philippines—are projected to increase by 14.3%, 13.0%, 11.7%, 11.9%, 10.4%, 10.1%, 5.3% respectively in 2023/24 over the baseline (Table 3). Meanwhile, domestic indica rice prices in India, Vietnam, Myanmar, Cambodia, the US,

<sup>4</sup> This value indicates the share of restricted products in a country's food imports, measured in kcal.

<sup>5</sup> Current prices and purchasing power parity in USD

<sup>6</sup> In this study, the planted area equations for japonica and indica rice depend on the lagging domestic prices of japonica and indica rice and wheat, as well as the lagging precipitation and lagging agricultural investments. As a result of setting scenario 1, the planted area will not increase in 2023/24. Refer to Koizumi & Furuhashi (2020) for more model equations and parameters.

and Brazil, which are net indica rice exporters, are projected to increase by 8.9%, 9.7%, 4.5%, 12.7%, 8.7%, and 7.5%, respectively (Table 3). In these countries, the increase in domestic indica rice prices is projected to continue in 2023/24-2026/27, and with a slight increase in 2023/24-2045/46 on average.

Domestic japonica rice prices for net importers and exporters of japonica rice in 2023/24 are projected to rise between 0.1% and 2.2% in 2023/24, compared with the baseline. Limited domestic price increases are also projected for 2023/24-2026/27 and 2023/24-2045/46 on average (Table 3). The CVs of domestic indica rice prices of net exporting and importing countries from 2023/24 to

2034/35 in the scenario are higher than in the baseline. Meanwhile, those of domestic indica rice prices in the scenario from 2035/36 to 2044/45 are almost the same as the baseline. Furthermore, the CV of domestic japonica rice prices in net exporting and importing countries from 2023/24 to 2034/35 and from 2035/36 to 2045/46 in the scenario is almost the same as in the baseline.

### Discussion: Indian rice export restrictions' impact on food security

Among net indica rice-importing countries, the impact on domestic indica rice prices was higher in

**Table 1. Scenario impact on indica and japonica world rice markets**

|                                   | 2023/24  | 2023/24-2026/27 | 2023/24-2045/46 |
|-----------------------------------|----------|-----------------|-----------------|
| Indica rice market in India       |          |                 |                 |
| Production                        | 0.000%   | 0.200%          | 0.030%          |
| Consumption                       | -0.800%  | -0.100%         | -0.020%         |
| Exports                           | -27.000% | -6.300%         | -1.100%         |
| World indica rice market          |          |                 |                 |
| Production                        | 0.000%   | 0.200%          | 0.030%          |
| Consumption                       | -1.000%  | 0.200%          | 0.030%          |
| Imports                           | -7.900%  | -1.900%         | -0.300%         |
| Exports                           | -7.900%  | -1.900%         | -0.300%         |
| International indica rice price   | 22.700%  | 3.900%          | 0.600%          |
| Japonica rice market in China     |          |                 |                 |
| Production                        | 0.000%   | 0.020%          | 0.000%          |
| Consumption                       | 0.020%   | 0.020%          | 0.000%          |
| Exports                           | -2.100%  | -0.350%         | -0.070%         |
| World japonica rice market        |          |                 |                 |
| Production                        | 0.000%   | 0.010%          | 0.030%          |
| Consumption                       | 0.010%   | 0.010%          | 0.030%          |
| Imports                           | -0.200%  | -0.010%         | 0.001%          |
| Exports                           | -0.200%  | -0.010%         | 0.001%          |
| International japonica rice price | 2.400%   | 0.200%          | 0.010%          |

Note: The baseline scenario shows the percentage change in each variable relative to the sensitivity scenario.

**Table 2. Scenario impact on international indica and japonica rice prices**

|                                | 2023/24-2034/35               |                    |          | 2035/36-2045/46               |                    |          |
|--------------------------------|-------------------------------|--------------------|----------|-------------------------------|--------------------|----------|
|                                | Coefficient of variation (CV) | Standard Deviation | Average  | Coefficient of variation (CV) | Standard Deviation | Average  |
| Baseline: Indica rice price    | 0.0956                        | 62.1508            | 650.1362 | 0.1199                        | 102.0278           | 850.8082 |
| Scenario : Indica rice price   | 0.1208                        | 79.5533            | 658.3789 | 0.1199                        | 102.0315           | 850.8064 |
| Baseline: Japonica rice price  | 0.3397                        | 14.5183            | 42.7369  | 0.2623                        | 13.4154            | 51.1406  |
| Scenario : Japonica rice price | 0.3413                        | 14.5986            | 42.7691  | 0.2623                        | 13.4159            | 51.1406  |

Note: The baseline scenario shows the percentage change in each variable relative to the sensitivity scenario.

2023/24 for Côte d'Ivoire, Nigeria, and Bangladesh. The POU in 2021/23 in these countries was between 9.6% and 18.0%, higher than in other countries (Table 4). Moreover, the prevalence of moderate or severe food insecurity in the total population (2020–2022) of these countries ranged from 30.5% to 73.9%, which is higher than in other

countries. In particular, more than 70% of the total population in Nigeria experienced food insecurity in 2020–2022. Furthermore, the indices of food safety net programs in these countries were between 0 and 1 in 2022, much lower than those in other countries.

Côte d'Ivoire, Nigeria, and Bangladesh experienced

**Table 3. Scenario impact on domestic indica and japonica rice prices**

|                              | 2023/24 | 2023/24–2026/27 | 2023/24–2045/46 | 2023/24–2034/35               |          | 2035/36–2045/46               |          |
|------------------------------|---------|-----------------|-----------------|-------------------------------|----------|-------------------------------|----------|
|                              |         |                 |                 | Coefficient of variation (CV) |          | Coefficient of variation (CV) |          |
|                              |         |                 |                 | Baseline                      | Scenario | Baseline                      | Scenario |
| Domestic indica rice price   |         |                 |                 |                               |          |                               |          |
| Exporting countries          |         |                 |                 |                               |          |                               |          |
| India                        | 8.9%    | 1.5%            | 0.2%            | 0.0398                        | 0.0501   | 0.0502                        | 0.0502   |
| Vietnam                      | 9.7%    | 1.6%            | 0.3%            | 0.0429                        | 0.0540   | 0.0540                        | 0.0540   |
| Myanmar                      | 4.5%    | 0.7%            | 0.1%            | 0.0206                        | 0.0259   | 0.0260                        | 0.0260   |
| Cambodia                     | 12.7%   | 2.1%            | 0.3%            | 0.0557                        | 0.0702   | 0.0701                        | 0.0701   |
| USA                          | 8.7%    | 1.9%            | 0.3%            | 0.0956                        | 0.1208   | 0.1199                        | 0.1199   |
| Brazil                       | 7.5%    | 1.2%            | 0.2%            | 0.0630                        | 0.0795   | 0.0793                        | 0.0793   |
| Importing countries          |         |                 |                 |                               |          |                               |          |
| China                        | 13.0%   | 2.2%            | 0.4%            | 0.0460                        | 0.0741   | 0.0382                        | 0.0382   |
| Nigeria                      | 11.7%   | 2.0%            | 0.3%            | 0.0517                        | 0.0651   | 0.0651                        | 0.0651   |
| EU27                         | 4.7%    | 0.8%            | 0.1%            | 0.0214                        | 0.0269   | 0.0270                        | 0.0270   |
| Côte d'Ivoire                | 14.3%   | 2.4%            | 0.4%            | 0.0623                        | 0.0785   | 0.0784                        | 0.0784   |
| The Philippines              | 5.3%    | 0.9%            | 0.1%            | 0.0238                        | 0.0299   | 0.0300                        | 0.0300   |
| Bangladesh                   | 11.4%   | 1.9%            | 0.3%            | 0.0503                        | 0.0634   | 0.0633                        | 0.0633   |
| Indonesia                    | 10.1%   | 1.7%            | 0.3%            | 0.0448                        | 0.0564   | 0.0564                        | 0.0564   |
| Malaysia                     | 2.3%    | 0.4%            | 0.1%            | 0.0105                        | 0.0132   | 0.0133                        | 0.0133   |
| Nepal                        | 10.4%   | 1.7%            | 0.3%            | 0.0459                        | 0.0579   | 0.0579                        | 0.0579   |
| Sri Lanka                    | 11.9%   | 2.0%            | 0.3%            | 0.0525                        | 0.0662   | 0.0661                        | 0.0661   |
| Laos                         | 8.4%    | 1.4%            | 0.2%            | 0.0373                        | 0.0469   | 0.0470                        | 0.0470   |
| Domestic japonica rice price |         |                 |                 |                               |          |                               |          |
| Exporting countries          |         |                 |                 |                               |          |                               |          |
| China                        | 1.1%    | 0.1%            | 0.0%            | 0.1671                        | 0.1679   | 0.1311                        | 0.1311   |
| USA                          | 2.0%    | 0.2%            | 0.0%            | 0.2894                        | 0.2908   | 0.2241                        | 0.2241   |
| Egypt                        | 0.5%    | 0.0%            | 0.0%            | 0.0767                        | 0.0770   | 0.0611                        | 0.0611   |
| Importing countries          |         |                 |                 |                               |          |                               |          |
| EU27                         | 2.2%    | 0.2%            | 0.0%            | 0.3204                        | 0.3219   | 0.2476                        | 0.2476   |
| South Korea                  | 0.1%    | 0.0%            | 0.0%            | 0.0234                        | 0.0235   | 0.0189                        | 0.0189   |

Notes:

1. The baseline scenario shows the percentage change in each variable relative to the sensitivity scenario.
2. We could not obtain reliable indica and japonica rice market data for Myanmar, Cambodia, Côte d'Ivoire, Bangladesh, Nepal, Sri Lanka, or Laos. Therefore, the rate of change in domestic rice prices in these countries was not derived from the model's supply-and-demand equilibrium but rather from the price transmission elasticity of the RECC model for those countries. For the elasticity, refer to Koizumi & Kanamaru (2016), Koizumi (2017), and Koizumi & Furuhashi (2020).
3. The domestic rice price in Thailand is an international indica rice price. We could not obtain reliable time-series domestic rice price data for Pakistan. Because of Japan's special trade structure for rice due to its minimum access and higher secondary tariff rate, we found no correlation between international rice prices and the domestic rice price in Japan. Therefore, the price changes between the scenario and the baseline are not shown for Thailand, Pakistan, or Japan.

a higher impact on domestic indica rice prices due to Indian rice export restrictions. These countries have higher ratios of moderate and severe food insecurity in their population and POU, and a lower index for food safety net programs. Food safety net programs are essential policy tools for mitigating external damage to domestic food security. As for supplementary indicators, the percentage of calories imported due to export restrictions and the cereal import dependency ratio in these countries are relatively higher than those in other countries, and per capita GDP is lower than that in other countries. These findings indicate that food export restrictions on items other than rice have a significant impact on food import calories, on the proportion of cereal imports, and on consumer purchasing power. Although Bangladesh had a lower rate of domestic indica rice price increases than Côte d'Ivoire and Nigeria, we find that, with no alternative food options, its impact was greater because rice is a staple food there, accounting for 64% of total average food calories. Therefore, the restrictions have a severe impact on food security in Côte d'Ivoire, Nigeria, and Bangladesh among the 24 countries/regions covered in our model.

Meanwhile, India, Vietnam, and Cambodia experienced a higher impact on domestic indica rice prices from Indian restrictions. Although the index of food safety net programs in India, Vietnam, and Cambodia was higher than in other countries, these countries have higher ratios of POU and moderate and severe food insecurity in the total population. Homegrown export restrictions in India provoked an 8.9% increase in domestic indica rice price, which is higher than the 6.6% change in the rate of the average CPI food price index in India in 2023. Export restrictions should, in theory, increase domestic supply and lead to a short-term decline in domestic prices. However, the results of this study show that the restrictions increase domestic indica and japonica rice prices, due to the price transmission elasticity between the international and domestic rice prices<sup>7</sup>.

## Conclusions

This study examined the impact of India's rice export restrictions on indica and japonica rice markets using a partial equilibrium model. The results of our simulated sensitivity analysis showed that India's restrictions on rice exports led to a 22.7% increase in the international price of indica rice in 2023/24, showing that the restrictions increased in the international price of japonica rice in 2023/24 by 2.4%, demonstrating a substitution effect from changes in the relative prices of indica and japonica rice. We found that India's export restrictions on rice increased the volatility of international indica and japonica rice prices in the medium term (2023/24 to 2034/35). However, we found no evidence of increased volatility in either price in the long term (2035/36 to 2045/46). The results indicated that India's export restrictions on rice affect the global indica and japonica rice markets in the short and medium term but not in the long term.

Domestic indica rice prices in many net indica rice importers and exporters were expected to increase in 2023/24, with the impact expected to continue in 2023/23-2026/27. Furthermore, the restrictions could increase volatility in domestic indica rice prices for net importers and exporters in the medium term (2023/24 to 2034/35). Our comprehensive assessment of the impact of country-level restrictions demonstrated that Indian rice export restrictions may significantly affect food security in Côte d'Ivoire, Nigeria, and Bangladesh, among the 24 countries examined in the model. Therefore, India's restrictions pose a major risk to the domestic food security of both net importers and exporters of indica rice in the short and medium term.

This study focused on the impact of India's export restrictions on global markets for indica japonica rice. Wheat price affects the area planted, per capita consumption of indica and japonica rice. Furthermore, wheat, corn, soybeans, roots & tubers, and other agricultural commodity prices affect agricultural investments exogenously. However, we did not conduct a direct impact assessment of the export restriction on

<sup>7</sup> The change in international rice prices can transmit to domestic prices in India, and the change in the domestic rice price in India can influence the international indica rice price because India is a large country which has a significant export share in the world rice markets and can affect the international rice price. Furthermore, India has limited its import policy of rice. The value of the estimated rice price transmission elasticity for India was 0.9819 (Koizumi & Kanamaru 2016). Therefore, the international indica and domestic rice prices in India correlated in the mid-long term. The estimate was for the period 1991-2007 from FAOSTAT data, due to limitations derived from reliable datasources. Deuss (2017) identified the long-run impact of export bans by showing whether the introduction of these bans caused a structural break in the long-term relationship between prices in international markets and consumer prices in domestic markets. One might consider whether India's export restrictions may have weakened price linkages with the international market, potentially causing domestic prices to diverge from global trends. Therefore, we need to estimate the elasticity applying reliable recent data.

**Table 4. Rice export restriction impact on domestic food security**

| Main indicator                    |                                                   | Reference indicators                                                     |                                                                                      |                                                                                  | Supplementary indicators                |                                                                   |                                            |                                                               |                                                   |
|-----------------------------------|---------------------------------------------------|--------------------------------------------------------------------------|--------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|-----------------------------------------|-------------------------------------------------------------------|--------------------------------------------|---------------------------------------------------------------|---------------------------------------------------|
|                                   | Scenario impact on domestic rice prices (2023/24) | Prevalence of undernourishment in the total population (POU) (2021-2023) | Prevalence of moderate or severe food insecurity in the total population (2020-2022) | Percentage of rice in total food calories consumed (kcal/capita/day) (2020-2022) | Food safety net programmes (2022) (0-4) | Percentage of calories imported due to export restrictions (2022) | Cereal import dependency ratio (2020-2022) | Gross domestic product per capita, current prices (2022-2024) | Changing rate of CPI food price index (2023/2022) |
| Unit                              | %                                                 | %                                                                        | %                                                                                    | %                                                                                | Index (0-4)                             | %                                                                 | %                                          | Purchasing power parity; international dollars                | %                                                 |
| Source                            | This study                                        | FAO (2024)                                                               | FAO (2024)                                                                           | FAO (2024)                                                                       | Economist impact (2022)                 | IFPRI (2023)                                                      | FAO (2024)                                 | IMF (2025)                                                    | World Bank (2025)                                 |
| Indica rice exporting countries   |                                                   |                                                                          |                                                                                      |                                                                                  |                                         |                                                                   |                                            |                                                               |                                                   |
| India                             | 8.9                                               | 13.7                                                                     |                                                                                      | 25.4                                                                             | 3                                       | 55.8                                                              | -12.3                                      | 10,184                                                        | 6.6                                               |
| Vietnam                           | 9.7                                               | 15.3                                                                     | 10.8                                                                                 | 46.3                                                                             | 4                                       | 8.7                                                               | 14.0                                       | 15,019                                                        | 3.4                                               |
| Myanmar                           | 4.5                                               | 5.3                                                                      | 32.0                                                                                 | 57.7                                                                             | 1                                       | 26.8                                                              | -12.8                                      | 5,020                                                         | -                                                 |
| Cambodia                          | 12.7                                              | 4.6                                                                      | 50.5                                                                                 | 51.3                                                                             | 4                                       | 36.0                                                              | -2.4                                       | 7,603                                                         | 3.2                                               |
| USA                               | 8.7                                               | < 2.5                                                                    | 9.1                                                                                  | 2.0                                                                              | 4                                       | 7.9                                                               | -23.1                                      | 82,432                                                        | 4.9                                               |
| Brazil                            | 7.5                                               | 3.9                                                                      | 18.4                                                                                 | 7.6                                                                              | 3                                       | 5.8                                                               | -23.7                                      | 18,981                                                        | 4.0                                               |
| Indica rice importing countries   |                                                   |                                                                          |                                                                                      |                                                                                  |                                         |                                                                   |                                            |                                                               |                                                   |
| China                             | 13.0                                              | < 2.5                                                                    |                                                                                      | 25.3                                                                             | 4                                       | 9.6                                                               | 8.8                                        | 24,417                                                        | -0.3                                              |
| Nigeria                           | 11.7                                              | 18.0                                                                     | 73.9                                                                                 | 8.5                                                                              | 0                                       | 24.2                                                              | 17.8                                       | 6,345                                                         | 22.8                                              |
| EU27                              | 4.7                                               | < 2.5                                                                    | 7.5                                                                                  | 1.5                                                                              | 4                                       | 21.9                                                              | -25.3                                      | 60,610                                                        | 12.1                                              |
| Côte d'Ivoire                     | 14.3                                              | 9.6                                                                      | 39.4                                                                                 | 23.4                                                                             | 1                                       | 21.3                                                              | 49.0                                       | 7,202                                                         | 6.5                                               |
| The Philippines                   | 5.3                                               | 5.9                                                                      | 44.1                                                                                 | 42.6                                                                             | 3                                       | 11.9                                                              | 30.8                                       | 11,256                                                        | 7.9                                               |
| Bangladesh                        | 11.4                                              | 11.9                                                                     | 30.5                                                                                 | 64.0                                                                             | 1                                       | 42.5                                                              | 15.7                                       | 9,182                                                         | -60.9                                             |
| Indonesia                         | 10.1                                              | 7.2                                                                      | 4.9                                                                                  | 39.1                                                                             | 4                                       | 22.1                                                              | 14.1                                       | 15,514                                                        | 4.9                                               |
| Malaysia                          | 2.3                                               | < 2.5                                                                    | 16.7                                                                                 | 24.0                                                                             | 4                                       | 15.1                                                              | 76.5                                       | 38,744                                                        | 4.8                                               |
| Nepal                             | 10.4                                              | 5.7                                                                      | 37.0                                                                                 | 29.0                                                                             | 1                                       | 46.0                                                              | 20.3                                       | 5,155                                                         | 6.1                                               |
| Sri Lanka                         | 11.9                                              | 4.1                                                                      | 11.4                                                                                 | 43.2                                                                             | 3                                       | 25.2                                                              | 25.6                                       | 14,058                                                        | -5.6                                              |
| Laos                              | 8.4                                               | 5.4                                                                      | 36.3                                                                                 | 44.7                                                                             | 1                                       | 28.4                                                              | -0.9                                       | 9,237                                                         | 24.4                                              |
| Japonica rice exporting countries |                                                   |                                                                          |                                                                                      |                                                                                  |                                         |                                                                   |                                            |                                                               |                                                   |
| China                             | 1.1                                               |                                                                          |                                                                                      |                                                                                  |                                         |                                                                   |                                            |                                                               |                                                   |
| USA                               | 2.0                                               |                                                                          |                                                                                      |                                                                                  |                                         |                                                                   |                                            |                                                               |                                                   |
| Egypt                             | 0.5                                               | 8.5                                                                      | 29.8                                                                                 | 9.7                                                                              | 4                                       | 54.3                                                              | 43.0                                       | 20,015                                                        | 63.9                                              |
| Japonica rice importing countries |                                                   |                                                                          |                                                                                      |                                                                                  |                                         |                                                                   |                                            |                                                               |                                                   |
| EU27                              | 2.2                                               |                                                                          |                                                                                      |                                                                                  |                                         |                                                                   |                                            |                                                               |                                                   |
| South Korea                       | 0.1                                               | < 2.5                                                                    | 5.7                                                                                  | 17.4                                                                             | 4                                       | 12.9                                                              | 77.9                                       | 60,070                                                        | 5.0                                               |

Note: The domestic rice price in Thailand is an international indica rice price. We could not obtain reliable time-series domestic rice price data for Pakistan. Because of Japan's special trade structure for rice due to its minimum access and higher secondary tariff, we found no correlation between international rice prices and domestic rice prices in Japan. Therefore, the price changes between the scenario and baseline in Thailand, Pakistan, and Japan are not shown.

wheat, corn, roots, tubers, or other agricultural commodity prices that are potential substitutes for indica and japonica rice. Therefore, we used the percentage of rice in total food calories consumed to assess the availability of alternatives to rice consumption as a reference indicator. We also employed the percentage of calories imported due to the export restrictions by IFPRI (2023) to assess the impact of the 2022 export restrictions not only on rice, but also on other food imported as a supplementary indicator. However, even with these

references and complementary indicators, we consider that the assessment of the impact of India's export restrictions on wheat, corn, root and tubers, and other food is insufficient. Therefore, assessing the endogenous impact of India's export restrictions on food prices other than indica and japonica rice is a future direction for this study. Moreover, India's export restrictions may have weakened the price linkage with the international market, causing domestic prices to diverge from the global trend. Estimating price transmission elasticity using recent,

reliable data from the leading countries is also a future direction of this study.

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**Table A1. Global indica rice markets (1) (baseline projection)**

|                 | Harvested area (1,000 ha) |         |                                                | Yield (t/ha)      |         |                                                | Production (1,000 t) |         |                                                |
|-----------------|---------------------------|---------|------------------------------------------------|-------------------|---------|------------------------------------------------|----------------------|---------|------------------------------------------------|
|                 | 2020/21-<br>22/23         | 2045/46 | Annual<br>growth rate<br>(2020/22-<br>2045/46) | 2020/21-<br>22/23 | 2045/46 | Annual<br>growth rate<br>(2020/22-<br>2045/46) | 2020/21-<br>22/23    | 2045/46 | Annual<br>growth rate<br>(2020/22-<br>2045/46) |
| World           | 122,584                   | 153,124 | 0.9%                                           |                   |         |                                                | 456,790              | 648,173 | 1.5%                                           |
| Thailand        | 11,197                    | 14,448  | 1.1%                                           | 3.0               | 3.0     | 0.1%                                           | 21,861               | 29,058  | 1.2%                                           |
| Vietnam         | 7,197                     | 9,003   | 0.9%                                           | 6.2               | 6.5     | 0.2%                                           | 28,014               | 37,135  | 1.2%                                           |
| Indonesia       | 10,506                    | 11,253  | 0.3%                                           | 5.6               | 6.2     | 0.4%                                           | 34,958               | 41,208  | 0.7%                                           |
| Malaysia        | 650                       | 640     | -0.1%                                          | 4.1               | 4.4     | 0.3%                                           | 1,669                | 1,769   | 0.2%                                           |
| India           | 46,233                    | 63,632  | 1.3%                                           | 4.2               | 4.5     | 0.3%                                           | 128,867              | 189,626 | 1.6%                                           |
| China           | 20,871                    | 19,388  | -0.3%                                          | 6.7               | 7.0     | 0.2%                                           | 97,660               | 94,633  | -0.1%                                          |
| Japan           | 0                         | 0       |                                                | 0.0               | 0.0     |                                                | 0                    | 0       | -                                              |
| South Korea     | 0                         | 0       |                                                | 0.0               | 0.0     |                                                | 0                    | 0       | -                                              |
| USA             | 895                       | 1,243   | 1.4%                                           | 8.0               | 8.4     | 0.2%                                           | 5,017                | 7,296   | 1.6%                                           |
| EU27            | 86                        | 77      | -0.4%                                          | 6.4               | 7.0     | 0.4%                                           | 381                  | 375     | -0.1%                                          |
| The Philippines | 4,803                     | 5,553   | 0.6%                                           | 4.1               | 4.7     | 0.6%                                           | 13,007               | 17,334  | 1.2%                                           |
| Brazil          | 1,654                     | 2,012   | 0.8%                                           | 6.8               | 7.1     | 0.2%                                           | 7,647                | 9,662   | 1.0%                                           |
| Egypt           | 0                         | 0       |                                                | 0.0               | 0.0     |                                                | 0                    | 0       | -                                              |
| Nigeria         | 4,365                     | 5,622   | 1.1%                                           | 1.8               | 2.3     | 1.1%                                           | 5,003                | 8,313   | 2.1%                                           |
| Pakistan        | 3,283                     | 5,759   | 2.4%                                           | 3.8               | 4.8     | 1.0%                                           | 8,355                | 18,459  | 3.4%                                           |

**Table A2. Global indica rice markets (2) (baseline projection)**

|                 | Consumption (1,000 t) |         |                                                | Imports (1,000 t) |         |                                                | Exports (1,000 t) |         |                                                |
|-----------------|-----------------------|---------|------------------------------------------------|-------------------|---------|------------------------------------------------|-------------------|---------|------------------------------------------------|
|                 | 2020/21-<br>22/23     | 2045/46 | Annual<br>growth rate<br>(2020/22-<br>2045/46) | 2020/21-<br>22/23 | 2045/46 | Annual<br>growth rate<br>(2020/22-<br>2045/46) | 2020/21-<br>22/23 | 2045/46 | Annual<br>growth rate<br>(2020/22-<br>2045/46) |
| World           | 454,336               | 645,414 | 1.5%                                           | 49,823            | 79,522  | 2.0%                                           | 51,474            | 79,522  | 1.8%                                           |
| Thailand        | 13,670                | 13,442  | -0.1%                                          | 147               | 98      | -1.7%                                          | 6,997             | 15,547  | 3.4%                                           |
| Vietnam         | 22,559                | 25,328  | 0.5%                                           | 1,505             | 1,238   | -0.8%                                          | 6,743             | 12,971  | 2.8%                                           |
| Indonesia       | 36,026                | 42,078  | 0.6%                                           | 520               | 963     | 2.6%                                           | 2                 | 2       | -0.3%                                          |
| Malaysia        | 2,858                 | 3,473   | 0.8%                                           | 1,268             | 1,710   | 1.3%                                           | 89                | 0       | -                                              |
| India           | 105,556               | 162,911 | 1.8%                                           | 6                 | 0       | -                                              | 20,684            | 26,131  | 1.0%                                           |
| China           | 101,803               | 101,600 | 0.0%                                           | 5,019             | 12,541  | 3.9%                                           | 1,890             | 3,641   | 2.8%                                           |
| Japan           | 411                   | 320     | -1.0%                                          | 411               | 320     | -1.0%                                          | 0                 | 200     | -                                              |
| South Korea     | 267                   | 254     | -0.2%                                          | 267               | 254     | -0.2%                                          | 0                 | 0       | -                                              |
| USA             | 4,134                 | 4,544   | 0.4%                                           | 1,149             | 961     | -0.7%                                          | 2,003             | 3,707   | 2.6%                                           |
| EU27            | 2,184                 | 1,454   | -1.7%                                          | 1,934             | 1,319   | -1.6%                                          | 124               | 242     | 2.8%                                           |
| The Philippines | 16,294                | 28,299  | 2.3%                                           | 3,191             | 10,997  | 5.3%                                           | 0                 | 0       | -                                              |
| Brazil          | 7,239                 | 9,832   | 1.3%                                           | 809               | 1,202   | 1.7%                                           | 1,150             | 1,023   | -0.5%                                          |
| Egypt           | 411                   | 134     | -4.6%                                          | 411               | 134     | -4.6%                                          | 0                 | 0       | -                                              |
| Nigeria         | 7,353                 | 15,997  | 3.3%                                           | 2,347             | 7,692   | 5.1%                                           | 0                 | 0       | -                                              |
| Pakistan        | 4,239                 | 9,168   | 3.3%                                           | 12                | 27      | 3.4%                                           | 4,118             | 9,304   | 3.5%                                           |

**Table A3. Global japonica rice markets (1) (baseline projection)**

|             | Harvested area (1,000 ha) |         |                                                | Yield (t/ha)      |         |                                                | Production (1,000 t) |         |                                                |
|-------------|---------------------------|---------|------------------------------------------------|-------------------|---------|------------------------------------------------|----------------------|---------|------------------------------------------------|
|             | 2020/21-<br>22/23         | 2045/46 | Annual<br>growth rate<br>(2020/22-<br>2045/46) | 2020/21-<br>22/23 | 2045/46 | Annual<br>growth rate<br>(2020/22-<br>2045/46) | 2020/21-<br>22/23    | 2045/46 | Annual<br>growth rate<br>(2020/22-<br>2045/46) |
| World       | 12,516                    | 14,661  | 0.7%                                           | -                 | -       | -                                              | 68,143               | 75,012  | 0.4%                                           |
| China       | 8,945                     | 10,769  | 0.8%                                           | 8.0               | 7.2     | -0.4%                                          | 50,086               | 54,235  | 0.3%                                           |
| Japan       | 1,407                     | 1,185   | -0.7%                                          | 7.2               | 7.1     | 0.0%                                           | 7,382                | 6,164   | -0.7%                                          |
| South Korea | 729                       | 782     | 0.3%                                           | 6.8               | 6.5     | -0.2%                                          | 3,718                | 3,794   | 0.1%                                           |
| USA         | 156                       | 173     | 0.5%                                           | 9.8               | 10.6    | 0.3%                                           | 1,072                | 1,289   | 0.8%                                           |
| EU27        | 314                       | 242     | -1.1%                                          | 5.7               | 4.6     | -0.9%                                          | 1,240                | 778     | -1.9%                                          |
| Egypt       | 616                       | 1,115   | 2.5%                                           | 8.9               | 10.2    | 0.5%                                           | 3,800                | 7,834   | 3.1%                                           |

**Table A4. Global japonica rice markets (2) (baseline projection)**

|             | Consumption (1,000 t) |         |                                                | Imports (1,000 t) |         |                                                | Exports (1,000 t) |         |                                                |
|-------------|-----------------------|---------|------------------------------------------------|-------------------|---------|------------------------------------------------|-------------------|---------|------------------------------------------------|
|             | 2020/21-<br>22/23     | 2045/46 | Annual<br>growth rate<br>(2020/22-<br>2045/46) | 2020/21-<br>22/23 | 2045/46 | Annual<br>growth rate<br>(2020/22-<br>2045/46) | 2020/21-<br>22/23 | 2045/46 | Annual<br>growth rate<br>(2020/22-<br>2045/46) |
| World       | 68,720                | 74,938  | 0.4%                                           | 1,245             | 5,719   | 6.6%                                           | 1,511             | 5,724   | 5.7%                                           |
| China       | 50,193                | 53,712  | 0.3%                                           | 1                 | 1       | 0.1%                                           | 413               | 479     | 0.6%                                           |
| Japan       | 7,661                 | 7,482   | -0.1%                                          | 352               | 1,415   | 6.0%                                           | 87                | 115     | 1.2%                                           |
| South Korea | 3,741                 | 4,107   | 0.4%                                           | 123               | 390     | 4.9%                                           | 54                | 62      | 0.5%                                           |
| USA         | 571                   | 504     | -0.5%                                          | 28                | 43      | 1.9%                                           | 541               | 806     | 1.7%                                           |
| EU27        | 1,481                 | 2,162   | 1.6%                                           | 535               | 2,292   | 6.2%                                           | 301               | 898     | 4.7%                                           |
| Egypt       | 3,852                 | 4,589   | 0.7%                                           | -                 | -       | -                                              | 2                 | 949     | 29.4%                                          |

## Appendix: Global indica and japonica rice data

We estimated global indica and japonica rice data using a rice balance sheet dataset by country from the OECD-FAO Agricultural Outlook (OECD-FAO 2024). Next, we estimated the total shares of indica and japonica rice in terms of production and harvested area using countries' statistical yearbooks and statistics, including those of the US, the EU, and China (USDA-ERS 2024, European Commission 2024, National Bureau of Statistics of China 2024). We estimated indica and japonica rice imports and exports based on countries' rice customs trade data from the UN Comtrade database (UN Statistics Division 2024) with countries such as China, Australia, Japan, South Korea, Turkey, and Egypt predominantly producing and consuming japonica rice. Japan and South Korea's customs data were obtained from their respective customs bureaus. US rice customs data were sourced from west-coast ports (USDA-FAS 2024a), and EU rice customs data were estimated based on Eurostat (2024).

We calculated China's japonica rice stocks based on its estimated japonica production shares and China's rice stocks of the OECD-FAO Agricultural Outlook balance sheet (OECD-FAO 2024), given that the Chinese government has not released detailed stocks for many years. We estimated japonica rice stocks in the US and the EU by referencing statistics from the USDA Economic Research Service (USDA-ERS 2024) and the EU (European Commission 2024), respectively.

We then calculated the stocks of japonica rice in other countries by multiplying their estimated production shares by rice stock statistics, as released by the OECD-FAO (2024). We determined the japonica rice balance sheets for other countries from trade shares and quantities of indica and japonica rice via customs statistics of the countries covered in the UN Comtrade database (UN Statistics Division 2024), as well as country rice balance sheets of the OECD-FAO Agricultural Outlook (OECD-FAO 2024).