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November 2025
IATRC Commissioned Paper CP-37

International Agricultural Trade Research Consortium

Commissioned Paper No. 37

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This Commissioned Paper was co-authored by scholars working in the area of trade economics who responded to a call for Commissioned Papers from the Executive Committee of the IATRC.

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The International Agricultural Trade Research Consortium (IATRC) is an organization of approximately 220 economists from 28 different countries, interested in research, policy analysis, and current developments in international agricultural trade. It is supported by the United States Department of Agriculture (ERS, FAS, and OCE), Agriculture and Agri-Food Canada, and the participating organizations. Funding for this commissioned paper comes from the U.S. Department of Agriculture's Foreign Agricultural Service.

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This volume contains information which was presented at an International Agricultural Trade Research Consortium Annual Meeting, which was held in Fort Lauderdale, Florida, from December 8 – 10, 2024.

Global Economic Effects of Trade Restrictions on Japanese Seafood following Nuclear Wastewater Discharge

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Abstract

In 2021, the Japanese government announced its decision to release treated radioactive water from the disabled Fukushima Daiichi Nuclear Power Plant into the Pacific Ocean. This controversial decision, implemented in August 2023, sparked international debate and led to trade restrictions on Japanese seafood products. This study uses a computable general equilibrium modeling framework to simulate the global economic impacts of import restrictions on Japanese seafood. Key findings show declines in Japanese seafood exports, production, and prices, leading to a significant contraction in the domestic seafood market and substantial welfare losses. Meanwhile, other seafood-exporting regions, such as North America, Europe, and Central and South America, benefit from minor export growth as they fill the gap left by Japan. Since Japan accounts for a small share of global seafood trade, the overall global seafood market remains stable, with only moderate price increases concentrated in East Asia.

Keywords: Nuclear wastewater discharge; International trade; Trade restrictions; Economic impacts; Fukushima; Computable general equilibrium model

JEL Codes: F10, F13, F18, Q10, Q17, Q18

1. Introduction

In 2021, the Japanese government announced its controversial decision to release more than 1.2 million metric tons of treated radioactive water from the disabled Fukushima Daiichi Nuclear Power Plant into the Pacific Ocean, commencing in 2023, with a projected 40-year timeline for the wastewater discharge (Zhang et al. 2023). This decision came a decade after the 2011 nuclear disaster when a catastrophic tsunami, triggered by a 9.0 magnitude earthquake, disabled the power supply and cooling systems for three Fukushima reactors, leading to their meltdown. The wastewater accumulated because the meltdown included water used to cool nuclear fuel as well as rain and groundwater that seeped into the facility, all containing isotopes such as tritium.

The Fukushima plant's first wastewater discharge occurred from August 24 to September 11, 2023.[1] During this period, the Tokyo Electric Power Company (TEPCO) disclosed the release of 7,800 tons of treated water, drawn from a compilation of 10 tanks. However, the complete discharge procedure is expected to extend for more than three decades, given that the holding facilities encompass more than one million tons of accumulated wastewater. The process includes a slow discharge realized through dilution with seawater, emphasizing the long-term nature of this environmental intervention.

Japan's decision to discharge nuclear wastewater has sparked extensive international debate. Despite the escalating controversy, Japan insists that releasing the treated water is both a safe and critical step to alleviate space constraints at the damaged nuclear facility.[2] While the

[1] FOX NEWS, October 5 2023. Japan releases 2nd round of Fukushima's radioactive wastewater into the sea | Fox News
[2] Science: Despite opposition, Japan may soon dump Fukushima wastewater into the Pacific

United States (U.S.) and Taiwan have shown support for the discharge, noting that the tritium levels are expected to have minimal impact, mainland China and the Pacific Islands have expressed strong opposition. They argue that the discharge could carry widespread regional and global consequences, potentially endangering human health and marine ecosystems (Wang, Zhang and Huang 2022).

In response to Japan's actions, both mainland China and Hong Kong prohibited all seafood imports from Japan in August 2023, followed by Russia in October 2023. These developments have significant economic implications for Japan. In 2022, Japan exported seafood valued at roughly $942.4 million to China, and approximately $432.3 million to Hong Kong.[3] South Korea has enforced a ban on seafood from the Fukushima region since 2013 and reaffirmed its commitment to maintaining this restriction.[4] Similarly, the Malaysian government is contemplating a prohibition on Japanese marine products due to potential radiation risks[5], and The Thailand Consumer Council (TCC) has urged the Food and Drug Administration (FDA) and the Department of Fisheries to implement strict screening measures on seafood imported from Japan, citing concerns over potential radioactive contamination.[6]

Given the uncertainty surrounding the impact of radioactive water on marine ecosystems and human health (Fu and Li 2024), public apprehension about marine contamination may influence and reshape dietary preferences. Consumers might forgo wild caught seafood from certain regions, turning instead to protein-dense alternatives from aquaculture, land-based sources, or aquatic products from regions deemed safe, to compensate for the protein deficit.

[3] CNN NEWS. Fukushima waste water: China says its ban on Japanese seafood is about safety. Is it really? | CNN Business
4 The Korea Times. Korea stands firm on Fukushima seafood import ban
[5] Malaysia Doesn't Import Live Marine Fish From Japan, Says Health Minister's Advisor
[6] Fears linger over possibly 'radioactive' seafood from Japan

Consequently, understanding the potential impacts of trade policy responses to nuclear wastewater discharge on seafood and substitute food markets is crucial. Accordingly, this research provides an overview of global seafood production and trade and employs a computable general equilibrium modeling framework to examine the global economic effects of import restrictions on seafood from Japan following nuclear wastewater discharge. By analyzing different scenarios of trade restrictions, the study offers insights into the potential economic consequences of these policy decisions for Japan, its trading partners, and the global seafood market. The findings of this research provide a deeper understanding of the relationships between environmental concerns, international trade, and economic impacts to inform policy decisions.

2. Background

Fisheries, which include marine capture and aquaculture activities, play a crucial role in the global supply chain, providing critical resources such as fish, mollusks, and crustaceans. These industries are essential not only for food supply but also as important sources of income, employment, and trade, particularly for coastal and rural communities. Therefore, the study of the impact of trade policies targeting Japan's fishing exports is integral to understanding how shifts in regulations and agreements can influence both the local and global landscape of seafood distribution, potentially affecting livelihoods, economic stability, and food availability. As shown in this section, Japan accounts for only 2.3% of global fishery production, yet it plays an outsized role in global seafood trade due to its position as one of the world's largest importers of fresh and processed seafood. This imbalance between relatively low domestic production and high

consumption underlines Japan's dependence on both imports to meet domestic demand and exports to support its fishing industry. As a result, Japan's seafood sector is particularly exposed to external trade shocks. Trade restrictions imposed by its primary export markets are expected to negatively affect domestic producers and exporters. However, given Japan's modest share in global production, the spillover effects on international or regional seafood prices are likely to be limited.

Table 1 provides details on the top ten exporters and importers of fresh seafood in 2022, along with additional data for Japan. Norway was the largest fresh seafood exporter, exporting 1.224 million metric tons (MMT) worth $8.9 billion, followed by Sweden (0.574 MMT, $4.01 billion), Denmark (0.253 MMT, $1.13 billion), and China (0.219 MMT, $1.48 billion). Japan exported 42,848 tons of fresh seafood valued at $380 million in 2022, ranking 18th globally. Sweden was also the largest fresh seafood importer (0.512 MMT, $4.05 billion), followed by Denmark (0.325 MMT, $1.33 billion), France (0.324 MMT, $2.16 billion), and Spain (0.281 MMT, $1.69 billion). Japan ranked as the 18th largest fresh seafood importer, importing 66,087 metric tons worth $896 million. This overview highlights the significant scale of the global fresh seafood trade and the key players driving both supply and demand in this sector.

Table 1. Fresh seafood exporters and importers in 2022

Ranking	Countries	Quantity (MMT)	Value (USD million)
Export			
1	Norway	1.224	8,927
2	Sweden	0.574	4,005
3	Denmark	0.253	1,133
4	China	0.219	1,484
5	Spain	0.161	794
6	Greece	0.140	789
7	Chile	0.132	1,050
8	Canada	0.126	1,262
9	United Kingdom	0.126	1,056
10	Netherlands	0.125	873
18	Japan	0.0428	380
Import			
1	Sweden	0.512	4,045
2	Denmark	0.325	1,330
3	France	0.324	2,162
4	Spain	0.281	1,693
5	U.S.	0.275	3,114
6	Italy	0.236	1,557
7	Poland	0.223	1,573
8	Netherland	0.161	991
9	Norway	0.150	207
10	China	0.148	1,540
18	Japan	0.066	896

Note: Values are, respectively, fresh seafood exports (top panel) and fresh seafood import (bottom panel), quantities are given in MMT and trade values are given in millions USD.
Source: UN Comtrade (2022)

Table 2 describes the top ten exporters and importers of processed seafood[7] in 2022, along with additional data for Japan. China dominated the sector as the leading exporter (2.874 million metric tons (MMT), $17.03 billion) and importer (3.357 MMT, $12.62 billion) of processed seafood worldwide. Ecuador was the second-largest exporter (1.619 MMT, $9.93 billion), followed by Norway (1.219 MMT, $5.81 billion) and India (1.090 MMT, $6.52 billion). Japan exported 427,212 tons of processed seafood, valued at approximately $1.4 billion, ranking

[7] Processed seafood contains prepared and preserved fish, crustaceans, molluscs and other aquatic invertebrates.

eleventh for total exports. On the import side, the U.S. ranked as the second-largest importer (2.674 MMT, $26.93 billion), followed by Japan (1.633 MMT, $11.74 billion) and South Korea (1.196 MMT, $3.96 billion). Japan's imports totaled 1.6 million tons, valued at $4.9 billion.

Table 2. Processed seafood product exporters and importers in 2022

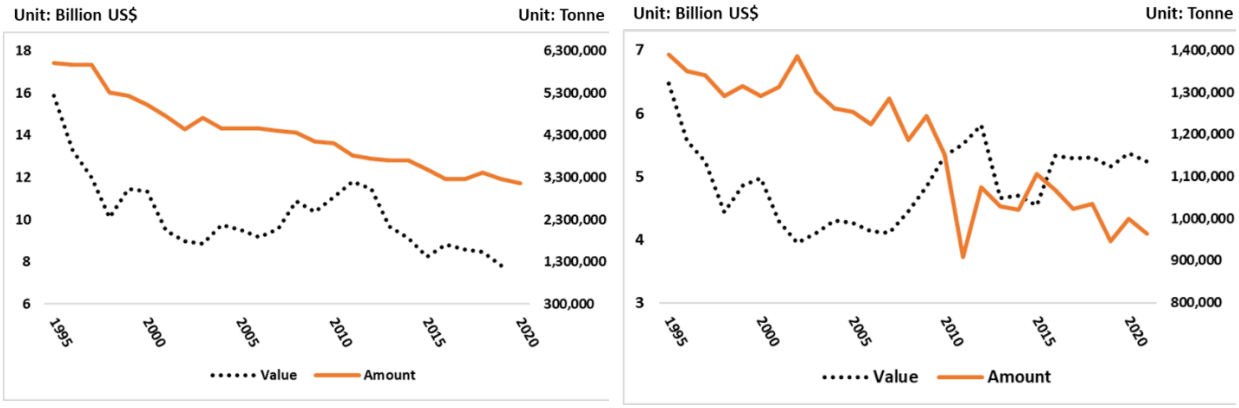
Ranking	Reporter	Net Weight	Trade value
Export			
1	China	2.874	17,032
2	Ecuador	1.619	9,929
3	Norway	1.219	5,806
4	India	1.090	6,521
5	U.S.	0.934	3,707
6	Netherlands	0.928	4,205
7	Chile	0.908	5,858
8	Spain	0.737	3,521
9	South Korea	0.689	1,798
10	Morocco	0.530	1,350
11	Japan	0.427	1,432
Import			
1	China	3.357	12,618
2	U.S.	2.674	26,926
3	Japan	1.633	11,737
4	South Korea	1.196	3,962
5	Spain	0.945	4,947
6	Germany	0.812	5,381
7	France	0.749	5,024
8	Netherlands	0.665	2,745
9	Côte d'Ivoire	0.634	739
10	Italy	0.608	4,518

Note: Values are, respectively, processed seafood export (top panel) and processed seafood import (bottom panel), net weights are given in million metric ton and trade values are given in millions USD.
Source: UN Comtrade (2022)

From the 1930s to the 1980s, Japan held the distinguished position of being the world's largest fishing nation. Historically, Japan has been a significant player in the international trade of marine products, both as an exporter and importer (Tsutsui 2023). Fisheries in Japan have a crucial role in ensuring a stable supply of fish as well as providing income and employment opportunities (Hotta 2000). The left panel in Figure 1 shows the status of wild catch, while the

right panel shows aquaculture production in Japan. Wild catch volumes have declined to half of their 1995 levels, whereas aquaculture production has remained relatively unchanged. Japan relies more heavily on wild catch than on aquaculture. In 2020, Japan's wild catch totaled about 3 million tons, compared to 0.99 million tons from aquaculture.

Figure 1. Japan's wild catch (left) and aquaculture production (right) in 2020



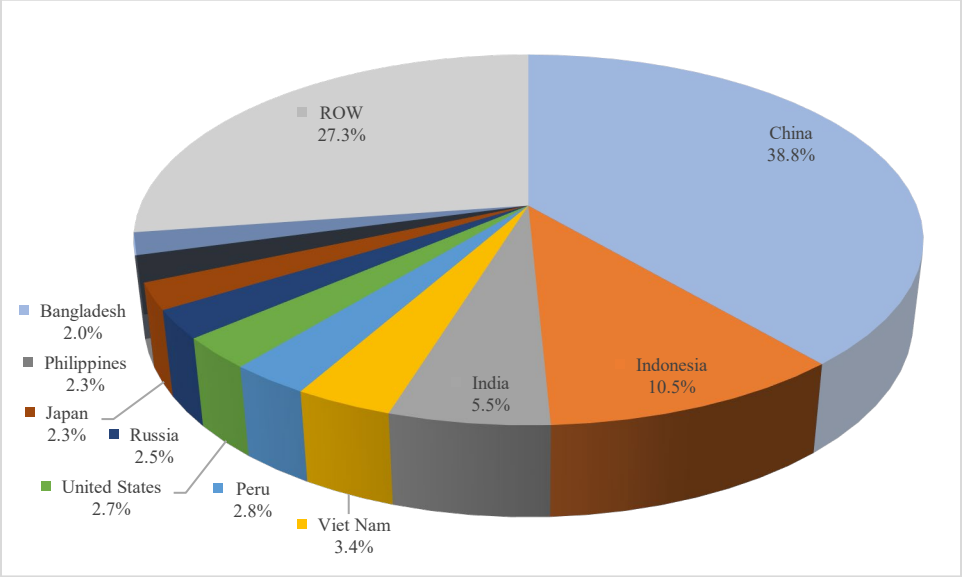
Wild catch production in Japan Aquaculture production in Japan

Note: Production values are given in billion USD and production amounts are in tonnes.
Source: Organization for Economic Co-operations and Development (OECD)

Despite a reduction in both wild catch and aquaculture output, Japan remains among the world's top 10 fisheries producers (Figure 2). From 2011 to 2020, Japan contributed an average of 2.3% to global fisheries production, producing 4.53 million metric tons (MT) of fisheries products annually. This consistent output highlights Japan's ongoing significance in the global seafood industry. China is the world's largest fishery producer, with 75,806,574.46 MT yearly, accounting for 38.8% of the world's total fisheries production. Figure 2 also shows that Southeast Asian countries, such as Indonesia, Vietnam, and the Philippines, hold a significant share of

global fisheries production. Interestingly, Japan outpaces many of these countries in seafood exports, trading more seafood products than several nations with higher production rates.

Figure 2. World top 10 fisheries producers

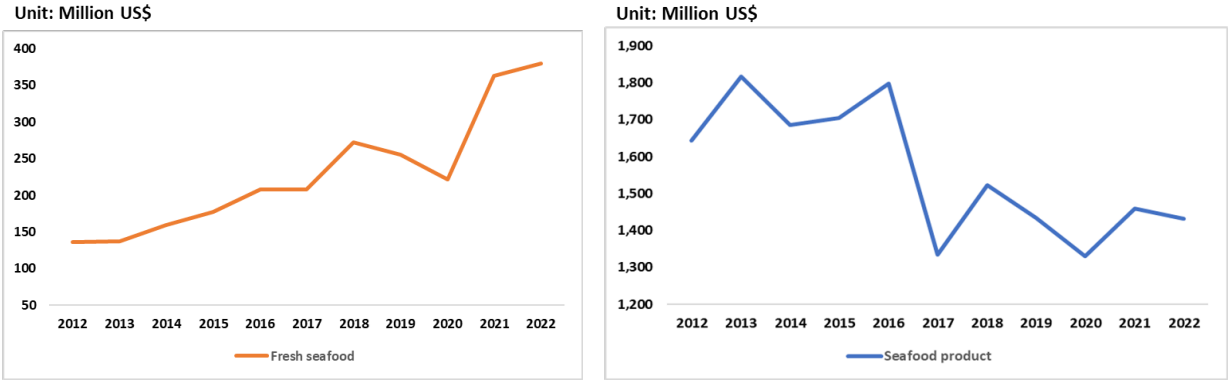


Note: This figure represents the share of global fisheries production for the world's top 10 countries from 2011 to 2020, with the share calculated based on the 10-year average.

Source: The World bank: [Total fisheries production (metric tons) | Data (worldbank.org)]

Figure 3 illustrates Japan's exports from 2012 to 2022. The left panel shows fresh seafood exports, while the right panel depicts processed seafood product exports. Japan's fresh seafood exports steadily increased during this period, whereas processed seafood product exports declined. However, the value of Japan's exports of processed seafood ($1.4 billion in 2022) was three times higher than the value of its exports of fresh seafood ($0.38 billion in 2022). The largest export destinations for Japanese fresh seafood in 2022 were South Korea, Hong Kong, and China, while the main destinations for processed seafood were Hong Kong, the U.S., and China. Therefore, restricting seafood imports from Japan in both China and Hong Kong may significantly impact Japan and other countries economically.

Figure 3. Japan's fresh seafood (left) and seafood product (right) exports in 2022



Note: Figures are, respectively, Japan's fresh seafood exports (Left panel), and processed seafood products exports (right panel) given in millions USD.
Source: UN Comtrade

3. Related Literature

3.1 Previous incidents of trade restrictions on seafood and other meat products

Trade bans on food imports between countries often occur for food safety or political reasons. Contamination or outbreaks of foodborne illnesses can lead countries to impose temporary or long-term bans on imported foods to safeguard public health. These trade restrictions affect the economies of both exporting and importing nations. For example, Cato and Dos Santos (1998) examined the economic impact of a European Union (EU) import ban on shrimp from Bangladesh seafood to the due to safety and quality reasons that resulted in lost revenues of up to $14.67 million for the Bangladesh frozen shrimp processing industry. Similarly, the EU banned fish from Kenya and Oman because the supply chains did not meet hygiene and food safety standards (Henson, Brouder and Mitullah 2000; Bose et al. 2019). Henson et al. (2020) found that the EU's import restrictions had a substantial impact on Kenyan fish exports, with total exports falling by approximately 400 metric tonnes (29%) in 1998 and 200 metric tonnes (21%) in 1999 compared to 1996. Exports to the EU dropped by over 60% in both years, with fresh fish exports especially affected, declining by 86% in 1998. While Kenyan

exporters partially offset losses by accessing alternative markets like Israel and Singapore, overall export values remained significantly lower by approximately 37% in 1998 and 24% in 1999 (Henson, Brouder and Mitullah 2000). The EU also banned fishery products from Sri Lanka from 2015 to 2016 for similar reasons (De Silva et al. 2019; Sandaruwan and Banerjee 2020; Bandara and Gamage 2020; Sandaruwan and Weerasooriya 2019). Sandaruwan and Weerasooriya (2019) found that between 2015 and 2016, Sri Lanka's share of total fish imports into the EU dropped from 0.52% to 0.06%, and its rank among EU fish suppliers fell from 36th to 74th. Fish export values to the EU declined from over $100 million in 2014 to less than $25 million by 2016. Although some exports continued during the ban, overall volumes and value declined sharply, and post-ban recovery remained limited, highlighting the lasting adverse effect of the EU's restrictions. Furthermore, the U.S. imposed import bans in 1996 on shrimp from several countries that did not meet the requirement for turtle excluder devices in shrimp harvesting (Stewart 1998; Srivastava and Ahuja 2002). This spurred changes in production practices in India from wild catch to cultured shrimp to resume exports and maintain market share in the U.S. (Srivastava and Ahuja 2002). There are also many examples of trade restrictions for other meat and livestock products. In 1996, the EU banned imports of British beef in response to the detection of Bovine Spongiform Encephalopathy (BSE) (Hubbard and Philippidis 2001). In 2003, a case of BSE in Canada prompted a global embargo on Canadian cattle and beef, affecting major destination markets including the U.S., Mexico, and Japan (Panagiotou and Azzam 2010; Peterson and Burbidge 2012), and the detection of BSE in Brazil in 2023 led to immediate trade policy restrictions imposed by China (De Menezes, Countryman, Hagerman, et al. 2024). Foot-and-Mouth Disease (FMD) also triggered trade restrictions on beef exports from Latin American countries during the 2001 outbreaks; for example, the U.S.

maintains import bans on fresh meat and animal products from FMD-susceptible species in affected countries such as Brazil and Argentina (Bown and Hillman 2017; Countryman and Hagerman 2017; De Menezes et al. 2022; De Menezes, Ferreira Filho and Countryman 2023). Highly Pathogenic Avian Influenza (HPAI) resulted in restrictions on U.S. poultry exports beginning in 2022 (Padilla, Baker and MacLachlan 2025; MacLachlan, Boussios and Hagerman 2021), and the presence of African Swine Fever (ASF) has resulted in trade restrictions across infected countries (Herrera-Ibatá et al. 2017).

Trade bans can also be implemented in response to geopolitical tensions or political disputes. In reaction to Russia's annexation of Crimea and its ongoing military involvement in eastern Ukraine, the U.S., in coordination with the EU and other nations, imposed several economic sanctions on Russia. In response, in August 2014, the Russian government banned the import of agricultural and processed food products from Australia, Canada, the EU, Norway, and the U.S. The banned items included dairy, meat, fruits, vegetables, and fish products. EU Member States were significantly impacted in terms of export volumes, accounting for 73% of the total agricultural food products affected by the trade restrictions (Nelson 2015; Arina and Fabrizio 2015; Smutka et al. 2016; Boulanger et al. 2016; Kutlina-Dimitrova 2017; Liefert et al. 2019; Smutka and Abrhám 2022). Certain sectors and Member States within the EU experienced more pronounced impacts, with a notable 31% reduction in EU milk product exports and a 29% decline in fruit and vegetable exports. The overall restrictions imposed by Russia threatened trade worth 5 billion euros in 2014 (Dreve, CĂLIN and BAZGĂ 2015).

The economic ramifications of imposing trade bans can lead to considerable disturbances within the food supply chain and result in price fluctuations. Agricultural producers in exporting countries may face financial losses due to reduced market access, and importing countries may

experience inflationary pressures and increased production costs. Even though other analyses have assessed the effects of trade restrictions on either fresh seafood or frozen seafood, to our knowledge, no economic study has assessed the potential impacts of trade restrictions on both fresh and processed seafood products simultaneously. Given Japan's substantial exports of fresh and processed seafood to global markets, a trade ban targeting these sectors could negatively affect trade flows leading to concurrent impacts for both producers and consumers, necessitating a comprehensive evaluation to understand the full extent of these effects.

3.2 Trade restrictions related to environmental concerns

Since the 1970s, international trade has increasingly recognized the importance of environmental issues, with transboundary concerns gaining prominence in trade negotiations by the 1980s. As Jayadevappa and Chhatre (2000) documented, differing environmental regulations can influence the competitive dynamics of nations and industries. When countries share natural resources, such as rivers and air sheds, their environmental policies or lack thereof can have cross-border impacts, necessitating cooperative solutions. This becomes particularly critical in the face of global environmental challenges. In this context, trade interventions have been proposed as mechanisms to address environmental externalities. For instance, Anderson and Blackhurst (1994) suggest that while pollution-abating trade interventions might seem counterproductive to welfare, Chapman (1991) argues for the strategic use of environmentally related import tariffs in the absence of uniform global regulations. Moreover, Copeland (1996) presents a two-country model demonstrating the potential of trade policies, such as pollution content tariffs or process standards on imports, to regulate transboundary pollution. Studies from the 1970s through the 1990s underscore the complex relationship between trade policies and

environmental regulation, advocating for policy frameworks that balance environmental protection with international trade considerations (Pethig 1976; Bhagwati and Hudec 1996).

However, there is still a research gap concerning the synergy of trade policies and environmental protection in scenarios such as Japan's decision to release nuclear wastewater despite the potential for restrictions on seafood exports. Current studies have not yet thoroughly examined the conversations necessary to address transboundary environmental issues, particularly in a global context where national priorities often clash with broader international welfare needs. Considering retaliatory trade restrictions on Japanese seafood, recognizing and understanding the economic consequences becomes essential.

3.3 Methods to Investigate Economy-wide Effects of Trade Restrictions

Extensive literature explores the impact of trade restrictions using computable general equilibrium (CGE) modeling frameworks including the Global Trade Analysis Project (GTAP) model. In the context of agricultural biotechnology regulatory discrepancies, Henseler et al. (2013) used GTAP-AGR, an augmented version of the standard GTAP model focused on agricultural markets, to simulate the hypothetical cessation of soybean exports from Argentina, Brazil, and the U.S. to the EU due to inconsistent biotechnology approval procedures between the EU and major soybean producers. Similarly, Pavleska and Kerr (2020) highlighted the contentious nature of international biotechnology regulatory disparities, using GTAP to simulate the potential impacts of regulations on global trade flows.

Several studies employing the GTAP model have analyzed the impact of trade restrictions resulting from animal disease outbreaks. Hubbard and Philippidis (2001) provided an

ex post CGE assessment of the 1996 British beef export ban, using the GTAP model in a comparative static, sequential manner to analyze the ban's imposition and eventual reversal. De Menezes et al. (2024) simulated the economy-wide impact of BSE in Brazil under various trade ban scenarios, including a one-month ban on cattle and beef exports to Egypt and Saudi Arabia, 1-, 3-, and 6-month bans on exports to China, and a 6-month ban imposed by seven regions (Canada; China and Hong Kong; the EU and UK; Japan; South Korea; Mexico; and the U.S.). De Menezes et al. (2022) estimated the economic consequences of a hypothetical FMD outbreak in Brazil using GTAP model, simulating trade and welfare impacts under various trade restrictions. Carriquiry et al. (2020) employed a global agricultural modeling system and a U.S. input-output model to estimate the economic impact of complete bans on U.S. pork exports on U.S. agriculture. While De Menezes, Countryman and Story (2024) used the GTAP model to analyze a 40% export ban on Brazilian hogs and pork.

Another strand of studies employs the GTAP model to quantify the economic implications of trade restrictions driven by geopolitical events. Boulanger et al. (2016) employed the GTAP model to conduct a quantitative analysis of the direct market impacts of the 2014 Russian import ban on agri-food products from countries implementing Ukraine-related sanctions against Russia, providing insights into the ban's short-term effects. Similarly, Mahlstein et al. (2022) explored the short- to medium-term economic consequences of a hypothetical Allied countries' trade embargo against Russia following its invasion of Ukraine, applying the GTAP model to investigate the potential ramifications of economic sanctions. Despite the extensive applications of GTAP in various trade-related analyses, few studies have investigated the impact of seafood trade regulations using the GTAP model, and to our knowledge, no studies have explicitly accounted for fresh and processed seafood products in the

GTAP model. This paper fills a research gap by using the GTAP model to analyze the potential global impacts of trade restrictions on Japanese seafood, including fresh and processed products, due to nuclear wastewater concerns. By disaggregating processed seafood products from other processed food categories in our modified GTAP database, we provide insights into the specific impacts of trade restrictions on the seafood industry, contributing to a deeper understanding of potential global trade effects in this context.

3. Modeling Framework

This study employs a computable general equilibrium modeling framework to simulate the potential economic impacts of various scenarios involving trade restrictions on Japanese seafood, triggered by the discharge of treated nuclear wastewater from Fukushima. We use version 7 of the static GTAP model and the GTAPv11 database, which has a base year of 2017 (Aguiar et al. 2022; Corong et al. 2017; Hertel 1997), a widely used framework for trade policy analysis that integrates microeconomic foundations, a multi-country perspective, and multisector macroeconomic linkages (Kutlina-Dimitrova 2017). The GTAP model was designed with the specific purpose of trade policy analysis and has widely used for its effectiveness in conducting economic impact assessments of various trade policy measures (Mahlstein et al. 2022). The GTAP modeling framework enables the quantitative assessment of the impact of trade policies on a global scale, including changes in trade flows and welfare and is well suited for this analysis (Pavleska and Kerr 2020).

3.1 Model Specification

We employ the GTAP modeling framework to simulate the global repercussions of trade policy restrictions on Japanese seafood exports in response to Japan's discharge of treated radioactive water. The standard GTAP model, based on principles of perfect competition, assumes that production technologies exhibit constant returns to scale. In its production function, intermediate inputs are integrated through a Constant Elasticity of Substitution (CES) composite, acknowledging that intermediates sourced from various regions are not perfect substitutes. The model incorporates elements of international trade and transport margins, calculating the bilateral disparities between the cost, insurance, and freight (cif) prices and the free on board (fob) prices for each nation (Corong et al. 2017; Countryman and Bonanno 2020).

The standard GTAP modeling framework is particularly suitable for simulating the effects of trade restrictions on Japanese seafood given its comprehensive coverage of connections between global production, processing, trade, and prices. For bilateral trade, the model employs the Armington assumption, wherein producers and consumers differentiate demand between domestically produced goods and an import composite, further distinguishing imported varieties by their country of origin (Armington 1969). On the demand side, regional household consumption patterns are depicted using a Constant Difference of Elasticities (CDE) specification (Corong et al. 2017).

3.2 Data

We employ the GTAP v11 database (Aguiar et al. 2022), which covers 141 countries, 19 aggregate regions, and 65 sectors. We aggregated regions by grouping continents, except for

China, Japan, South Korea, and Russia. These four countries were kept separate due to their proximity to Japan and the assumption that the impacts of a seafood trade ban may be more substantial in these regions, with the exception of Russia which imports nominal seafood from Japan. The final aggregation employed for this work comprises 10 regions listed in Table 3: Japan, China, South Korea, Russia, Rest of East Asia and Oceania, Southeast Asia, Europe, North America, Central and South America, and Rest of the World. This aggregation allows us to focus on the key players in seafood trade that are also proximate to Japan while still maintaining a global perspective.

However, the standard GTAP database has limitations that are relevant for this study, primarily its lack of a fully integrated seafood sector. While the current fishing sector does cover a range of activities including hunting, trapping, game propagation, and associated services such as fish farming, the fishing sector omits key segments of the industry including processed seafood including frozen and other prepared seafood products, which are aggregated with other processed foods in the standard GTAP database. Neglecting these important processed seafood products could lead to a substantial underestimation of the trade ban's impact. To address this issue, we separate the frozen and prepared seafood categories from the broader “other food” sector and integrate them into the existing fishing sector. Specially, we disaggregate the "other food products" GTAP sector (ofd) into "processed seafood" (pfsh) and "other foods" (oofd)[8] using the "SplitCom" software.[9] We then aggregate "fresh seafood" and "processed seafood" into

[8] Sector descriptions for processed seafood (pfsh) and other foods (oofd) are included in the Appendix, Table A1. & A2.

[9] SplitCom disaggregates GTAP sectors by allocating production, consumption, and bilateral trade flows to newly defined subsectors using user-specified or default weights for output, use, imports, and exports at the regional level, while preserving GTAP’s core accounting identities, including welfare and returns to primary factors. SplitCom proportionally distributes tariffs and taxes across the split products and rebalances the database using a RAS-like

a single "Seafood" sector. This adjustment creates a representative seafood sector for this study, enabling a more accurate assessment of the trade ban's effects on Japan's seafood industry. The final sectoral aggregation for this work includes six sectors shown in Table 3: Seafood, Meat & Livestock, Processed Food, Crops, Manufacturing, and Services.

Table 3. Regions and sectors modeled

Region Aggregation		Sector Aggregation	
1	Japan	1	Seafood
2	China	2	Meat & Livestock
3	South Korea	3	Processed Food
4	Rest of East Asia and Oceania	4	Crops
5	Southeast Asia	5	Manufacturing
6	Russian Federation	6	Services
7	Europe		
8	North America		
9	Central and South America		
10	Rest of the World		

Note: Detailed region and sector aggregations are included in Appendix Tables A3 and A4.

We supplemented the GTAP data with information from the United Nations Industrial Development Organization (UNIDO) and UN Comtrade. UNIDO data was used to combine 2017 production data with 2005-2016 data where 2017 values were missing.[10] Processed seafood[11] and other food trade data were obtained from UN Comtrade. For countries with missing export data, we used average export share values from nearby countries or continental averages.[12] This data augmentation process ensures a more complete and accurate representation of the global seafood trade landscape in the newly developed Seafood sector for this analysis.

procedure to ensure consistency with the original dataset, allowing accurate reaggregation and preserving the integrity of trade and policy analyses.

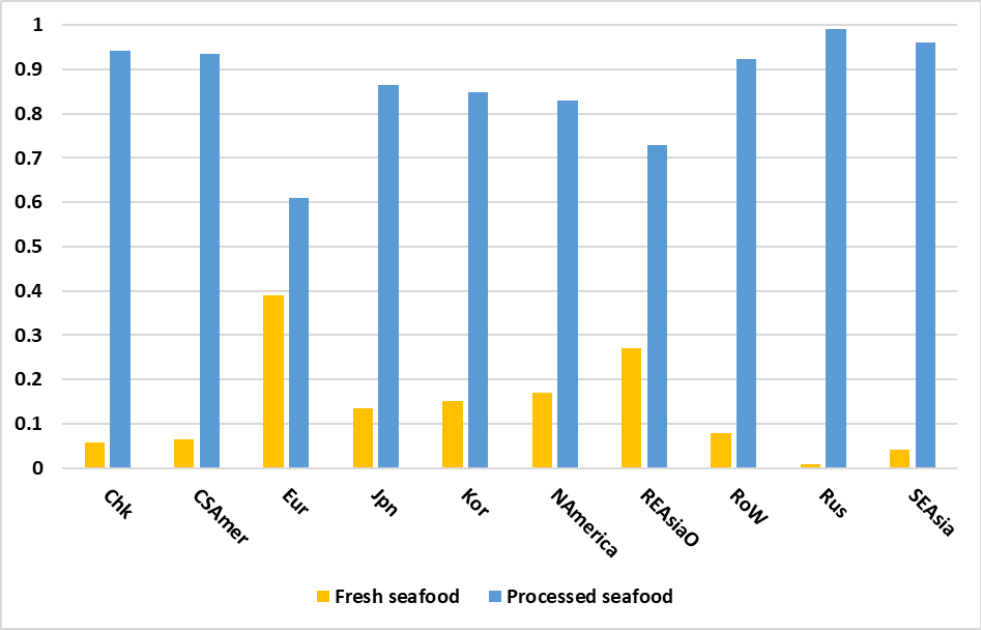
[10] Detailed information is included in the Appendix, Table A5.

[11] Processed seafood (pfsh) are defined as 'prepared and preserved fish, crustaceans, molluscs and other aquatic invertebrates' from other food (oofd).

[12] Detailed information is included in the Appendix, Table A6.

Figure 4 shows the export shares of fresh seafood and processed seafood among total seafood exports in 2017 for the ten study regions. Europe showed the highest share of fresh seafood exports, while Russia led in processed seafood exports. Japan's fresh seafood comprised 13% of its total seafood exports, ranking fifth among the ten regions. This share is relatively high for a single country, especially when compared to China. The variation in export shares across regions highlights the diverse nature of the global seafood market and underscores the potential for differential impacts of trade restrictions on Japanese seafood exports.

Figure 4. Fresh seafood and processed seafood export shares (2017)



Note: The yellow bars indicate fresh seafood export shares, blue bars indicate processed seafood export shares for total seafood exports from each region, respectively. See Appendix Table A3 for definitions of the regional acronyms used in the figure.
Source: UN Comtrade, 2024.

3.3. Scenario Design

The scenarios employed for this study are designed to capture a range of potential trade policy responses to Japan's nuclear wastewater discharge, from current real-world situations to

hypothetical extreme cases. By simulating these scenarios, we provide a comprehensive understanding of the potential economic impacts across various levels of trade restrictions.

3.3.1 Scenario 1: Trade Restrictions imposed by China and Russia

Scenario 1 (S1) reflects the current situation where China, Hong Kong, and Russia have enforced a complete embargo on all seafood imports from Japan in response to the nuclear wastewater discharge. In the GTAP model, we simulate this by applying a 99.9% reduction in bilateral trade of seafood from Japan to these regions[13]. This scenario captures the immediate and direct impact of these trade restrictions on Japan's seafood industry and the broader economic implications for Japan, the countries restricting imports, and the economy overall. However, it is important to note that Russian imports of Japanese seafood prior to the ban are negligible. Accordingly, the percentage changes in exports reflect inconsequential changes in Russian seafood imports. This scenario serves as a baseline for comparing the effects of more extensive trade restrictions in subsequent simulations.

3.3.2 Scenario 2: Scenario 1 with expanded Trade Restrictions by Observant Countries

In Scenario 2 (S2), we consider the potential restriction of Japanese seafood imports of additional countries including South Korea and several Pacific Island nations, which are currently adopting a wait-and-see approach. While these countries have not yet implemented trade restrictions, we simulate the effects of the imposition of a seafood trade ban on Japan in addition to the trade restrictions included in S1. This scenario allows us to evaluate the impacts

[13] Due to the functional form of the GTAP model, trade flows cannot be reduced to exactly zero. Applying a 99.9% reduction approximates a trade embargo.

of more moderate trade restrictions to understand how different levels of restrictions could impact the seafood industry and global trade landscape. By comparing the results of S2 with S1, we can assess the incremental impact of additional countries implementing trade bans on Japanese seafood.

3.3.3 Scenario 3: Universal Trade Restrictions on Japanese Seafood by All Countries

In Scenario 3 (S3), we delve into a considerably more extreme situation where all countries prohibit Japanese seafood imports. Although such a global embargo is unlikely in practice, this scenario serves as a useful benchmark to assess the upper bound, or worst-case scenario, of potential economic impacts resulting from international responses to Japan's nuclear wastewater discharge. The purpose of this scenario is to illustrate the maximum potential disruption to Japan's seafood sector and broader economy, as well as global seafood trade. Results from this scenario offer valuable insights into the vulnerabilities and resilience of Japan's economy and the global seafood market under conditions of severe trade isolation driven by environmental concerns.

4. Results

The results of this study focus on changes in key variables for the three scenarios. First, we analyze changes in trade flows and domestic consumption for each scenario. Next, we discuss the potential effects on seafood prices and output across different countries and regions. Finally, we evaluate regional welfare changes.

4.1 Effects on Trade

Table 4 illustrates the impact of trade restrictions on seafood exports across regions. Japan's total seafood exports show a sharp decline due to bans from China and Russia, dropping by 26.62% ($362.68 million) in S1, which is driven by decreased exports to China as exports to Russia are minor. This decline escalates to 61.18% ($833.63 million) in S2, with additional trade restrictions from South Korea and Southeast Asia. Given that Asian countries are major importers of Japanese seafood, their absence from the market significantly reduces Japan's export opportunities. The loss of export markets leads to excess supply in Japan's domestic seafood market, which in turn places downward pressure on domestic prices (Table 5). As prices fall, Japanese consumers substitute away from imported seafood toward relatively cheaper domestically produced seafood. This is reflected in Appendix Tables A7 and A8, which show a decrease in Japan's seafood imports and an increase in domestic seafood consumption. However, this increase in consumption is insufficient to offset the export losses, resulting in an overall contraction in Japan's seafood industry. This underscores Japan's heavy reliance on these specific markets and highlights the vulnerability of its seafood industry to international trade restrictions.

Conversely, other regions including Russia, Southeast Asia, North America, Europe, Central and South America, and the Rest of the World (RoW) all show a minor growth in fresh and processed seafood exports across all scenarios as they step in to replace exports from Japan. The model reveals these increases are relatively small, with each region making modest contributions to compensate for Japan's reduced role in the global seafood market. This is because Japan accounts for only a small share of the global seafood market, contributing just 1.0% of fresh seafood exports and 1.3% of processed seafood exports worldwide in 2022. As a

result, even with the decline in Japanese seafood exports, the overall global export market remains largely unaffected, with no significant shift in the distribution of seafood trade as Japanese exports decrease. Appendix Table A8 presents domestic consumption of seafood and other agricultural products, showing that the decline in Japanese seafood imports is not significant enough to drive major changes in dietary patterns in Japan and other regions. While minor substitutions may occur, such as slight increases in domestic seafood consumption in Japan, the overall impact remains limited. This suggests that consumers either rely on alternative suppliers or that Japanese seafood was not a crucial part of their diet. Despite trade disruptions, the fundamental food consumption structure remains stable across countries.

Table 4. Percentage and Value Changes in Seafood Exports

	S1		S2		S3	
Country/Region	%	Value ($ Mil.)	%	Value ($ Mil.)	%	Value ($ Mil.)
Japan	-26.62	-362.68	-61.18	-833.63	-99.90	-1361.22
Russia	0.74	19.23	1.37	35.57	1.63	42.59
China	-0.05	-5.69	1.20	127.76	1.91	203.67
South Korea	0.43	6.03	-0.21	-2.87	0.30	4.21
Southeast Asia	0.42	52.95	0.73	91.34	1.42	179.3
Rest of east Asia and Oceania	0.81	27.15	1.47	49.53	1.11	37.28
North America	0.46	34.59	0.75	57.11	1.35	102.5
Europe	0.16	53.62	0.31	106.48	0.63	214.48
Central and South America	0.28	30.91	0.63	69.03	1.09	118.54
Rest of the World	0.20	21.43	0.62	67.42	1.10	118.69

Note: S1 includes an import ban on Japanese seafood in China and Russia. S2 extends the trade ban to include China, Russia, South Korea, and Southeast Asia. S3 represents the scenario in which there is a trade ban on Japanese seafood in all regions.
Source: Authors' simulations

4.2 Effects on Production and Prices

Table 5 presents key trends in seafood supply prices and output across regions under three trade restriction scenarios (S1, S2, S3). Japan shows a relatively small, consistent decline in both seafood prices and output across all scenarios, underscoring the adverse effects of trade

restrictions on its seafood sector. Seafood price reductions range from -0.5% (S1) to -1.83% (S3), while output declines from -0.68% (S1) to -2.57% (S3), signaling a slight contraction in Japan's seafood market. These results suggest that the trade restrictions not only reduce Japan's export capabilities but also negatively affect its domestic seafood industry, potentially leading to economic challenges for seafood producers and related sectors in Japan.

Table 5. Percentage Changes in Seafood Supply Prices and Output

	Prices			Output		
Country/Region	S1(%)	S2(%)	S3(%)	S1(%)	S2(%)	S3(%)
Japan	-0.5	-1.13	-1.83	-0.68	-1.57	-2.57
Russia	0.08	0.13	0.16	0.14	0.23	0.28
China	0.11	0.17	0.21	0.08	0.13	0.16
South Korea	0.03	0.39	0.43	0.04	0.47	0.52
Southeast Asia	0.06	0.29	0.4	0.05	0.22	0.3
Rest of east Asia and Oceania	0.13	0.24	0.7	0.14	0.26	0.69
North America	0.05	0.1	0.27	0.07	0.13	0.35
Europe	0.04	0.08	0.18	0.05	0.1	0.23
Central and South America	0.05	0.11	0.2	0.05	0.12	0.21
Rest of the World	0.03	0.08	0.16	0.02	0.05	0.1

Note: S1 includes an import ban on Japanese seafood in China and Russia. S2 extends the trade ban to include China, Russia, South Korea, and Southeast Asia. S3 represents the scenario in which there is a trade ban on Japanese seafood in all regions.
Source: Authors' simulations

In contrast, other regions show slight increases in both seafood prices and output. As Japan's export share in the global seafood market declines, other countries and regions show a very minor increase in seafood prices and production as they expand their supply to meet the unfilled domestic demand. However, given that Japan ranked only as the 18th largest exporter of fresh seafood and the 11th largest exporter of processed seafood in 2022 (Tables 1 and 2), the loss of Japanese seafood exports is not substantial enough to disrupt the global seafood market. Consequently, price increases remain relatively moderate and evenly distributed across regions outside Japan.

4.3 Welfare

Table 6 shows the simulated welfare effects across all scenarios, measured in terms of equivalent variation (EV)[14] in millions of USD. Japan shows welfare losses in all scenarios, with EV declines of -$105.34 million in S1, increasing to -$393.2 million in S3. The primary driver of these losses is the sharp decline in Japanese seafood exports due to the trade restrictions. As key importers restrict Japanese seafood, Japan faces reduced access to major foreign markets, leading to a contraction in its seafood industry. This decline affects not only seafood producers but also related industries such as seafood processing and distribution.[15] The diminishing export revenues put downward pressure on domestic seafood prices in Japan as shown in Table 5, further straining the industry. Additionally, the trade restrictions could lead to structural adjustments in Japan's seafood sector, including potential job losses, lower investment, and declining profitability for firms reliant on international trade.

There are minor welfare losses for Russia across scenarios, consistent with the real-world situation, as Japan exports very little seafood to Russia. This limited trade relationship results in the import restrictions having no substantive economic impact on Russia. In contrast, China faces the largest welfare losses from the import restrictions, with EV declines ranging from -265.49 million USD in S1 to -273.8 million USD in S3. Notably, China's welfare losses in S1 and S2 exceed those of Japan. This outcome is driven by China's negative technology effects (-164.28 million USD in S1) and greater allocative efficiency losses (-70.28 million USD in S1),

[14] In this study, EV reflects the overall change in a country's economic well-being as a result of the trade restrictions on Japanese seafood. It represents the dollar value a country would need to gain or lose to reach the same level of welfare as under the baseline without trade bans.

[15] As shown in Appendix Table A9, Japan's returns to capital, skilled labor, and land in the seafood sector decline across all scenarios, with losses intensifying under broader trade restrictions, reaching up to 3.2% in the most severe case (S3).

whereas Japan's negative welfare impacts are primarily due to decreased terms of trade (-76.37 million USD in S1) and allocative efficiency losses (-29.44 million USD in S1).[16] Although Japan was only China's ninth-largest seafood import source, accounting for just 3% of imports, the total import value from Japan was still considerable at approximately 545 million USD[17] in 2022. As the exporting nation subject to restrictions, Japan maintains unchanged production technologies while China adapts its downstream processing industries that depend on Japanese inputs. For instance, China's seafood processing industry, which relies on Japanese imports for raw materials and intermediate inputs, faces minor cost increases and operational inefficiencies as firms seek alternative suppliers. The difference in allocative efficiency effects suggests China faces greater market distortions as it reallocates resources across its seafood value chain when substituting alternative import sources, while Japan's allocative efficiency effects are primarily limited to redirecting resources from export to domestic markets.

Table 6. Changes in Welfare (Equivalent Variation, US$ Million)

Country/Region	S1	S2	S3
Japan	-105.34	-245.02	-393.2
Russia	-2.75	-1.87	-3.45
China	-265.49	-266.22	-273.8
South Korea	0.85	-112.95	-112.37
Southeast Asia	19.64	-70.07	-45.49
Rest of east Asia and Oceania	11.28	19.78	-88.88
North America	26.39	33.42	-29.98
Europe	42.52	57.13	37.25
Central and South America	28.24	57.83	91.79
Rest of the World	5.27	3.62	-12.36

Note: S1 includes a Japanese seafood import ban in China and Russia. S2 extends the ban to include China, Russia, S. Korea, and SE Asia. S3 includes a Japanese seafood ban in all regions.
Source: Authors' simulations

[16] Total welfare effects include changes in allocative efficiency, technological change, terms of trade, and savings and investment.
[17] These data are from the UN Comtrade Database.

The EU and Central and South America consistently see minor welfare gains across all scenarios, including S3, despite imposing their own import restrictions on Japanese seafood. These regions benefit from their strong position as major global seafood exporters, both fresh and processed (as shown in Tables 1 and 2). With well-established seafood industries, advanced processing capabilities, and diversified export markets, these regions are well-equipped to adapt to shifts in global trade patterns. As other countries restrict Japanese seafood imports, they step in as alternative suppliers, expanding exports to fill the supply gap left by Japan's reduced presence in the global market. This trend is reflected in Table 4, which shows the increases in the absolute value of their seafood exports, albeit on a relatively small scale. By capitalizing on rising global demand for seafood from sources other than Japan, higher seafood prices, and new trade opportunities in markets that previously relied on Japan, they strengthen their competitive advantage and sustain minor welfare gains across all scenarios.

5. Conclusion and Discussion

This study employs a CGE modeling framework to simulate the potential economic impacts of import bans on Japanese seafood. Specifically, we apply the standard GTAP modelling framework with the GTAP v11 database to evaluate international trade policy responses to Japan's release of treated nuclear wastewater from Fukushima. By analyzing various trade restriction scenarios, this study provides insights into the potential economic consequences for Japan, its trading partners, and the global seafood market.

Our analysis simulates a substantial decline in Japan's seafood exports, accompanied by minor welfare losses. As major trading partners impose restrictions, Japan's seafood industry

faces declining output, export contractions, and broader economic pressures. These results underscore the vulnerability of export-dependent industries to international trade policies and highlight how environmental decisions can have far-reaching economic ramifications.

At the global level, the trade restrictions cause minor adjustments in seafood exports, prices, and production. Other seafood-exporting regions, including North America, Europe, and Central and South America, show modest gains as they expand exports to fill the gap left by Japan's reduced market presence. However, Japan's role in global seafood trade is relatively small, allowing the overall seafood market to remain stable, with only minor price increases, primarily concentrated in East Asia. The welfare effects of these trade changes vary across regions. While Japan and China show relatively large welfare losses, the EU and Central and South America benefit from increased exports and minor increases in seafood prices. Despite these trade changes, our analysis of domestic consumption patterns indicates that the decline in Japanese seafood exports has a negligible impact on global food consumption structures.

The results underscore the complex relationship between environmental policies, trade restrictions, and economic welfare. While the import restrictions on Japanese seafood are intended as precautionary measures in response to concerns over Japan's release of nuclear wastewater, they also introduce economic disruptions, particularly for Japan and its key seafood exporting partner, China. Although the restrictions do not cause widespread instability in the global seafood market, they lead to localized losses, forcing adjustments in supply chains and trade flows. At the same time, increased exports from seafood suppliers helps stabilize global markets. Regions such as the EU and Central and South America, with their well-established trade networks, successfully expand exports to meet global demand. This adaptability highlights

the importance of strengthening trade partnerships, improving supply chain flexibility, and investing in sustainable seafood production to reduce vulnerability to trade shocks. Moving forward, policies addressing environmental concerns must also consider economic trade-offs, especially in industries highly dependent on international markets, to mitigate unintended disruptions and enhance long-term market resilience.

This research also sheds light on the broader impacts of geopolitical decisions related to global food security and trade. Japan's decision, driven by space constraints at the Fukushima facility, has ignited international debate and a range of policy responses. This situation reflects the trade-offs between addressing environmental safety concerns and maintaining economic interests. The varied responses from countries highlight the challenges in achieving international agreement on issues that intersect environmental regulation and global trade.

It is important to acknowledge certain limitations of this study. The CGE model relies on several key assumptions that may influence the results. First, the model assumes perfect competition and constant returns to scale, which may not fully reflect real-world market conditions in the seafood industry. While the seafood industry is influenced by government subsidies and trade regulations that are accounted for in the model, there may be supply chain constraints that are not explicitly modeled under the assumptions of perfect competition. Second, the Armington assumption, which differentiates products by country of origin, might overstate the differentiation between domestic and imported goods. If consumers view imported seafood as a near-perfect substitute for domestic products, price and demand fluctuations may be more minor than the model predicts. On the other hand, in cases where imported seafood is perceived as lower quality or subject to safety concerns, such as the challenges currently faced by Japanese

seafood due to concerns over nuclear wastewater release, the negative impact on trade could be even greater than simulated. Consumers may actively avoid Japanese seafood, even in regions without formal trade bans, leading to a potential broader decline in demand for Japanese seafood. Third, the study also faces data limitations, particularly in disaggregating the processed seafood sector from the broader other processed food sector in the GTAP database. This could potentially affect the precision of sector-specific impacts. Finally, this study focuses on economic impacts and does not directly assess the potential environmental or health effects of Japan's nuclear wastewater release, which could have additional indirect economic consequences. If long-term environmental damage to marine ecosystems occurs, it could reduce seafood supply, drive up prices, and disrupt global trade, with impacts extending beyond the scope of this study.

Overall, the economic impact of import bans on Japanese seafood highlights the complex interactions between environmental policies, global trade, and economic welfare. While these import restrictions serve as protective measures for concerned nations, they also disrupt established trade relationships and food markets, benefiting some regions while imposing economic costs on others. The findings emphasize the need for a balanced approach to policy design, ensuring that environmental protection measures are aligned with trade stability and economic resilience. As global trade becomes increasingly interconnected, cooperation, transparency, and adaptability will be essential for navigating future trade disruptions, maintaining market stability, and enhancing environmental sustainability.

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Appendix

Table A1. GTAP Other Food (ofd) Sector Description

GTAP Sector	Code	Description
	212	Prepared and preserved fish, crustaceans, molluscs and other aquatic invertebrates
	213	Prepared and preserved vegetables, pulses and potatoes
	214	Prepared and preserved fruits and nuts
	2311	Wheat and meslin flour
	2312	Other cereal flours
	2313	Groats, meal and pellets of wheat and other cereals
	2314	Other cereal grain products (including corn flakes)
ofd	2317	Other vegetable flours and meals
	2318	Mixes and doughs for the preparation of baker' wares
	232	Starches and starch products; sugars and sugar syrups n.e.c.
	233	Preparations used in animal feeding; lucerne (alfalfa) meal and pellets
	234	Bakery products
	236	Cocoa, chocolate and sugar confectionery
	237	Macaroni, noodles, couscous and similar farinaceous products
	239	Food products n.e.c.

Table A2. Detailed Sector Composition of Processed Seafood (pfsh) and Other Food (oofd).

	Description	ISIC4 Description	ISIC3 Description
pfsh	Prepared and preserved fish, crustaceans, molluscs and other aquatic invertebrates	1020 Processing/preserving of fish, etc.	1512 Processing/preserving of fish
oofd	• Prepared and preserved vegetables, pulses and potatoes • Prepared and preserved fruits and nuts • Wheat and meslin flour • Other ceral flours • Groats, meal and pellets of wheat and other cereals • Other cereal grain products (including corn flakes) • Other vegetable flours and meals • Mixes and doughs for the preparation of bakers' wares • Starches and starch products; sugars and sugar syrups n.e.c. • Preparations used in animal feeding; lucerne (alfalfa) meal and pellets • Bakery products • Cocoa, chocolate and sugar confectionery • Macaroni, noodles, couscous and similar farinaceous products • Food products n.e.c.	1030 Processing/preserving of fruit,vegetables 1050 Dairy products 1061 Grain mill products 1062 Starches and starch products 1071 Bakery products 1073 Cocoa, chocolate and sugar confectionery 1074 Macaroni, noodles, couscous, etc. 1075 Prepared meals and dishes 1079 Other food products n.e.c. 1080 Prepared animal feeds	1513 Processing/preserving of fruit & vegetables 1520 Dairy Products 1531 Grain mill products 1532 Starches and starch products 1541 Bakery products 1543 Cocoa, chocolate and sugar confectionery 1544 Macaroni, noodles & similar products 1549 Other food products n.e.c. 1533 Prepared animal feeds

Table A3. Region aggregation table

Aggregated region	Description	Conutries/Regions in standard GTAP dataset
Chk	China and Hong Kong	chn hkg
CSAmer	Central and South America	arg bol bra chl col ecu pry per ury ven xsm cri gtm hnd nic pan slv xca dom hti jam pri tto xcb
Eur	Europe	aut bel bgr hrv cyp cze dnk est fin fra deu grc hun irl ita lva ltu lux mlt nld pol prt rou svk svn esp swe gbr che nor xef alb srb blr ukr xee xer kaz kgz tjk uzb xsu arm aze geo
Jpn	Japan	jpn
Kor	South Korea	kor
NAmerica	Northern America	can usa mex xna
REAsiaO	Rest of Asia and Oceana	aus nzl xoc twn xea
ROW	Rest of World	Mng afg bgd ind npl pak lka xsa bhr irn irq isr jor kwt lbn omn pse qat sau syr tur are xws dza egy mar tun xnf ben bfa cmr civ gha gin mli ner nga sen tgo xwf caf tcd cog cod gnq gab xac com eth ken mdg mwi mus moz rwa sdn tza uga zmb zwe xec bwa swz nam zaf xsc xtw
Rus	Russia	rus
SEAsia	Southeast Asia	brn khm idn lao mys phl sgp tha vnm xse

Table A4. GTAP Sector Aggregation

Aggregated sector	Description	GTAP Sectors Included
Crops	Crops	pdf wht gro v_f c_b pfb ocr
MeatLstk	Meat and Livestock	ctl oap rmk wol cmt omt
Mnfc	Manufacturing	frs coa oil gas oxt tex wap lea lump pp p_c rpp nmm i_s nfm fmp ele eeq ome mvh otn omf
OthServices	Services	chm bph ely gdt wtr cns trd afs otp wtp atp whs cmn ofi ins rsa obs ros osg edu hht dwe
ProcFood	Processed food	osd vol mil pcr sgr Oofd b_t
Seafood	Fresh and processed seafood	fsh pfsh

We employ supplemental data to replace missing values for 2017. First, we use INDSTAT4 2023, ISIC Revision 4 to obtain 2017 production data as shown in Table A5. Second, if a country does not have production data in 2017, we use the latest value near 2017 to fill in the missing production shares. Third, if a country does not have production data from 2005 to 2017, we use the INDSTAT4 2023, ISIC Revision 3 database to obtain the missing production values. This database contains production information from the period 1997 to 2017. Average values from the period 2005 to 2016 were used to fill remaining missing production shares. Finally, if a country still does not have production data in ISIC4 or ISIC3, missing production shares were calculated by averaging the production shares of neighboring countries**.** We follow a similar approach for missing export data described in Table A6.

Table A5. Countries with Missing Production Values

ISIC4 (2005-2016)	Countries	ISIC3 (1997-2016)	Countries
	China (2015)		Brunei Darussalam (2010)
	Japan (2010)		Viet Nam (2000)
	Indonesia (2013)		Nepal (2008)
	Lao People's Democratic Republic (2015)		Bolivia (2001)
	Malaysia (2015)		Trinidad and Tobago (2006)
	Thailand (2016)		Malta (2008)
	Bangladesh (2012)		Tajikistan (2017)
	Pakistan (2016)		Lebanon (2007)
	Chile (2016)		Morocco (2011)
	Uruguay (2014)		Sudan (2001)
	Algeria (2015)		Cameroon (2008)
	Ghana (2013)		

Note: Numbers indicate the values used for years with missing values.

Table A6. Countries/Regions with Missing Seafood Export Data

Countries/Regions with missing data	Countries/Regions used to calculate average export value			
Taiwan	China	China, Hong Kong SAR	Japan	South Korea
	Rest of East Asia	Brunei Darussalam	Cambodia	Indonesia
	Lao	Malaysia	Philippines	Singapore
	Thailand	Viet Nam	Rest of Southeast Asia	
Bangladesh	India	Nepal	Pakistan	Sri Lanka
	Rest of South Asia			
Venezuela	Argentina	Brazil	Chile	Colombia
	Ecuador	Peru	Uruguay	Rest of South America
Haiti	Costa Rica	Guatemala	Honduras	Nicaragua
Puerto Rico	Panama	El Salvador	Rest of Central America	Dominican Republic
	Jamaica	Trinidad and Tobago	Caribbean	
Rest of Former Soviet Union	Russian Federation	Ukraine	Rest of Eastern Europe	Rest of Europe
	Kazakhstan	Kyrgyzstan	Uzbekistan	
Iraq	Bahrain	Iran	Israel	Jordan
Syrian Arab Republic	Kuwait	Lebanon	Oman	Palestine
Rest of Western Asia	Saudi Arabia	Türkiye	United Arab Emirates	
Guinea	Algeria	Egypt	Morocco	Tunisia
	Rest of North Africa	Benin	Burkina Faso	Cameroon
	Cote d'Ivoire	Ghana	Mali	Niger
	Nigeria			
Chad	Central African Republic	Congo	Democratic Republic Con	South-Central Africa
Equatorial Guinea	Comoros	Ethiopia	Keny	Madagascar
Gabon	Malawi	Mauritius	Mozambique	Rwanda
Rest of the World	Sudan	United Republic of Tanzania	Uganda	Zambia
	Zimbabwe	Rest of Eastern Africa	Botswana	Eswatini
	Namibia	South Africa	Rest of Southern African Custo	

Table A7. Percentage and Value Changes in Seafood Imports

	S1		S2		S3	
Country/Region	%	Value ($ Mil.)	%	Value ($ Mil.)	%	Value ($ Mil.)
Japan	-0.66	-57.23	-1.55	-133.35	-2.5	-215.01
Russia	-0.37	-6.94	-0.4	-7.52	-0.47	-8.95
China	-2.88	-244.06	-2.93	-248.9	-3.07	-260.72
South Korea	-0.02	-0.95	-2.55	-100.36	-2.6	-102.25
Southeast Asia	0.02	2.04	-1.35	-157.05	-1.35	-157.38
Rest of east Asia and Oceania	0.09	3.6	0.12	4.85	-2.86	-111.37
North America	0	-0.26	-0.04	-5.72	-0.65	-89.71
Europe	-0.01	-3.29	-0.03	-10.36	-0.14	-53.45
Central and South America	-0.01	-0.28	-0.02	-0.75	-0.08	-3.46
Rest of the World	-0.02	-1.92	-0.05	-3.96	-0.41	-33.08

Note: S1 includes an import ban on Japanese seafood in China and Russia. S2 extends the trade ban to include China, Russia, South Korea, and Southeast Asia. S3 represents the scenario in which there is a trade ban on Japanese seafood in all regions.
Source: Authors' simulations

Table A8. Percentage Changes in Domestic Sales of Commodity

	Crops	Meat and Livestock	Seafood	Processed Food
		S1		
Japan	0	-0.002	0.227	0.007
Russia	0	-0.002	-0.037	-0.001
China	-0.002	-0.004	-0.062	-0.006
South Korea	0	-0.001	-0.018	-0.002
Southeast Asia	0	0	-0.014	-0.001
Rest of east Asia and Oceania	0	0	-0.063	-0.001
North America	0	0	-0.037	-0.001
Europe	0	0	-0.023	-0.001
Central and South America	0	0	-0.014	0
Rest of the World	0	0	-0.006	0
		S2		
Japan	0.001	-0.005	0.515	0.015
Russia	0	-0.003	-0.054	-0.002
China	-0.002	-0.004	-0.083	-0.008
South Korea	-0.002	-0.017	-0.52	-0.033
Southeast Asia	-0.003	-0.007	-0.093	-0.007
Rest of east Asia and Oceania	0	-0.001	-0.126	-0.004
North America	0	-0.001	-0.073	-0.002
Europe	0	-0.001	-0.05	-0.002
Central and South America	0	0.001	-0.032	0
Rest of the World	0	-0.001	-0.018	-0.001
		S3		
Japan	0.002	-0.008	0.843	0.025
Russia	-0.001	-0.003	-0.064	-0.003
China	-0.003	-0.005	-0.098	-0.01
South Korea	-0.002	-0.019	-0.546	-0.036
Southeast Asia	-0.003	-0.007	-0.118	-0.009
Rest of east Asia and Oceania	-0.002	-0.008	-0.762	-0.023
North America	0	-0.002	-0.304	-0.008
Europe	0	-0.003	-0.129	-0.005
Central and South America	0	0.001	-0.057	0
Rest of the World	-0.001	-0.001	-0.041	-0.002

Note: S1 includes an import ban on Japanese seafood in China and Russia. S2 extends the trade ban to include China, Russia, South Korea, and Southeast Asia. S3 represents the scenario in which there is a trade ban on Japanese seafood in all regions.
Source: Authors' simulations

Table A9. Percentage Changes in Factor Returns in the Seafood Sector Across Regions

	Capital			Labor (Skilled)			Land		
	S1 (%)	S2 (%)	S3 (%)	S1(%)	S2 (%)	S3 (%)	S1 (%)	S2 (%)	S3 (%)
Japan	-0.85	-1.95	-3.18	-0.85	-1.95	-3.17	-0.82	-1.89	-3.08
Russia	0.16	0.27	0.32	0.16	0.27	0.32	0.16	0.27	0.33
China	0.12	0.19	0.23	0.11	0.19	0.23	0.12	0.19	0.24
South Korea	0.05	0.65	0.72	0.05	0.65	0.72	0.06	0.63	0.7
Southeast Asia	0.07	0.31	0.43	0.07	0.31	0.42	0.07	0.3	0.41
Rest of east Asia and Oceania	0.2	0.37	0.98	0.2	0.37	0.98	0.19	0.37	0.96
North America	0.09	0.16	0.44	0.09	0.16	0.44	0.09	0.16	0.44
Europe	0.07	0.13	0.29	0.07	0.13	0.29	0.07	0.14	0.3
Central and South America	0.07	0.16	0.27	0.07	0.16	0.27	0.07	0.15	0.27
Rest of the World	0.02	0.07	0.14	0.02	0.07	0.15	0.02	0.07	0.15

Note: S1 includes an import ban on Japanese seafood in China and Russia. S2 extends the trade ban to include China, Russia, South Korea, and Southeast Asia. S3 represents the scenario in which there is a trade ban on Japanese seafood in all regions.
Source: Authors' simulations