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Analysis of Driving Factors for Fluctuations in China's Tuna Product Exports from 2002 to 2022

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Abstract: Tuna products are among the most popular seafoods in the world and widely traded across the globe. China is a major contributor to the worldwide tuna industry as both a producer and an exporter. Employing the Constant Market Share model, this study examines the factors influencing the variations in China's tuna exports from 2002 to 2022, focusing on global, country, and product type levels. Results show that (1) China's expanded tuna exporting trade is partially due to the rising worldwide demand for tuna, which is mostly prominent in China's tuna exports to the USA, Vietnam, and Malaysia, as well as its exports of frozen tuna products. (2) China's competitive edge in tuna exports has steadily strengthened in most of its principal exporting markets, especially in Japan and the fresh tuna markets. Nevertheless, the competitiveness structure of Chinese tuna exports has challenges in satisfying the diverse requirements of different nations (regions) for various types of tuna products. (3) The second-order effect has been the primary driver of the expansion in Chinese tuna exports, with its contribution rate consistently rising in recent years. In response to the changes in international and domestic tuna markets, China must implement strategies to maximize the potential of the tuna importing market, further improve its global competitiveness, enhance communication and coordination among domestic and international tuna stakeholders, and cultivate domestic tuna markets.

Keywords: tuna; export fluctuation; constant market share; China

Key Contribution: The Constant Market Share model is applied to determine the variables influencing changes in China's tuna exports from 2002 to 2022 at the global, country, and product type levels. Policy recommendations are made in an effort to increase China's competitiveness in the world market for its tuna exports accordingly.

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Citation: Zhu, L.; Yang, C.; Yang, Z.; Lv, Z.; Wu, F.; Zhu, J. Analysis of Driving Factors for Fluctuations in China's Tuna Product Exports from 2002 to 2022. *Fishes* **2024**, *9*, 156. https://doi.org/10.3390/fishes9050156

Academic Editor: Dimitrios Moutopoulos

Received: 19 March 2024
Revised: 21 April 2024
Accepted: 23 April 2024
Published: 26 April 2024

1. Introduction

Tuna is a major species in the international seafood trade due to its extensive distribution, abundant resources, and high economic value. As reported by the United Nations Commodity Trade Statistics Database (UN Comtrade), global tuna exports were valued at around USD 14.0 billion in 2022, representing 8.16% of the total value of all aquatic product exports, indicating the widespread demand for tuna products in the global market. Meanwhile, pelagic fishing constitutes a significant proportion of China's capture fishery, with tuna fishery serving as its main industry. The growth of China's tuna product export market is crucial for the high-quality development of China's pelagic fishery.

The market for tuna exports from China has considerable potential and has experienced fast expansion in the 21st century. Between 2002 and 2022, China's tuna exports rose by USD 1.13 billion, according to UN Comtrade. With the rapid growth of its tuna

fishing industry, China has expanded international collaborations in the pelagic fisheries sector, engaging in mutually beneficial partnerships through various channels and methods. Chinese tuna-related enterprises have established overseas facilities, conducted research on tuna products, and consistently improved tuna fishing equipment and processing capabilities. China's export competitiveness in tuna products is on the rise. Nevertheless, China's tuna exports have experienced inconsistent variations and fluctuations. Internationally, the competition for tuna fishery resources and international trade is intensifying. Due to COVID-19, some importing countries have imposed restrictions on tuna imports, affecting the magnitude of China's tuna exports to some extent. China's tuna fishery started later than other major tuna fishing nations, making it challenging to establish export markets and resulting in limited competitiveness in China's tuna exports. Furthermore, there is a discrepancy between the fluctuations in China's tuna export competitiveness and the shifts in import market demand.

Therefore, it is essential to conduct an analysis of the driving elements behind the oscillations in China's tuna exports and identify the causes for the inconsistent growth of China's tuna exports. This will facilitate improved strategic planning for China's tuna export market and the implementation of appropriate policies to enhance the high-quality advancement of China's tuna exporting trade.

A growing area of study is assessing the exporting country's (region's) international competitiveness in the context of tuna trade. Kuldilok et al. (2013) [1] calculated the Revealed Comparative Advantage (RCA) indices of major tuna export countries in the international market and concluded that Thailand exhibited a comparative advantage in all major export markets. Du et al. (2018) [2] used the Market Share and Trade Specialization Index to analyze the competitive performance and competitive situation in different countries and regions and found that the degree of concentration of international production and trade monopolies became lower. Lv and Xu (2019) [3] employed RCA, Market Comparative Advantage, and Revealed Symmetric Comparative Advantage indices to evaluate China's competitiveness in the Japanese tuna market. The Constant Market Share (CMS) model was also applied as an analytical tool by Suhana et al. (2016) [4] to analyze the competitiveness of Indonesian tuna products in the international market from 1998 to 2014. Some scholars concentrate their research on tuna trade policy. Campling (2016) [5] investigated the impact of trade policy on the geographical distribution of canned tuna production around the world. Shen (2015) [6] examined the factors contributing to barriers in China's tuna export trade and proposed solutions to address trade barriers from the perspectives of both the government and businesses. Other studies have emerged focusing on tuna international market evolution and influencing factors. Song et al. (2024) [7] first used Complex Network Analysis to construct a worldwide tuna trade network and utilized the Hubness Measures Index to assess China's reliance on its principal tuna export markets. Using the Structure-Conduct-Performance analytical model, Yin et al. (2018) [8] conducted an investigation of the structure of the international market for tuna as well as the factors that contribute to its existence. Guillotreau et al. (2017) [9] discussed the current changes in tuna markets, including sashimi and cannery-grade tuna products, market structures, and trade, including a detailed analysis of global integration through pricing connections. Nga and Xoan (2024) [10] extended the gravity model to identify how factors including domestic tuna production and exchange rate influence Vietnam's tuna exports to other main import markets. Osmaleli et al. (2023) [11] employed panel data regression to analyze the determinants of tuna exports from Indonesia to several destination nations.

The CMS model is a frequently used method for analyzing the factors that cause fluctuations in export or import trade [12–16] (Wu et al., 2016; Zhang et al., 2023; Guo and You, 2023; Ge and Zhao, 2023; Fu and Tong, 2024). Despite this, there is a restricted application of the CMS model to examine the driving factors of the seafood export fluctuation. Among the limited research, most studies select either the global market as a whole or a specific country (region) to examine the factors influencing a country's export of aquatic products. At three different levels—the general level, the market level, and the product level—Miao

et al. (2021) [17] utilized the extended CMS model to investigate the factors that influenced changes in China's exports of aquatic products from the year 2000 to the year 2018 to specific locations. Xu and Hu (2019) [18] focused on the Singapore market and analyzed the dynamic growth of China's seafood exports to Singapore. Jiang (2018) [19] took the United States as a single market and analyzed the factors determining China's exports of aquatic products to the United States. Some other studies applied the CMS model to investigate the factors influencing export variations of particular seafood species such as tilapia, squid, and octopus (Dai et al., 2020; Yang et al., 2021) [20,21].

The existing research on tuna trade mostly examines trade policy, the international competitiveness of tuna products, and the international tuna market, with less focus on the determinants causing export fluctuations. With regard to current studies on analyzing the factors of seafood export variations using the CMS model, most focus on a broad range of seafood species, with few concentrating on particular species. Besides, the majority of the studies only perform first-level or second-level decomposition without further decomposition of the competitive market effect. Furthermore, limited investigations have been carried out at the country or product level, failing to capture the export fluctuation factors of particular importing markets and product categories.

This study will use the revised CMS model to examine the driving factors of fluctuations in China's tuna exports and analyze the determinants at global, country, and product type levels to identify the factors impacting China's tuna export trade and the specific reasons for export fluctuations. Detailed policy recommendations will be offered in accordance with the findings of the investigation. To the best of our knowledge, this is the first study to use a three-level CMS approach to investigate the underlying determinants influencing variations in China's tuna exports.

2. Data and Methods

2.1. Constant Market Share Model

The CMS model was initially introduced by Tyszynski (1951) [22] and was subsequently revised, improved, and extended by Jepma (1986), Milana (1988), Ge and Gao (2021), and Ahmadi-Esfahani (2006) [23–26], and other researchers. It is a significant model for analyzing the elements that contribute to export trade volatility, which can be used to decompose the export competitiveness of certain products in a market, explain the reasons behind export trade variations, and determine the extent of the impacts of each factor.

Following the works of Jepma (1986) [23] and Ge (2021) [25], the driving factors of China's tuna export fluctuation will be decomposed from the first, second, and third levels. At the first level, the factors influencing China's tuna export changes are decomposed into three parts: the scale effect, the competitive effect, and the second-order effect.

$$\Delta EX = \sum_{i}\sum_{j} S_{ij}^{0}\Delta D_{ij} + \sum_{i}\sum_{j} \Delta S_{ij} D_{ij}^{0} + \sum_{i}\sum_{j} \Delta S_{ij}\Delta D_{ij} \quad (1)$$

At the second level, the scale effect, competitive effect, and second-order effect are further subdivided.

The scale effect can be divided into the scale–aggregate growth effect, the scale regional market effect, the scale product effect, and the scale interaction effect. The formula is as follows:

$$\begin{aligned}\sum_{i}\sum_{j} S_{ij}^{0}\Delta D_{ij} = S^{0}\Delta D + \left(\sum_{i}\sum_{j} S_{ij}^{0}\Delta D_{ij} - \sum_{i} S_{i}^{0}\Delta D_{i}\right) + \left(\sum_{i}\sum_{j} S_{ij}^{0}\Delta D_{ij} - \sum_{j} S_{j}^{0}\Delta D_{j}\right) \\ + \left[\left(\sum_{i} S_{i}^{0}\Delta D_{i} - S^{0}\Delta D\right) - \left(\sum_{i}\sum_{j} S_{ij}^{0}\Delta D_{ij} - \sum_{j} S_{j}^{0}\Delta D_{j}\right)\right]\end{aligned} \quad (2)$$

The competitiveness effect can be decomposed into the competitive aggregate growth effect and the competitive market effect as follows:

$$\sum_{i}\sum_{j}\Delta S_{ij}D_{ij}^{0} = \Delta SD^{0} + \left(\sum_{i}\sum_{j}\Delta S_{ij}D_{ij}^{0} - \Delta SD^{0}\right) \quad (3)$$

The second-order effect can be decomposed into pure second-order effect and dynamic structural residual, and the formula is:

$$\sum_{i}\sum_{j}\Delta S_{ij}\Delta D_{ij} = \left(\frac{D^{1}}{D^{0}} - 1\right)\sum_{i}\sum_{j}\Delta S_{ij}D_{ij}^{0} + \left[\sum_{i}\sum_{j}\Delta S_{ij}\Delta D_{ij} - \left(\frac{D^{1}}{D^{0}} - 1\right)\sum_{i}\sum_{j}\Delta S_{ij}D_{ij}^{0}\right] \quad (4)$$

At the third level, the competitive market effect can be further subdivided into the competitive regional effect, the competitive product effect, and the competitive interaction effect. The formula is:

$$\begin{aligned}\left(\sum_{i}\sum_{j}\Delta S_{ij}D_{ij}^{0} - \Delta SD^{0}\right) &= \left(\sum_{i}\sum_{j}\Delta S_{ij}D_{ij}^{0} - \sum_{i}\Delta S_{i}D_{i}^{0}\right) + \left(\sum_{i}\sum_{j}\Delta S_{ij}D_{ij}^{0} - \sum_{j}\Delta S_{j}D_{j}^{0}\right) \\ &+ \left[\left(\sum_{i}S_{i}D_{i}^{0} - \Delta SD^{0}\right) - \left(\sum_{i}\sum_{j}\Delta S_{ij}D_{ij}^{0} - \sum_{j}\Delta S_{j}D_{j}^{0}\right)\right]\end{aligned} \quad (5)$$

In the formulas above, 0 represents the base year, 1 represents the reporting year, and Δ denotes the changes from the reporting year to the base year. *EX* is the change in China's tuna export value between two different years; i represents different tuna products, and j represents different target countries (regions) for China's tuna exports. Table 1 provides exhaustive definitions of variables utilized in the formulas, while Table 2 lists the definitions for all the effects at three levels explaining export changes.

Table 1. Explanatory notes of variables in formulas.

	Global Level	Country Level	Product Type Level
D_{ij}	The total import value of tuna product i by country j.	The total import value of tuna product i by selected country j.	The total import value of selected tuna product i by country j.
D	The total import value of all tuna products in global market.	The total import value of all tuna products by selected country j.	The total import value of selected tuna product i in global market.
D_{i}	The total import value of tuna product i in global market.	The total import value of tuna product i by selected country j.	The total import value of selected tuna product i in global market.
D_{j}	The total import value of all tuna products by country j.	The total import value of all tuna products by selected country j.	The total import value of selected tuna product i by country j.
S_{ij}	The proportion of China's exports of tuna product i to country j in the total imports of tuna product i by country j.	The proportion of China's exports of tuna product i to a selected country j in the total imports of tuna product i by selected country j.	The proportion of China's exports of selected tuna product i to country j in the total imports of selected tuna product i by country j.
S	The proportion of China's tuna exports to global market in the total imports of tuna by the globe.	The proportion of China's tuna exports to a selected country j in the total imports of all tuna products by selected country j.	The proportion of China's exports of selected tuna product i to global market in the total imports of selected tuna product i by the globe.
S_{i}	The proportion of China's export of tuna product i to global market in the total imports of tuna product i by the globe.	The proportion of China's exports of tuna product i to selected country j in the total imports of tuna product i by selected country j.	The proportion of China's exports of selected tuna product i to global market in the total imports of selected tuna product i by the globe.
S_{j}	The proportion of China's exports of all tuna products to country j in the imports of all tuna products by country j.	The proportion of China's tuna exports to selected country j in the total imports of all tuna products by selected country j.	The proportion of China's exports of selected tuna product i to country j in the total imports of selected tuna product i by country j.

Table 2. Explanatory notes on the driving factors of export fluctuation.

Level	Effect	Formula	Definition
0	Change in export value	ΔEX	Changes in the export value of products from one country to another.
1	Scale effect	$\sum_i \sum_j S_{ij}^0 \Delta D_{ij}$	Changes in the export value due to changes in the structure and scale of the importing market's demand.
2	Competitive effect	$\sum_i \sum_j \Delta S_{ij} D_{ij}^0$	Changes in the export value due to changes in the exporting country's competitiveness (export market share).
3	Second-order effect	$\sum_i \sum_j \Delta S_{ij} \Delta D_{ij}$	Changes in the export value due to interaction between change in the exporting country's competitiveness and changes in the structure and scale of the importing market's demand.
1.1	Scale–aggregate growth effect	$S^0 \Delta D$	Changes in the export value due to changes in the scale of the importing market's demand.
1.2	Scale regional effect	$\left(\sum_i \sum_j S_{ij}^0 \Delta D_{ij} - \sum_i S_i^0 \Delta D_i \right)$	Changes in the export value due to changes in the structure of the importing region's demand.
1.3	Scale product effect	$\left(\sum_i \sum_j S_{ij}^0 \Delta D_{ij} - \sum_j S_j^0 \Delta D_j \right)$	Changes in the export value due to changes in the structure of the importing products' demand.
1.4	Scale interaction effect	$\left[\left(\sum_i S_i^0 \Delta D_i - S^0 \Delta D \right) - \left(\sum_i \sum_j S_{ij}^0 \Delta D_{ij} - \sum_j S_j^0 \Delta D_j \right) \right]$	Changes in the export value due to interaction between change in region structure demand and change in products structure demand.
2.1	Competitive aggregate growth effect	$\Delta S D^0$	Changes in the export value due to changes in the exporting country's total competitiveness (export total market share).
2.2	Competitive market effect	$\left(\sum_i \sum_j \Delta S_{ij} D_{ij}^0 - \Delta S D^0 \right)$	Changes in the export value due to variations in the exporting country's market share structure in the importing target market.
3.1	Pure second-order effect	$\left(\frac{D^1}{D^0} - 1 \right) \sum_i \sum_j \Delta S_{ij} D_{ij}^0$	Changes in the export value due to interaction between change in the exporting country's competitiveness and changes in the scale of the importing market's demand.
3.2	Dynamic structural residual	$\left[\sum_i \sum_j \Delta S_{ij} \Delta D_{ij} - \left(\frac{D^1}{D^0} - 1 \right) \sum_i \sum_j \Delta S_{ij} D_{ij}^0 \right]$	Changes in the export value due to interaction between change in the exporting country's competitiveness and changes in the structure of the importing market's demand.
2.2.1	Competitive regional effect	$\left(\sum_i \sum_j \Delta S_{ij} D_{ij}^0 - \sum_i \Delta S_i D_i^0 \right)$	Changes in the export value due to variations in the exporting country's market share of the same tuna products in different importing countries.

Table 2. *Cont.*

Level	Effect	Formula	Definition
2.2.2	Competitive product effect	$\left(\sum_i \sum_j \Delta S_{ij} D_{ij}^0 - \sum_j \Delta S_j D_j^0\right)$	Changes in the export value due to variations in the exporting country's market share of different tuna products in the same importing country.
2.2.3	Competitive interaction effect	$\left[\left(\sum_i \Delta S_i D_i^0 - \Delta S D^0\right) - \left(\sum_i \sum_j \Delta S_{ij} D_{ij}^0 - \sum_j \Delta S_j D_j^0\right)\right]$	Changes in the export value due to interaction between variations in the exporting country's market share of the same tuna products in different importing countries and those in the exporting country's market share of different tuna products in the same importing country.

At the global level, i denotes different tuna products, and j represents different target countries (regions) for China's tuna exports. At the country level, j represents a selected country (region). At the product type level, i represents a selected tuna product.

2.2. Data Source

The data used in this study were collected from the UN Comtrade Database and classified according to the Harmonized System (HS). In Table 3, tuna products in international trade are subdivided into four groups: live, fresh or chilled, frozen, prepared, and preserved.

Table 3. HS codes of different tuna product categories.

Classification	HS Code
Live	030194, 030195
Fresh or chilled	030231, 030232, 030233, 030234, 030235, 030236, 030239
Frozen	030341, 030342, 030343, 030344, 030345, 030346, 030349, 030487
Prepared and preserved	160414

The study spans from 2002 to 2022 and includes 9 countries as sample markets for Chinese tuna export: Japan, Thailand, USA, Spain, Mexico, Vietnam, Italy, Malaysia, and Philippines. China's tuna exports to these 9 nations represented an average of 77.45% of the total exports during the study period, indicating a highly representative sample. Annual trade data are used to examine the elements contributing to the year-on-year variations in China's tuna exports. The US dollar values for exports rather than the quantity are adopted following Miao et al. (2021) [17] and Ahmadi-Esfahani (1994) [27]. The value-change version CMS model is proposed and popularized by Leamer and Stern (1970) [28] and improved by Jepma (1989) [23], among others. Meanwhile, the lack of comprehensive data impedes the use of export quantity data in our analysis. In terms of the currency representing the export value, Ahmadi-Esfahani (2006) [26] points out that in the CMS model, the most popular currency in international trade should be utilized, and in empirical studies, it is observed that trade is predominantly conducted in US currency due to the weak currencies of the countries being studied.

In order to analyze the factors influencing the scale of China's tuna export, this study divides the research period into three segments: 2002–2007, 2008–2019, and 2020–2022, based on the changing patterns of China's tuna export. The primary rationale for segmenting time periods is as follows: (1) China joined the WTO in 2001, and its pelagic fishery production escalated, leading to a rapid development in its tuna export trade. Meanwhile, due to a lack of data on China's tuna exports before 2002, the study period began in that year. (2) In 2008, China's tuna exports were significantly affected by the Asian financial

crisis and the contraction of the international market. (3) The COVID-19 pandemic that emerged worldwide in late 2019 has had a substantial effect on Chinese tuna exports for several years thereafter. A total of 902 observations were used in our CMS analysis, including China's export data (export value of each of the different tuna subproducts) to the nine nations selected in years 2022, 2020, 2019, 2008, 2007, and 2002, as well as the tuna import data (import value of each of the different tuna subproducts) of these nine nations in the years above.

3. Overview of China's Tuna Products Export Trade

3.1. Trade Value of China's Tuna Exports

China's tuna export sector has experienced rapid growth following its accession to the WTO in 2001. As shown in Figure 1, from 2002 to 2022, China's export value of tuna products rose by around USD 1.13 billion, and its share of the global tuna export value has generally exhibited a fluctuating upward pattern, rising from 0.23% to 8.16%. Between 2002 and 2016, China's tuna export share grew steadily, peaking at 9.12% in 2016; however, global competition in the tuna market intensified, leading to a decline in China's export market share from 2017 to 2019; subsequently, from 2020 to 2022, China's tuna export share experienced a slight but fluctuating recovery.

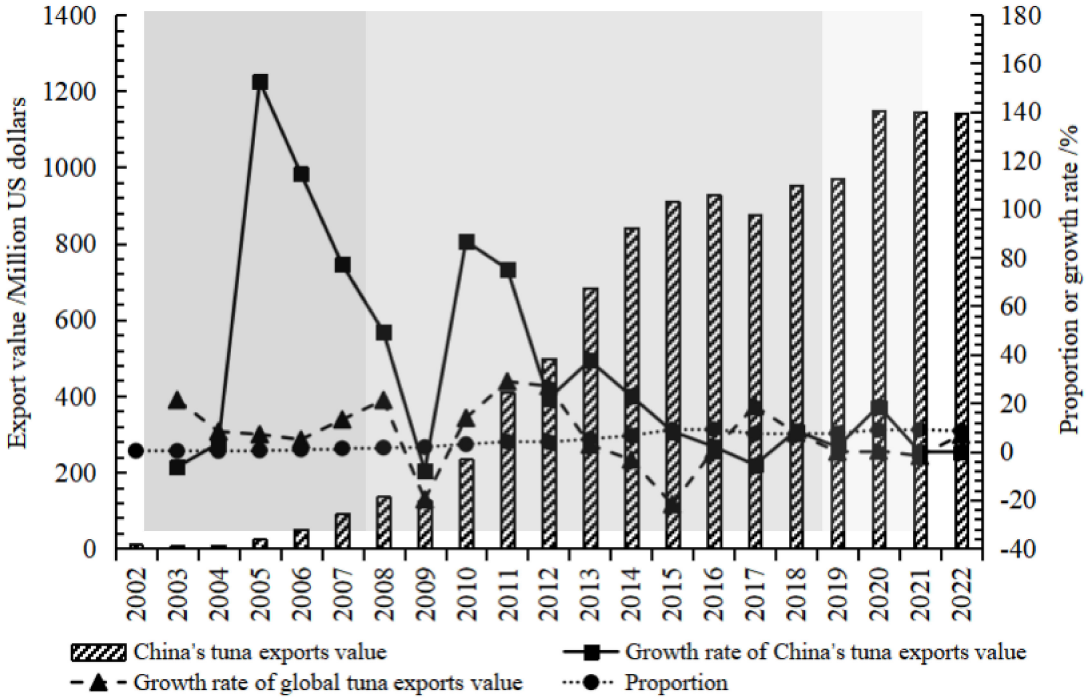

Figure 1. China's tuna export value and its position in the global tuna export trade, 2002–2022.

3.2. Primary Export Destinations for China's Tuna Products

With respect to export destination distribution, China's tuna product exports are mostly focused on East Asia, Europe, and the United States, especially concentrated in the two major markets of Japan and Thailand. As displayed in Figure 2, China's main tuna export markets in 2022 were Thailand and Japan, collectively accounting for nearly 50% of the market share. The significance of the United States and Japan in China's tuna export market has declined, while the share of China's tuna exports to Spain and Vietnam has generally risen. The proportion of exports to the United States initially increased and then declined. These changes suggest a more diversified export market for Chinese tuna products.

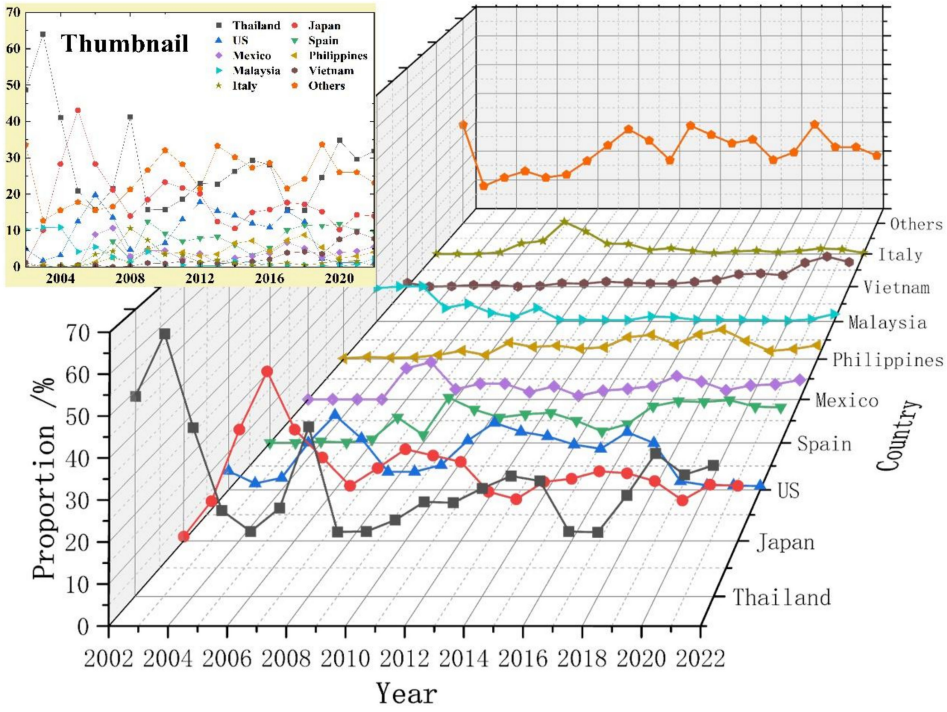

Figure 2. Major export destinations for China's tuna products from 2002 to 2022.

3.3. China's Tuna Product Export Structure

China's exports of live, fresh, and chilled tuna products are constrained by packaging, transportation, and other constraints, representing a small portion of China's overall tuna product exports and being primarily targeted at the Japanese market. China predominantly exports frozen, prepared, and preserved tuna products, with the proportion of these items in China's overall tuna exports fluctuating notably between 2002 and 2022 in Figure 3. Following the COVID-19 epidemic, there was a rise in the percentage of exported prepared and preserved tuna, driven by growing consumer demand for products like canned tuna.

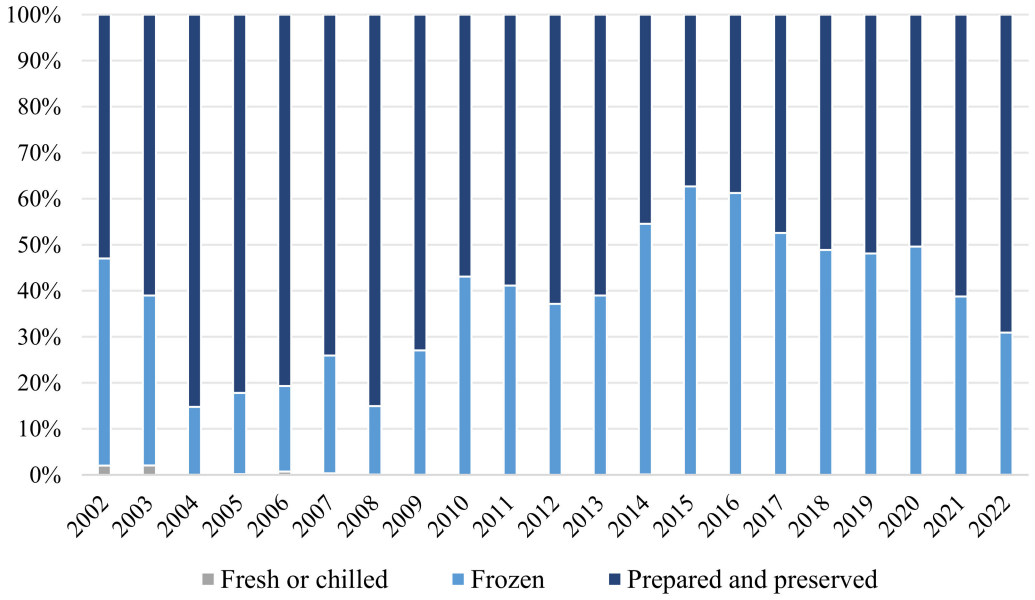

Figure 3. The proportion of tuna exports value in different products in China's total tuna exports value, 2002–2022.

4. Results and Discussion

4.1. Decomposition of Factors Affecting China's Tuna Export Fluctuations at the Global Level

As shown in Table 4, the first-level decomposition at the global level showed that China's tuna exports to major countries rose by USD 517.48 million from 2002 to 2022. The primary factor driving this growth was the second-order effect, which contributed 56.28%, followed by the scale effect and the competitive effect. During 2002–2007, China's official accession to the WTO stimulated enormous import market demand, and its tuna exports increased substantially, with the rate of scale effect contributing 5.27%; the contribution rate of competitive effect reached 80.22%, owing to China's labor endowment advantage; the second-order effect explained 14.51% of the fluctuations in tuna exports as the changes in its competitiveness aligned with those of import demand. During the second stage (2008–2019), all three effects exhibited a positive influence on tuna exports; meanwhile, the cost of tuna fishing, processing, and trade has increased, and the competitive effect has weakened significantly, with the contribution rate reaching 50.37%. From 2020 to 2022, China's tuna export value declined due to the COVID-19 pandemic and sluggish global economic development, leading to a notable reversal in the import demand effect, which explained −233.53% of the tuna export increase; its negative consequence was mitigated by the competitive effect and second-order effect, which significantly increased their contribution rates to 253.57% and 79.96%, respectively.

The second-level decomposition of the scale effect showed that during 2002–2022, the scale aggregate growth effect was the most prominent with a contribution rate of 27.08% (Table 4), but it exhibited a declining tendency and sharply dropped from 2020 to 2022. This indicates that China's tuna exports were impeded during the epidemic, probably due to trade restrictions, leading to a decline in the total demand for tuna in the import market. With an 8.32% contribution rate, the scale product effect ranked second in terms of its impact on China's tuna export growth from 2002 to 2022, suggesting that the product structure of China's tuna exports was generally consistent with the demands of the import market. Nevertheless, the magnitude of the scale product effect's contribution diminished and became negative throughout the duration of the COVID-19 pandemic. The scale regional effect had a consistently negative impact on China's tuna exports, suggesting that Chinese tuna products struggled to adjust to changes in the import demand of principal export markets, and there was a lack of export concentration in countries with the fastest-growing demand for tuna. In the first and second stages, the scale interaction effect generally has a negative impact with an intensifying trend over time; in the third stage (2020–2022), the contribution rate of the scale interaction effect changed from negative to positive, indicating that China's tuna exports faced challenges in adjusting to shifts in demand but demonstrated gradual enhancement.

Decomposition of the competitive effect at a second level reveals that the competitive aggregate growth effect has steadily risen from 2002 to 2022, making a beneficial contribution to the growth of China's tuna exports, which mitigates the adverse influence of the competitive market effect. Conversely, the competitive market effect's contribution rate has been consistently decreasing, thereby hindering the export of Chinese tuna.

Upon further analysis of the second-order effect at a second level, it becomes evident that the pure second-order effect has consistently maintained a positive contribution rate spanning the years 2002 to 2022, demonstrating that adjustments in China's export competitiveness have mirrored fluctuations in the magnitude of overall tuna imports scale and that shifts in supply and demand have collectively stimulated China's tuna exports. The contribution of the dynamic structural residual effect to China's tuna export growth showed fluctuating but generally positive values, which indicates that changes in China's tuna export competitiveness align with shifts in demand structure in the importing market.

In Table 4, the third-level decomposition analysis of the competitive market effect reveals significant changes in the competitive regional effect, leading to a shift from a positive to a negative contribution rate and a downward trajectory. The competitive product effect has a negative contribution rate during the first two periods, suggesting that

the competitiveness structure of Chinese tuna exports struggles to meet the demands of various countries (regions) for different tuna product types, while during the third stage, the competitive product effect turned out to exert a favorable impact on China's tuna exports. On the contrary, the competitive interaction effect had a positive impact during the first two periods, which alleviates the negative impact of the competitive product effect. From 2020 to 2022, China grew more competitive on international markets, importing major tuna product categories, and the competitive product effect increased throughout the COVID-19 pandemic.

Table 4. Analysis results at the global level using CMS.

Effect	Level	2002–2022		2002–2007		2008–2019		2020–2022	
		Changes in Export Value	Contribution Rate	Changes in Export Value	Contribution Rate	Changes in Export Value	Contribution Rate	Changes in Export Value	Contribution Rate
Total	0	517,479,283	100.00	130,968,360	100.00	313,984,265	100.00	−62,208,666	100.00
Scale effect	1	117,835,055.4	22.77	6,897,697.307	5.27	101,986,314.9	32.48	145,278,637	−233.53
Competitive effect	2	108,404,542.5	20.95	105,065,373.5	80.22	158,153,569.8	50.37	−157,745,524.5	253.57
Second-order effect	3	291,239,685.1	56.28	19,005,289.21	14.51	53,844,380.36	17.15	−49,741,778.59	79.96
Scale aggregate growth effect	1.1	140,156,214.3	27.08	33,981,470.06	25.95	85,404,662.62	27.20	147,483,111.7	−237.08
Scale regional effect	1.2	−32,510,360.57	−6.28	−20,220,589.67	−15.44	−5,126,542.034	−1.63	8,633,578.644	−13.88
Scale product effect	1.3	43,071,460.41	8.32	3,376,935.67	2.58	66,524,953.67	21.19	23,062,417.04	−37.07
Scale interaction effect	1.4	−32,882,258.68	−6.35	−10,240,118.74	−7.82	−44,816,759.37	−14.27	−33,900,470.39	54.49
Competitive aggregate growth effect	2.1	148,648,563.4	28.73	70,639,639.01	53.94	175,693,786.1	55.96	−171,897,818.7	276.32
Competitive market effect	2.2	−40,244,020.9	−7.78	34,425,734.48	26.29	−17,540,216.34	−5.59	14,152,294.26	−22.75
Pure second order effect	3.1	166,764,848.4	32.23	39,187,399.58	29.92	47,606,012.83	15.16	−34,682,394.07	55.75
Dynamic structural residual effect	3.2	124,474,836.8	24.05	−20,182,110.37	−15.41	6,238,367.523	1.99	−15,059,384.51	24.21
Competitive regional effect	2.2.1	−401,046.8774	−0.08	34,684,227.91	26.48	2,514,735.111	0.80	6,315,736.654	−10.15
Competitive product effect	2.2.2	−83,308,516.44	−16.10	−1,738,852.168	−1.33	−97,280,110.71	−30.98	−15,773,092.56	25.36
Competitive interaction effect	2.2.3	43,465,542.42	8.40	1,480,358.732	1.13	77,225,159.26	24.60	23,609,650.17	−37.95

Units: Changes in export value, USD; Contribution rate, %.

4.2. Decomposition of Factors Affecting China's Tuna Export Fluctuations at the Country Level

At the country level, attention is directed towards China's primary export markets for tuna from 2002 to 2022, which include Japan, Thailand, the USA, Spain, Mexico, Vietnam, Italy, Malaysia, and the Philippines. This level concentrates on a specific market; therefore, the competitive market effect is exclusively influenced by the competitive product effect, eliminating the necessity for conducting the third-level decomposition.

As shown in Table 5, the first-level analysis of CMS shows that the scale effect generally presents a positive effect during 2002–2022, particularly in Vietnam and Malaysia, where the scale effect contributed more than 100% of the changes in China's tuna export; in contrast, the scale effect is less significant in Spain, Mexico, and Italy. The competitiveness effect has a generally positive contribution rate throughout the sample period. The competitiveness effect accounts for 49.61% of the variation in the value of Chinese tuna exports to Japan, suggesting that China's tuna products maintain good competitiveness in Japan. Nevertheless, China's export competitiveness in the USA, Vietnam, and Malaysia still requires enhancement. The prominence of second-order effects in Thailand, Spain, Mexico, and the Philippines suggests that changes in the competitiveness of Chinese tuna exports correspond to fluctuations in the structure and magnitude of import demand in these four countries. This alignment propels the expansion of China's tuna export scale in these markets. Conversely, Vietnam and Malaysia exhibit a negative contribution from the second-order effect, indicating a disparity between changes in demand and the competitiveness of Chinese tuna exports.

Table 5. Results at the country level using CMS.

Effect	Level	Japan	Thailand	USA	Spain	Mexico	Vietnam	Italy	Malaysia	Philippines
Total	0	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Scale effect	1	24.14	8.91	98.39	0.13	0.12	126.94	0.65	200.89	5.44
Competitive effect	2	49.61	7.47	1.35	10.54	11.33	0.09	34.11	−15.01	4.67
Second order effect	3	26.24	83.62	0.26	89.33	88.55	−27.03	65.24	−85.87	89.89
Scale aggregate growth effect	1.1	9.77	10.95	71.87	0.40	0.10	83.40	0.72	72.92	5.66
Scale regional effect	1.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scale product effect	1.3	14.37	−2.04	26.52	−0.27	0.02	43.54	−0.08	127.97	−0.22
Scale interaction effect	1.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Competitive aggregate growth effect	2.1	76.12	27.14	8.42	23.14	13.21	0.02	30.36	10.05	5.74
Competitive market effect	2.2	−26.51	−19.68	−7.06	−12.60	−1.88	0.07	3.75	−25.06	−1.07
Pure second order effect	3.1	9.19	17.03	3.17	34.84	74.34	76.22	77.44	−25.45	72.03
Dynamic structural residual effect	3.2	17.05	66.59	−2.91	54.48	14.21	−103.25	−12.20	−60.42	17.86

Unit: Contribution rate, %.

The second-level decomposition of the scale effect on the variation of China's tuna exports to a specific market excludes the scale regional effect and the scale interaction effect, as indicated by the zero values in Table 5 and Figure 4. The contributions of the scale-aggregate growth effect and the scale product effect varied by country. The scale-aggregate growth effects were particularly pronounced in the USA and Vietnam, indicating that their expansion of import scale for tuna effectively promoted the development of China's tuna exports in these two markets. The scale product effect is notably prominent in Malaysia, with its contribution rate as high as 127.97%, indicating that the export structure of China's tuna products satisfies the import demand of Malaysia.

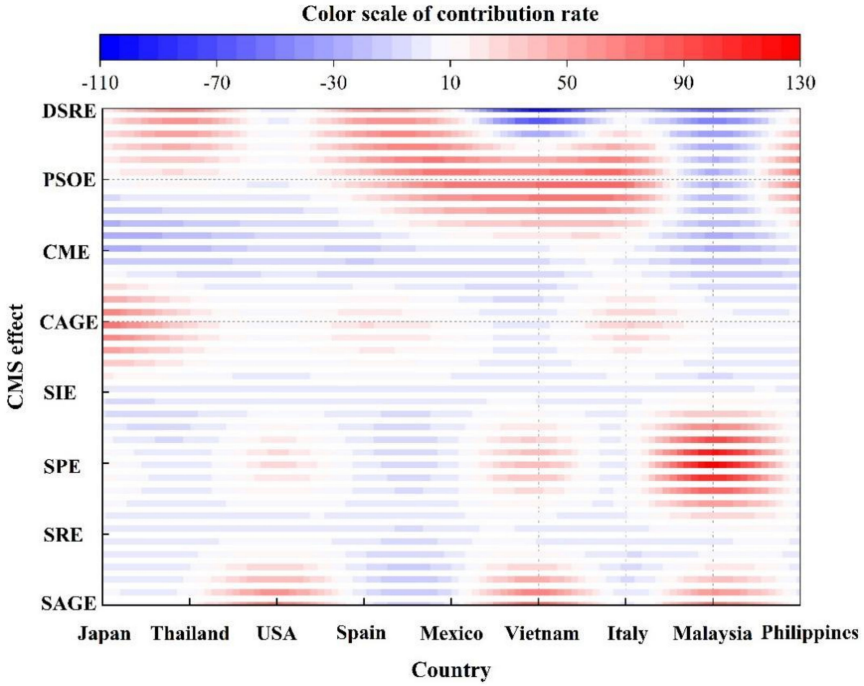

Figure 4. Illustration of the second-level decomposition results at the country level. Note: SAGE = scale-aggregate growth effect, SRE = scale regional effect, SPE = scale product effect, SIE = scale interaction effect, CAGE = competitive aggregate growth effect, CME = competitive market effect, PSOE = pure second-order effect, and DSRE = dynamic structural residual effect.

When further decomposing the competitiveness effect, it was discovered that the competitiveness aggregate growth effect was positive from 2002 to 2022. Particularly in Japan and Italy, the competitive aggregate growth effect significantly boosts China's tuna exports in these two markets. However, Chinese tuna's competitive market effect was mostly negative in various markets, suggesting that the allocation of Chinese export tuna products does not align with importing countries' market demand. This indicates a need to adjust the export competitiveness structure.

With regard to the second-order effect, the pure second-order effect contributes positively in all countries except Malaysia, indicating that changes in Chinese tuna export competitiveness generally correspond with changes in the import scale of its principal exporting markets. The dynamic structural residual effect contributes differently among different countries, showing significant positive contributions in Thailand and Spain and notable negative impacts in Vietnam and Malaysia.

4.3. Decomposition of Factors Affecting China's Tuna Export Fluctuations at the Product Level

At the product level, tuna products are subdivided into four categories: live, fresh or chilled, frozen, prepared, and preserved. Due to the low exporting scale of Chinese live tuna goods in the chosen import market, only fresh or chilled, frozen, prepared, and preserved

items will be analyzed. This level concentrates on a specific product type; therefore, the competitive market effect is exclusively influenced by the competitive regional effect, eliminating the necessity for conducting the third-level decomposition.

As shown in Table 6, the CMS first-level decomposition reveals significant variations in the scale effects of various tuna products; from 2002 to 2022, the contribution rate of fresh or chilled tuna scale effects was negative, whereas frozen, prepared, and preserved tuna scale effects were both positive. This indicates that frozen and processed tuna were preferred on international markets over fresh or chilled products, although the availability of the latter may be limited due to quarantine measures implemented in the midst of the COVID-19 pandemic. The competitiveness effects on China's exports across all tuna product categories were all positive, indicating that China's export competitiveness has improved for all types of tuna products during the sample period, which is beneficial for China's tuna exports; the competitive effect is most prominent in fresh tuna exports. The positive contribution rates of the second-order effect for fresh or chilled, frozen, prepared, and preserved tuna products indicate that the export competitiveness of all tuna product types from China is in line with the current demand for tuna on the import markets, which is most prominent in China's exports for prepared and preserved tuna.

Table 6. Analysis results at the product type level using CMS.

Effect	Level	Fresh or Chilled		Frozen		Prepared and Preserved	
		Changes in Export Value	Contribution Rate	Changes in Export Value	Contribution Rate	Changes in Export Value	Contribution Rate
Total	0	−221,827	100.00	243,264,429	100.00	274,436,681	100.00
Scale effect	1	40,258.13331	−18.15	110,939,124	45.60	6,855,673.277	2.50
Competitive effect	2	−221,827	100.00	88,847,599.95	36.52	19,778,769.51	7.21
Second-order effect	3	−40,258.13331	18.15	43,477,705.04	17.87	247,802,238.2	90.29
Scale–aggregate growth effect	1.1	−57,095.66427	25.74	144,974,287.2	59.60	5,428,224.477	1.98
Scale regional effect	1.2	97,353.79759	−43.89	−34,035,163.17	−13.99	1,427,448.8	0.52
Scale product effect	1.3	0.00	0.00	0.00	0.00	0.00	0.00
Scale interaction effect	1.4	0.00	0.00	0.00	0.00	0.00	0.00
Competitive aggregate growth effect	2.1	−221,827	100.00	37,365,780.01	15.36	71,661,636.32	26.11
Competitive market effect	2.2	0	0.00	51,481,819.94	21.16	−51,882,866.81	−18.91
Pure second-order effect	3.1	57,095.66427	−25.74	144,864,721.7	59.55	54,468,157.17	19.85
Dynamic structural residual effect	3.2	−97,353.79759	43.89	−101,387,016.7	−41.68	193,334,081	70.45

Units: Changes in export value, USD; Contribution rate, %.

The second-level decomposition of the scale effect on China's export variation of a particular tuna product category excludes the scale product effect and the scale interaction effect, as indicated by the zero values in Table 6 and Figure 5. For all three tuna product types, the scale-aggregate growth effect was more influential than the scale regional effect. The scale-aggregate growth effect contributed 59.60% and 25.74% for frozen and fresh tuna, respectively, providing a consistent expansion of market space for the development of

China's tuna exports. On the contrary, the scale regional effects exerted negative impacts on China's export growth of fresh and frozen tuna, revealing that China did not focus its exports on countries seeing a rapid increase in demand for chilled and frozen tuna.

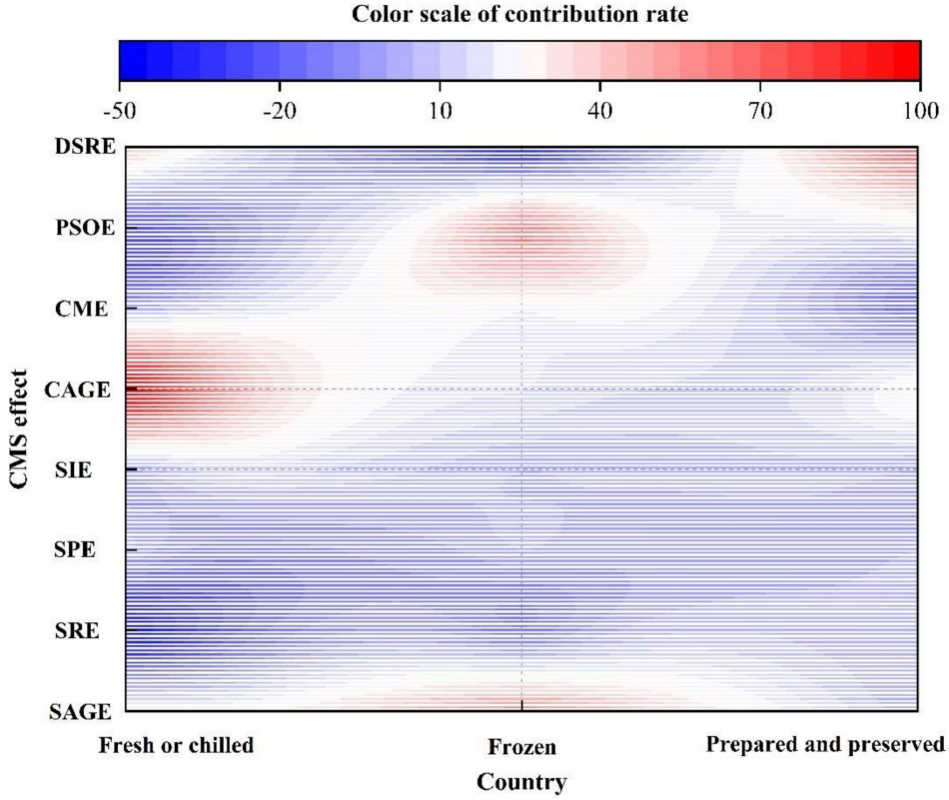

Figure 5. Illustration of the second-level decomposition results at the product type level. Note: SAGE = scale-aggregate growth effect, SRE = scale regional effect, SPE = scale product effect, SIE = scale interaction effect, CAGE = competitive aggregate growth effect, CME = competitive market effect, PSOE = pure second-order effect, and DSRE = dynamic structural residual effect.

A further analysis of the competitiveness effect shows that the competitive aggregate growth effects of fresh, frozen, and processed tuna were all positive, with fresh tuna contributing 100%. The improvement in the overall competitiveness of tuna has a strong driving effect on China's tuna exports. The contribution rate of the competitive market effect for frozen tuna was negative, partially offsetting the contribution of the competitive aggregate growth effect.

The pure second-order effect and dynamic structural residual effect in each type of tuna product differed significantly in their contribution rates. The pure second-order effect on frozen tuna accounted for 59.55%, showing that the interaction effect between changes in the scale of import demand for frozen tuna and changes in export competitiveness boosts exports. Additionally, the dynamic structural residual effect in fresh and processed tuna had a clearly positive impact, suggesting that the enhancement of the export competitiveness of Chinese tuna aligns with the shift in demand structure in major import markets, ultimately boosting Chinese tuna exports.

5. Conclusions and Policy Implications

5.1. Conclusions

Based on the CMS decomposition framework, this paper analyzes the factors affecting the change in China's tuna export scale from 2002 to 2022. The conclusions are as follows:

(1) The overall growth of China's tuna exports has been attributed in part to the scale effect, which has a notable impact on the expansion of export scale in the USA,

Vietnam, and Malaysia, as well as the frozen tuna market. To be specific, both the rising demand for Chinese tuna goods in the importing market and shifts in the product composition of imported demand support the expansion of China's tuna exports. Nevertheless, volatility in import demand, particularly during the COVID-19 pandemic, substantially decreased China's tuna exports as a result of a decline in demand within the import market.

(2) China's competitive edge in tuna exports has steadily strengthened in most of its principal exporting markets, greatly boosting the growth of China's tuna exports. Particularly pronounced is the export competitiveness of Chinese tuna products in the Japanese and fresh tuna markets. More precisely, the competitive aggregate growth effect contributed to China's increased competitiveness in tuna exports, whereas the competitive market effect had an adverse effect, indicating a mismatch between structural changes in China's tuna export competitiveness and the demand of the imported market. Among the three effects explaining the competitive market effect, the competitive product effect exerts the most pronounced adverse influence on China's tuna exports.

(3) The second-order effect significantly boosts Chinese tuna export growth and is the most crucial among the three effects at the first level. This tendency is noticeable in Thailand, Spain, Mexico, Italy, and the Philippines, as well as in the prepared and preserved tuna industry. Both the pure second-order effect and the dynamic structural residual effect contribute to a fluctuating growth trend, enhancing their impacts on China's tuna exports.

5.2. Policy Implications

As shown in the results above, the growth in demand for tuna in global markets exerts a positive influence on China's tuna exports. Therefore, it is necessary to further exploit the potential of the global market for tuna imports. China should improve bilateral and multilateral cooperation, expedite the signing of trade agreements with tuna-importing countries (regions), and strengthen mechanisms for coordinating and resolving disputes, thereby reducing trade costs and promoting trade facilitation. The decomposing results at the country level and the product type level imply that particular focus should be placed on countries such as the US, Malaysia, and Vietnam, as well as tuna products like frozen tunas, which are experiencing a rapid rise in demand. This growth is amplifying the scale regional effect and scale product effect on China's tuna exports. In order to enhance the resilience of China's tuna export trade by constructing a diversified, robust, and balanced trade pattern, the Chinese government and industry associations should coordinate the participation of tuna export enterprises in renowned international exhibitions and organize trade promotion activities, which will increase the visibility of Chinese tuna products in emerging markets.

The first-level decomposing result at the global level shows that China's tuna exports have benefited from the competitive effect. But a further decomposition of the competitive effect reveals that China's tuna exports did not match the demand for some specific products or in some specific markets, which negatively affected the growth of its tuna exports. Hence, the Chinese tuna industry's global competitiveness requires ongoing enhancement. Tuna-related enterprises, including fishing vessels and processing factories, should endeavor to obtain certification for their tuna products, such as from the Marine Stewardship Council (MSC), to meet the higher quality standards in the global tuna market. In order to consistently enhance the added value of their products, businesses involved in the tuna industry should strive to incorporate technological advancements or implement innovative practices. Furthermore, product marketing should be prioritized to broaden their sales channels and cultivate a robust brand identity.

It is necessary to improve communication and coordination among Chinese domestic and international tuna-related stakeholders, including tuna production, processing, trading, transport, and associated organizations, which may be achieved by holding regular tuna

industry conferences and releasing annual tuna industry reports. This will promote the favorable development of China's tuna sector. Tuna-related businesses are recommended to enhance communication with importing nations, track changes in demand in the import market, and acquire comprehensive knowledge of global tuna market data. The types of products and country structure of tuna exports must be adjusted accordingly in an appropriate manner.

The results of the CMS analysis demonstrate the vulnerability and risks of the international tuna market, which are influenced by various effects. Besides international market, the potential of the Chinese domestic tuna market should be maximized. The healthy growth of China's tuna sector is hampered by the large fluctuations in the scale and structure of the country's primary import market demand for tuna. Meanwhile, the local Chinese market for tuna consumption is in its nascent phase of development, with substantial market potential. China's domestic tuna fishing and processing companies should fortify their partnerships with sales companies, the catering industry, industry associations, etc., to develop processed tuna products customized to Chinese customers' tastes and recipes that highlight tuna's features. This will enhance Chinese consumers' knowledge of tuna products and cultivate consumption habits, ultimately boosting domestic demand. Simultaneously, domestic tuna trading companies in China should innovate their sales models, establish an improved sales network, and develop a reputable tuna brand.

Author Contributions: Conceptualization, L.Z. and C.Y.; Formal analysis, L.Z., C.Y. and F.W.; Funding acquisition, F.W. and J.Z.; Methodology, L.Z. and C.Y.; Supervision, C.Y. and J.Z.; Visualization, Z.Y.; Writing—original draft, L.Z. and C.Y.; Writing—review and editing, L.Z., C.Y. and Z.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Ministry of Agriculture and Rural Affairs of China through the project Monitoring and Assessment of the Dynamics of Globally Significant Fish Stocks (D-8025-23-1001-19), by the Department of Agriculture and Rural Affairs of Zhejiang Province through the project Detection and Harvesting of Albacore Tuna in the Eastern Pacific Ocean (CTZB2023080465), and by the Department of Agriculture and Rural Affairs of Shandong Province through the project Detection and Harvesting of Tuna in the Indian Ocean (20230201).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

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