Application of Stochastic Frontier Gravity Model for Determining Seafood Export

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Abstract

The efficiency estimation of industry-specific exports plays a vital role in identifying export potentials and appropriate marketing strategies. This paper aimed to investigate the main determinants of Iran's seafood exports to its 32 trading partners from 2001 to 2018, using the stochastic frontier gravity model. Moreover, this paper analyzed the efficiency and export potentials of Iran's seafood to its trading partners. The findings confirmed the consistency of stochastic frontier analysis for Iran's seafood exports. The results indicated that the GDP of Iran and its trading partners had significant positive effects. In contrast, the bilateral exchange rate, common border, common religion, distance, economic crisis, and sanctions had significant negative effects on Iran's seafood exports. In addition, the results of export efficiency revealed that Iran has great export potential to its trading partners, particularly neighboring countries. People's awareness of the benefits of seafood in neighboring countries with low consumption can increase their demand and increase Iran's exports to these countries. Considering the high export potential in neighboring countries with high religious and cultural similarities, it is suggested that Iran should strengthen its food trade relations with neighboring countries such as Iraq, Turkmenistan, Lebanon, Kuwait, the United Arab Emirates, and Afghanistan.

Keywords: Export efficiency, Export potential, Seafood exports, Stochastic frontier gravity model.

1. Introduction

Seafood, particularly fish, has a considerable potential to contribute to increasing food and nutrition security because of its nutritional properties and health benefits (Chan et al., 2019; Cai and Leung, 2022; Garlock et al., 2022; Stetkiewicz et al., 2022; Castro et al., 2023). Regarding

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seafood production, fisheries and aquaculture sectors are key sources of income for many households across many countries, especially developing countries (Asche et al., 2015).

Considering the share of seafood has increased in a diet because of its physical and mental benefits, seafood consumption shifted from local to international markets. Therefore, seafood production and trade have increased significantly. In addition, trade liberalization and improvements in logistics have contributed to an increase in the total supply and export markets for seafood products (Tveteras et al., 2012; Asche et al., 2015). Seafood products are among the most traded food commodities worldwide and are more important than poultry and pork combined (Asche et al., 2015; Natale et al., 2015; Bellmann et al., 2016). For example, in 2022, the trade value of seafood and poultry was approximately 295.5 billion dollars and 80 billion dollars, respectively (International Trade Center, 2023).

Regarding the high exposure to trade competition of primary production, the analysis of trade determinants of seafood products is important for developing countries, which rely on seafood exports as a source of income, and for developed countries, which are the main consumers (Asche et al., 2015).

Iran emphasized policies to increase non-oil exports in several years. The agricultural sector received special attention from policy-makers and planners due to its high capacity and climate diversity. Despite the high potential in Iran's fisheries and aquaculture sectors, seafood products have a low share in Iran's agricultural exports. Therefore, agricultural policy-makers have recently reemphasized the development of fisheries and aquaculture sectors. The volumes of both seafood production and exports have increased significantly in recent years. According to Table 1, seafood production increased by 216% over the last two decades (from 399.000 tons in 2001 to 1.262.403 tons in 2018), and seafood exports increased by 3730.4% (from 8.2 million dollars in 2001 to 313.8 million dollars in 2018). In addition, Iran's seafood export competitiveness has also increased. The value of the RCA index increased by 72.9% (from -0.830 in 2001 to -0.225 in 2018).

Table 1: Production, consumption, and trade statistics of seafood products (2001-2018).

Year	Production			Employment	Exports	Imports	Trade balance	RCA*
	Captures	Aquaculture	Total					
Unit	Tons	Tons	Tons	Person	1000$	1000$	1000$	
2001	325,355	73,645	399,000	144,397	8,192	3,179	5,013	-0.830
2002	311,843	89,827	401,670	144,584	27,135	7,020	20,115	-0.563
2003	331,661	110,175	441,836	156,470	46,242	26,788	19,454	-0.464

2004	349,940	124,560	474,500	158,597	49,506	13,511	35,995	-0.407
2005	388,379	134,180	522,559	162,890	29,398	16,785	12,613	-0.722
2006	420,882	154,678	575,560	169,297	41,367	8,716	32,651	-0.692
2007	368,745	193,677	562,422	170,358	43,474	24,692	18,782	-0.706
2008	378,947	183,647	562,594	174,067	50,550	21,013	29,537	-0.613
2009	392,401	207,353	599,754	181,381	91,355	32,220	59,135	-0.531
2010	412,310	251,374	663,684	186,482	141,206	75,729	65,477	-0.450
2011	449,728	285,351	735,079	191,629	206,375	61,299	145,076	-0.298
2012	500,015	338,877	838,892	204,534	216,465	60,159	156,306	-0.310
2013	514,081	370,876	884,957	208,116	243,319	97,676	145,643	-0.202
2014	575512	371,840	947,352	208,472	230,644	172,572	58,072	-0.367
2015	582,349	401,548	983,897	213,112	229,203	147,213	81,990	-0.309
2016	634,198	459,521	1,093,719	223,439	342,578	181,475	161,103	-0.177
2017	724,817	477,269	1,202,086	229,419	404,054	137,850	266,204	-0.105
2018	773,198	489,205	1,262,403	232,707	313,788	56,646	257,142	-0.225
Mean	468,576	262,089	730,665	186,664	150,825	63,586	87,239	-0.443
Growth	137.6	564.3	216.4	61.2	3730.4	1681.9	5029.5	72.9

Source: Author's calculation based on International Trade Center (ITC), food and agriculture organization (FAO) and Iran Fisheries Organization.

Note: RCA denotes the revealed comparative advantage index, which measures the competitiveness of Iran's seafood exports.

Countries are seeking to increase the benefits of exports. However, there are questions about the export efficiency of the exporting countries and the export potential in front of them in the importing countries. Empirical studies used the stochastic frontier gravity model, a combination of the gravity model (Tinbergen, 1962) and the stochastic frontier model (Aigner et al., 1977), to determine export efficiency, export potential, and export gap. Export efficiency is defined as the export performance of a country in its importing countries. Export potential is defined as the maximum value of exports that can be achieved when there are no barriers to trade, which provides a clear picture for a country about the capacity of international markets (Ahmad Hamidi et al., 2022).

The literature confirms that there is inefficiency in exports of commodities (Kalirajan, 2007; Ravishankar and Stack, 2014; Atif et al., 2019; Xu et al., 2022; Liu and Zhou, 2023), particularly agricultural commodities (Atif et al., 2017; Mohammadi et al., 2020; Abdullahi et al., 2022; Ahmad Hamidi et al., 2022; Nguyen, 2022; Tandra and Suroso, 2023). For instance, Atif et al. (2017) found that the potential of Pakistan's agricultural exports is more than actual exports to importing countries, particularly neighboring, European, and Middle Eastern countries. Mohammadi et al. (2020) showed the technical inefficiency of Iran's pistachio exports. In addition,

the average of Iran's pistachio export efficiency has decreased in all destination markets from 2001 to 2016. Ahmad Hamidi et al. (2022) found inefficiency in Indonesian and Malaysian palm oil exports. They revealed that both countries have great potential to increase palm oil exports.

From the review of previous studies concerning seafood trade, two gaps were identified in the literature. First, considering the previous studies on export efficiency, it is expected that there will be inefficiency in seafood exports. However, no study, to date, has been conducted to investigate the efficiency and potential of seafood exports using the stochastic frontier gravity model. For instance, Natale et al. (2015) investigated the factors affecting seafood trade using the gravity model with the Poisson pseudo-maximum likelihood (PPML) method. The results demonstrated that seafood trade was significantly positively influenced by GDP, income, and consumption in importing countries. In addition, trade agreements and exporters' production positively affected the seafood trade while, the geographical distance and exporting countries' GDP played a decreasing role in the trade of seafood. Shepotylo (2016) analyzed the factors influencing intensive and extensive margins of seafood trade using a gravity model. The findings revealed that technical barriers to trade (TBT) reduced extensive margins of seafood exports and increased intensive margins. In contrast, sanitary and phytosanitary (SPS) measures had the opposite effect compared to the TBTs on intensive and extensive margins. Additionally, the intensive and extensive margins of seafood exports were significantly positively affected by trade agreements, common language, and common border between exporters and importers. Gupta and Sangita (2022) examine the effect of food standards on marine products exports using the gravity model. The results demonstrated that marine exports were negatively affected by seafood standards. They found that, after imposing standards, seafood exports of richer nations increased, while decreased in poorer countries. Kim et al. (2023) investigated the effect of Russian sanctions on seafood trade using the gravity model with PPML method. The results showed that economic sanctions significantly influenced global seafood trade. They found importers and exporters' GDP, free trade agreements, and contiguity had significantly positive influence on seafood trade. Dong and Truong (2023) investigated the main factors and seafood potential in Vietnam using the gravity model and average standard trade potential (ASTP) index. The findings revealed that Vietnam's seafood exports were significantly positively influenced by importers' income and GDP. In addition, the variables of free trade agreement, region, and WTO have heterogeneous effects on seafood exports in Vietnam. They found that there is export potential in some destination countries.

Second, although the seafood trade literature is rich, few studies have investigated seafood exports in emerging countries in the global trade network, such as Iran. For example, Mohammadi et al. (2020) investigated the effect of food standards on Iran's fish exports using the gravity model. They found that the similarity of fish safety standard between Iran and its trading partners can increase Iranian fish exports.

Considering that Iran's fisheries and aquaculture productions have experienced a growth of more than 200 percent during the last two decades, information about the main determinants and level of seafood export efficiency can contribute to planners and policy-makers in choosing the appropriate market to expand their market shares. The purposes of this study included (i) to determine the main factors affecting seafood exports of Iran, using the stochastic frontier gravity model, (ii) to evaluate the efficiency and potential of Iranian seafood exports with its trading partners, and (iii) to cluster trading partners using the multivariate k-means clustering algorithm.

Our main contribution in this paper is investigating the main determinants of seafood exports in Iran. In the last two decades, much attention has been paid to Iran's fisheries sector, and today policy-makers are looking to identify the factors affecting the increase and decrease of Iran's seafood exports. Considering the different conditions of Iran and other countries, the findings of this study can be of great help to Iranian policy-makers and planners in the field of seafood export. For example, examining the effect of sanctions and other factors in the conditions of sanctions can provide important information to policy-makers and planners. Moreover, in this research, the performance of previous plans has been evaluated by calculating export efficiency, which can help policy-makers formulate future plans.

From the point of view of methodology, this research contributes to the literature in two ways. First, the stochastic frontier gravity model is used to determine the efficiency and potential of seafood exports. Second, in this study, for the first time, the clustering method has been used to identify seafood destination markets for planning and policy-making optimally.

The remaining study has been organized as follows: Section 2 discusses data sources and the methodology used in this study. Section 3 provides the empirical results of export efficiency and potential from the stochastic frontier gravity model. Section 4 provides the conclusions and policy suggestions.

2. Materials and methods

2.1. Data

The present study used balanced panel data of Iranian seafood exports with its 32 importing countries during 2001–2018. All variables, expected sign, and data sources have been presented in Table 2. All data used in this study was taken from a variety of sources. Seafood export data was downloaded from the International Trade Center (ITC). GDP, region, and income level data were taken from the World Development Indicators (WDI) database. Data on common border, common religion and weighted distances were taken from the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII).

Table 2: Expected signs and data sources of model variables.

Variable	Expected sign	Data source
Seafood exports		International trade center
GDP Partner	+	WDI Database
GDP Iran	+	WDI Database
Distance	-	CEPII database
Bilateral exchange rate	+ / -	Author's Calculation based on WDI Database
Border	+ / -	CEPII database
Religion	+ / -	CEPII database
RTA	+ / -	WTO database
Region	+ / -	WDI Database
High income	+	WDI Database
Economic crisis	-	Author's Calculation
Sanction	-	Author's Calculation

2.2. Stochastic frontier gravity model

Technical efficiency refers to the ability of a producer to achieve maximum output from a given set of inputs. From a trade perspective, export efficiency shows the ability of an exporter to achieve maximum exports in the destination country based on its supply capacity and Importer's demand capacity. To investigate export efficiency, Kalirajan (1999) suggested that the gravity model be estimated with the stochastic frontier analysis approach. So, the gravity model to estimate the efficiency of Iran's seafood exports is modified as follows:

$$Export_{jt} = f(X_{jt};\beta)exp^{(\varepsilon_{jt}-u_{jt})} \quad (1)$$

where, "$Export_{jt}$" is Iran's seafood exports to trading partner j at year t, $f(X_{jt};\beta)$ represents factors determining potential exports, and b is a vector of unknown parameters. The error term ε_{jt} denotes measurement and specification errors, which are assumed to follow a normal distribution with zero mean and variance σ_{ε}^2. The error term u_{jt} denotes export volume missing due to man-made trade resistance and proxies the magnitude of thr inefficiency of Iran exports with country j. The null hypothesis ($\sigma^2_e = 0$) can be tested against the alternate hypothesis ($\sigma^2_e > 0$) to estimate technical

efficiencies. The rejection of the null hypothesis confirms the stochastic frontier model is appropriate.

For the calculation of technical efficiency, Battese and Coelli's (1988) equation is used as follows:

$$E\left[\exp(-e_{jt})\middle|u_{jt}+e_{jt}\right]=\left[\frac{1-\phi[\sigma_{\alpha}+\gamma(u_{jt}+e_{jt})/\sigma_{\alpha}]}{1-\phi\gamma(u_{jt}+e_{jt})/\sigma_{\alpha}}\right]\exp[\gamma(u_{jt}+e_{jt})+\frac{\sigma_{\alpha}^{2}}{2}] \quad (2)$$

where, $\phi(.)$ denotes the density function. The technical efficiency from Eq. (2) for each country-pair ranges between zero and unity. High-efficiency values show actual exports are close reaching their frontier levels. In contrast, low efficiency values suggest deviations of actual exports from maximum potential, implying there are possibilities for further exports.

Following Eq. (1), the model specified to estimate export frontier:

$$LnExport_{jt}=\beta_0+\beta_1 LnGDP_i+\beta_2 LnGDP_p+\beta_3 LnDis+\beta_4 LnBER+\beta_5 Border+$$
$$\beta_6 Religion+\beta_7 RTA+\beta_8 Region+\beta_9 High+\beta_{10} FC+\beta_{11} Sanc+\varepsilon_{jt}-u_{jt} \quad (3)$$

where, GDP of Iran and its trading partners has been applied as a renowned proxy for the market size of a country. The market size of Iran and importers denotes the production and export capacity of seafood and demand for Iran's seafood exports, respectively. Dis denotes the geographical distance between the capitals of Iran and importing countries, which is a useful proxy for international transport costs, including interaction cost, shipping cost, and time-related costs. BER indicates a bilateral exchange rate between Iran and its trading partners. Trading partners with common borders are expected to do more trade. Therefore, a dummy variable which is equal to unity for Iran and its partner with common border, and zero otherwise. Common Religion may enhance bilateral trades due to similar lifestyle and communication patterns. So, a dummy variable which is equal to unity for importing countries with similar religion with Iran, and zero otherwise. Countries usually use the RTA to increase trade by reducing trade barriers between members of an agreement. This variable equals unity when Iran and its trading partners are members of the same agreement, and zero otherwise. Region denotes the region of Iran's trading partners. A dummy variable equals unity if importing countries are located in Asia, and zero otherwise. High denotes high-income countries. A dummy variable which is equal to unity for high-income trading partners, and zero otherwise. EC indicates an economic crisis. A dummy variable equals unity during 2007-2009, and zero otherwise. Sanc is an international economic sanction which imposed on Iran in a period between 2010 and 2015. A dummy variable which is equal to unity during the

sanction period, and zero otherwise. In equation (3), all non-dummy variables are estimated in logarithmic form.

2.3. K-means clustering algorithm

Clustering analysis is to give policy-makers and planners valuable insights into the commercial similarities of destination countries in order to formulate international marketing plan for boosting Iran's seafood exports.

The k-means technique is an appropriate tool for segmenting and classifying Iran's trading partners regarding actual exports, export efficiency, and export potential. It is applied to divide 32 countries into g clusters by minimizing the sum of squared error from each country to the cluster with the nearest center. Considering the high variances among variables, data normalization is needed before using the k-means clustering algorithm (Rafiee et al., 2022). The Min – Max technique was applied to normalize the actual exports, export efficiency, and export potential variables:

$$V^n = \frac{V - \min(V)}{\max(V) - \min(V)} \quad (4)$$

where, V^n and V denote the normalized and original value of variables, respectively. The next step in k-means technique is determining the number of clusters to segment the countries. The Calinski–Harabasz (1974) pseudo-F index, as one of the best clusters stopping rules, was used to estimate the number of clusters (Rafiee et al., 2022):

$$pseudo\ F = \frac{SSE_B/g-1}{SSE_W/k-g} \quad (5)$$

where SSE_B denotes the between-cluster sum of squared error, and SSE_W represents the within-cluster sum of squared error. g denotes the number of clusters, and k is the countries. A larger pseudo-F value shows a more distinct clustering of countries.

3. Results and Discussion

3.1. Gravity model results

Table 3 provides the results of the stochastic frontier gravity model. The results of Mu (μ) and Lambda (λ) parameters confirm the appropriateness of the stochastic frontier analysis approach to estimate the gravity model. First, the value of Mu is 2.820 and is statistically significant at 1 percent level, implying that there exist inefficiencies. The lambda parameter, measuring the ratio of the standard deviation of inefficiency to the standard deviation of the random error. The lambda value

is 6.313 and is statistically significant at 1 percent level, indicating that the stochastic frontier gravity model is suitable. Additionally, the results of Fisher unit root test show that unll hypothesis rejected at 1 percent level, meaning that the residual from the stochastic frontier gravity model is stationary.

The results reveal that the coefficient of importing countries' GDP as a proxy of economic size is positive and statistically significant at 1 percent level, suggesting that trading partners' income influenced the flow of seafood exports in a positive direction. This means higher GDP of partners leads to a higher demand and, thereby, more seafood imports. This result is consistent with previous findings (Natale et al., 2015; Gupta and Sangita, 2022; Kim et al., 2023), revealing that seafood exports were positively and significantly influenced by importing countries' GDP. The Iran's GDP captures the supply capacity; it is positive and statistically significant at 1 percent level. This finding confirms the results of previous studies (Shepotylo et al., 2016; Kim et al., 2023), indicating that exporter's GDP positively affected the seafood exports.

The coefficient of distance carries the expected negative sign on its coefficient and is statistically significant at 1 percent level, revealing that geographical distance plays an impeding role in Iran's seafood exports to its importing countries. This result is similar to the findings in other studies (Kareem, 2016; Mohammadi et al., 2020; Dong and Truong, 2023), emphasizing the negative effect of distance on seafood exports. The coefficient of the bilateral exchange rate is negative and statistically significant at 1 percent level. This finding indicates that the devolution of the Iranian Rial decreased seafood exports. Bostan et al. (2018) demonstrated a significantly negative relationship between exchange rate and exports. Similarly, Beak (2013) found that Korean food exports to Japan were negatively influenced by the exchange rate in the short-term. However, there are empirical studies that emphasize the positive relationship between the exchange rates and exports (Atif et al. 2017). One of the most important reasons for the negative effect of exchange rate on Iran's seafood exports is that the increase in the exchange rate in Iran has been severe and with high fluctuations; as a result, creating uncertainty about future economic conditions among supply chain actors such as producers and exporters. Therefore, despite the increase in the exchange rate, Iran's seafood exports have not increased. For example, Chizari and Sadafi Abkenar (2020) showed that exchange rate fluctuations had a negative effect on Iran's pistachio supply. They recommended to maintain stability in the exchange rate. In addition, Tarakçı et al. (2022) demonstrated that Türkiye's exports were negatively affected by exchange rate volatility in the

long-term. They stated that their results are consistent with the "wait and see" approach for exporters, which has resulted in a decrease in Türkiye's long-term exports.

For qualitative dummy variables, the results show that the coefficient of the border dummy is negative and significant at 1 percent level. This result contradicts Natale et al. (2015) and Gupta and Sangita (2022), which confirmed that common borders and similar religions positively affected seafood trade. In addition, the coefficient of the religion dummy is negative and statistically significant at 1 percent level. One of the most important reasons is that the seafood consumption in some importing countries with the same border and religion is very low. For instance, seafood consumption in Afghanistan, a neighboring country with a common border and similar religion, is very low and equal to 0.42 kg per person per year in 2018 (FAO, 2022). For this reason, a large share of Iranian seafood products has been exported to non-border countries with different religions. According to the findings in a study by Natale et al. (2015), there was a significantly positive relationship between seafood consumption and seafood imports in countries.

The coefficient of the RTA dummy is positive but statistically insignificant. This means Iran's seafood exports were not significantly influenced by trade agreements between Iran and its trading partners. Similarly, Shepherd and Wilson (2013) and Kareem et al. (2016) found that trade agreements between countries had no significant effect on seafood exports. In contrast, studies by Natale et al. (2015) and Dong and Truong (2023) demonstrated the significant positive effect of RTA on seafood exports.

The coefficient of the region dummy is positive and statistically significant at 1 percent level, showing that Iran has mainly focused on Asian countries to export seafood. This result is consistent with the findings of Dong and Truong (2023), who stated that the geographical region of importing countries had a significant effect on seafood exports.

The coefficient of high-income dummy is positive but statistically insignificant. This shows that a small share of Iran's seafood is exported to high-income countries. Shepherd and Wilson (2013) showed a positive and significant relationship between seafood exports and the high-income importing countries.

The coefficient of the crisis dummy is negative and statistically significant at 1 percent level. This result is consistent with previous studies (Ferto and Zserb, 2017; Mohammadi et al., 2020), which found that economic crisis plays a decreasing role in trade flows. The coefficient of the sanction dummy is negative and statistically significant. This means sanctions imposed on Iran

have reduced Iran's seafood exports. Similarly, Kim et al. (2023) found that the global seafood trade was significantly influenced by economic sanctions imposed against Russia.

Table 3: The results of stochastic frontier gravity model.

Variable	Coefficient	Standard error	p-Value
GDP Partner	0.361	0.069	0.000
GDP Iran	0.515	0.251	0.041
Distance	-2.068	0.263	0.000
Bilateral exchange rate	-0.190	0.049	0.000
Common border	-1.515	0.506	0.003
Common religion	-2.193	0.459	0.000
RTA	0.031	0.456	0.945
Region	1.573	0.355	0.000
High income	0.376	0.459	0.413
Economic crisis	-1.090	0.296	0.000
Sanction	-0.517	0.226	0.022
Constant	4.978	7.259	0.493
μ	2.802	0.551	0.000
λ	6.313	0.235	0.000
Log likelihood	-1085.138		
Wald	243.01 (0.000)		

Source: research findings

Note: Standard errors are robust, clustered by country.

3.2. Export's efficiency and potential

The estimation of export's technical efficiency and export's potential for Iran's trading partners has been shown in Tables 4 and 5. Considering the change in Iran's government in 2013 and also the change in policymakers' view of international relations, it is important to interpret the performance results in the period of 2013-2018 and compare it with the previous periods. Therefore, for the sake of comparison, the whole period is divided into three sub-periods of 2001–2006, 2007–2012, and 2013–2018 to estimate average technical efficiency. Our findings indicate that Iran is not doing maximum exports with its trading partners, and there exists a huge potential to increase exports with these countries. The results revealed a rapid reorientation of seafood exports toward Asian countries. Iran's seafood export efficiency ranges from 0.27 in Turkmenistan to 42.45 in UAE, with an average score of 12.97 during 2001-2018. The average efficiency of

seafood exports is equal to 11.31, 11.78, and 14.29 for the 2001-2006, 2007-2012, and 2013-2018 periods, respectively. This suggests that the export performance of Iran has improved in recent years. The main reason is to pay attention to Iran's agricultural export potential and change the export portfolio of the agricultural sector. In the last decades, Iran has been a traditional exporter of products such as pistachios and saffron, but in recent years, more attention has been paid to other capacities of the agricultural sector, like seafood.

In the 2013-2018 period, the export efficiency varied between 0.10 and 61.10, suggesting that seafood export efficiency is higher than 50 percent, including UAE, Vietnam, and Iraq, implying that the Iranian seafood export efficiency to importing countries was less than half of the maximum capacity. The Iranian seafood exports' gap was calculated by subtracting Iran's potential exports from its actual exports. Our findings indicate substantial potential for Iranian seafood exports with its importing countries.

Table 4: The results of export efficiency of Iran with its trading partners.

Countries	Years				Countries	Years			
	2001-2006	2007-2012	2013-2018	2001-2018		2001-2006	2007-2012	2013-2018	2001-2018
Afghanistan	10.81	52.11	43.78	35.57	Luxembourg	23.68	42.87	1.20	19.38
Azerbaijan	0.06	0.80	1.67	0.94	Malaysia	24.24	0.21	33.85	20.54
Bahrain	0.64	1.23	3.15	1.73	Oman	6.38	4.08	19.19	10.95
Belgium	19.23	18.87	2.97	13.04	Pakistan	0.96	8.81	2.79	4.10
Canada	22.70	1.58	0.51	7.41	Qatar	6.65	0.24	3.31	3.21
China	2.38	8.43	11.97	7.59	Russian Federation	0.02	0.01	1.62	1.02
Egypt	1.35	34.23	11.78	22.13	Spain	52.24	13.69	14.47	27.57
France	31.95	6.44	7.49	16.27	Sri Lanka	-	0.25	2.64	2.30
Germany	31.78	10.34	1.24	14.45	Switzerland	5.33	1.02	0.24	2.55
Hong Kong	1.57	2.70	46.67	13.97	Thailand	3.86	15.02	26.28	15.05
Iraq	5.66	49.37	61.10	38.71	Türkiye	0.82	0.80	1.00	0.88
Italy	5.07	5.54	2.41	4.34	Turkmenistan	0.13	0.20	0.47	0.27
Japan	3.04	0.30	0.10	1.33	UAE	28.55	44.06	54.72	42.45
Korea, Republic of	0.27	0.95	0.54	0.59	UK	7.44	0.02	1.72	4.23
Kuwait	12.85	31.81	33.29	25.98	USA	39.10	3.78	2.61	19.72
Lebanon	1.66	2.89	3.43	2.72	Viet Nam	0.32	14.46	59.22	34.03

Source: research findings.

Table 5: The results of potential exports of Iran with its trading partners.

Countries	Actual exports	Potential exports	Exports gap	Countries	Actual exports	Potential exports	Exports gap
Afghanistan	2183	6138	-3955	Luxembourg	827	4265	-3438
Azerbaijan	203	21589	-21386	Malaysia	450	2189	-1739
Bahrain	143	8245	-8102	Oman	647	5909	-5261
Belgium	1163	8913	-7751	Pakistan	244	5955	-5711
Canada	207	2793	-2586	Qatar	528	16449	-15921
China	5776	76070	-70294	Russian Federation	794	78089	-77295
Egypt	889	4019	-3129	Spain	4391	15928	-11537
France	3203	19689	-16486	Sri Lanka	1356	59036	-57680
Germany	3538	24483	-20945	Switzerland	318	12446	-12129
Hong Kong	14855	106307	-91451	Thailand	7796	51786	-43990
Iraq	66669	172227	-105559	Türkiye	68	7789	-7721
Italy	1024	23585	-22561	Turkmenistan	143	52101	-51958
Japan	1134	85285	-84152	UAE	11742	27664	-15922
Korea, Republic of	637	108322	-107685	UK	618	14612	-13994
Kuwait	8393	32303	-23910	USA	1181	5990	-4808
Lebanon	1539	56640	-55101	Viet Nam	40225	118201	-77976

Source: research findings.

3.3. Clustering results

The high number of importing countries and the limited budget do not allow deep attention to all destination markets. Therefore, it is necessary that the best markets are selected for in-depth investigation in order to develop marketing plans and strategies to enter the market and develop exports. The results of cluster analysis as a powerful tool in market segmentation can determine the best destination countries for seafood exports based on Iran's trade objectives. Cluster analyses are performed based on export efficiency, actual exports and export potential. The results indicated that the number of four clusters is suitable for segmenting the trading partners of Iran’s seafood exports (Table 6). The four-group solution with a Calinski–Harabasz pseudo-F value of 74.26 is

the largest, indicating that the four-group solution is the most distinct compared with other group solutions.

The cluster solution is shown in Table 7. The first cluster includes Iraq and Vietnam, with the highest actual and potential exports. Moreover, this cluster is characterized by the highest efficiency in comparison to other clusters. Cluster 2 includes the countries with low actual exports and export efficiency and low potential exports. The countries of this cluster are mainly from the European regions. These countries also had access to the sea at a high geographical distance from Iran. On the one hand, Asian countries in this cluster also have access to the sea. On the other hand, they have a low population, such as Bahrain, Qatar, and Oman. This has led to lower Iranian exports and export efficiency in these countries. Cluster 3 includes countries with the lowest export efficiency. Countries in this cluster have high potentials, followed by cluster 1. The countries in cluster 3 have two important characteristics. One of these features is their food style, which is based on seafood consumption. For this reason, even though some of these countries are the biggest exporters of seafood, they are also importers of seafood. For example, although China is the second exporter of seafood, it is also the second largest importer of seafood after the United States.

On the other hand, the two countries, Turkmenistan and Lebanon, have high cultural, political and geographical affinities with Iran, which can create suitable conditions for seafood exports. Therefore, cluster 3 is the most attractive cluster for seafood exports, and it is necessary for the countries of this cluster must be special attention by planners and decision-makers. Cluster 4 with high efficiency in comparison to clusters 2 and 3. This cluster also has suitable capacities for seafood exports. Especially the countries of Afghanistan and the United Arab Emirates, which have the most agricultural trade exchanges with Iran.

Table 6: The results of Calinski–Harabasz pseudo-F.

Number of clusters	3	4	5	6	7	8
pseudo-F	30.21	74.26	65.31	50.98	55.42	38.88

Source: research findings.

Table 7: Cluster solution.

Index	unit	Cluster 1	Cluster 2	Cluster 3	Cluster 4
		Iraq	Azerbaijan	China	Afghanistan
		Vietnam	Bahrain	Japan	Hong Kong, China
			Belgium	Korea, Republic of	Kuwait
			Canada	Lebanon	Malaysia
			Egypt	Russian Federation	Thailand

			France Germany Italy Luxembourg Oman Pakistan Qatar Spain Switzerland Türkiye United Kingdom United States	Sri Lanka Turkmenistan	United Arab Emirates
Export efficiency	%	60.16	4.57	2.97	39.77
Actual exports	1000$	96055	455	2397	14432
Potential exports	1000$	159144	12184	70277	36413

Source: research findings.

4. Conclusion

In this study, the main determinants and efficiency of Iran's seafood exports to its 32 trading partners were estimated using the stochastic frontier gravity model during 2001–2018. The findings of the stochastic frontier gravity model confirm that the economic size of Iran (GDP) and its trading partners have positive effects whereas geographical distance has a negative effect on Iran's seafood exports. Additionally, the devaluation of the Iranian currency (Rial) compared to other international currencies is a barrier in increasing the export revenues. The region variable has positive and significant effect on seafood exports; however, high-income trading partners, common border, common religion, and RTA could not contribute to Iran's seafood exports in our analyses. Furthermore, Iran's seafood exports are negatively significantly affected by the economic crisis and international sanctions. According to the results, Iran has shown weak efficiency in seafood exports to many of its trading partners. The efficiency of seafood exports is less than 50% in most trading partners, which had a downward trend in recent years. Further, although Iran's seafood exports had a rapid reorientation towards Asian countries during the 2013-2108 period, there are huge export gaps for all importing countries, particularly neighboring countries with common borders and similar religions.

According to our analysis and discussion, some policy suggestions are proposed to boost Iran's seafood exports. First, considering the negative role of financial and economic sanctions in Iran's seafood exports, the government and policy-makers should make efforts to provide appropriate conditions for producers and exporters to minimize the negative effects of sanctions. Creating

flexible long-term contracts has a great influence on limiting the adverse effects of sanctions (See Bělín and Hanousek, 2021). Additionally, Iran should enhance political mutual with its trading partners to reduce the effects of sanctions. Second, according to the regional effects, Iran should focus on strengthening relations with Asian countries that import seafood. Third, stability in the exchange rate can help supply chain actors improve their decision-making. Therefore, considering the sharp increase in the exchange rate and its high fluctuations during the last decade, policy-makers and decision-makers should formulate policies for the relative stability of the exchange rate.

Fourth, since Iran's neighboring countries have high export potential, Iran should strengthen its trade relations with neighboring countries with high religious and cultural similarities, such as Iraq. Making people aware of the health benefits of seafood products can increase their seafood consumption and, thereby, their demand for these products (Krešić et al., 2022; Menozzi et al., 2023). Therefore, Iran should invest to create awareness among people in neighboring countries with low seafood consumption. Fifth, considering the limited marketing budget, it is suggested that the countries of the first cluster, particularly Iraq, which has the most efficiency and high potential, should be prioritized for planning and policy-making. It is also suggested that neighboring countries of the third and fourth clusters, such as Turkmenistan, Lebanon, Kuwait, the United Arab Emirates, and Afghanistan, which have a higher average potential, should be considered.

Finally, although this study tried to examine most influencing variables on Iran's seafood exports, future studies can examine the possible effect of other variables such as institutional quality (Xu et al., 2023), and logistic performance (Obeng et al., 2023). In addition, because the export efficiency of different products in the destination markets may be different, it is suggested that in future studies, the export efficiency should be done separately for each product (See Dong and Truong, 2023).

Appendix

Table A1: Descriptive statistics of the study variables

Variable	Unit	Mean	Std. Dev	Min	Max
Seafood exports	Thousand dollars	5164	18411	0	150651
GDP Partner	Billion dollars	1430	3030	2.46	20500
GDP Iran	Billion dollars	362	143	127	599
Distance	Kilometer	3703	2550	540	10191
Bilateral exchange rate	-	11364	18075	0.12	135332

Border	-	0.34	0.48	0	1
Religion	-	0.44	0.50	0	1
RTA	-	0.31	0.46	0	1
Region	-	0.63	0.48	0	1
High income	-	0.56	0.50	0	1
Economic crisis	-	0.17	0.37	0	1
Sanction	-	0.33	0.47	0	1

Source: research findings

REFERENCES

1. Abdullahi, N. M., Zhang, Q., Shahriar, S., Irshad, M. S., Ado, A. B., and Huo, X. 2022. Examining the determinants and efficiency of China's agricultural exports using a stochastic frontier gravity model. *PLoS One*, **17(9)**: e0274187.
2. Ahmad Hamidi, H. N., Khalid, N., Karim, Z. A., and Zainuddin, M. R. K. 2022. Technical Efficiency and Export Potential of the World Palm Oil Market. *Agriculture*, **12(11)**: 1918.
3. Aigner, D., Lovell, C.K., and Schmidt, P. 1977. Formulation and estimation of stochastic frontier production function models. *J. econom.*, **6(1)**: 21-37.
4. Asche, F., Bellemare, M. F., Roheim, C., Smith, M. D., and Tveteras, S. 2015. Fair enough? Food security and the international trade of seafood. *World Dev.*, **67**: 151-160.
5. Atif, R. M., Haiyun, L., and Mahmood, H. 2017. Pakistan's agricultural exports, determinants and its potential: an application of stochastic frontier gravity model. *J. Int. Trade Econ. Dev.*, **26(3)**: 257-276.
6. Atif, R.M., Mahmood, H., Haiyun, L., and Mao, H. 2019. Determinants and efficiency of Pakistan's chemical products' exports: An application of stochastic frontier gravity model. *PLoS One*, **14(5)**: 1-15.
7. Baek, J. 2013. Does the exchange rate matter to bilateral trade between Korea and Japan? Evidence from commodity trade data. *Econ. Model.*, **30**: 856-862.
8. Battese, G.E., and Coelli, T.J. 1988. Production of firm level efficiencies: With a generalized frontier production function and panel data. *J. Econom.*, **38**: 387–399.
9. Bělín, M., and Hanousek, J. 2021. Which sanctions matter? Analysis of the EU/Russian sanctions of 2014. *J. Comp. Econ.*, **49(1)**: 244-257.
10. Bellmann, C., Tipping, A., and Sumaila, U. R. 2016. Global trade in fish and fishery products: An overview. *Mar. Policy*, **69**: 181-188.

11. Bostan, I., Toderaşcu, C., and Firtescu, B. N. 2018. Exchange rate effects on international commercial trade competitiveness. *J. risk financ. manag.*, **11(2)**: 19.

12. Cai, J., and Leung, P. 2022. Unlocking the potential of aquatic foods in global food security and nutrition: A missing piece under the lens of seafood liking index. *Glob. Food Sec.*, **33**: 100641.

13. Caliński, T., and Harabasz, J. 1974. A dendrite method for cluster analysis. *Commun. Stat. Theory Methods*, **3(1)**: 1-27.

14. Castro, Ó., Borrull, S., Riu, J., Gimeno-Monforte, S., Montesdeoca-Esponda, S., Sosa-Ferrera, Z., Santana-Rodríguez, J.J., Pocurull, E and Borrull, F. 2023. Seafood consumption as a source of exposure to high production volume chemicals: A comparison between Catalonia and the Canary Islands. *Food Chem. Toxicol.*, **175**: 113729.

15. Centre d'Etudes Prospective et d'Informations Internationals. 2022. CEPII Database. Available at http://www.cepii.fr/

16. Chan, C. Y., Tran, N., Pethiyagoda, S., Crissman, C. C., Sulser, T. B., and Phillips, M. J. 2019. Prospects and challenges of fish for food security in Africa. *Glob. Food Sec.*, **20**: 17-25.

17. Chizari, A. H., and Sadafi Abkenar, S. 2020. Impact of price and non-price factors on the Iranian Pistachios Market. *J. Agric. Sci. Technol.*, **22(6)**: 1415-1430.

18. Dong, C. V., and Truong, H. Q. 2023. Determinants and potential of seafood trade: evidence from a transitional economy. *Foreign Trade Rev.*, **58(3)**: 428-454.

19. Ferto, I., and Szerb, A.B. 2017. The role of food crisis and trade costs in the Hungarian maize exports. *P. Agric. Econ.*, **353(4)**: 110-124.

20. Food and Agriculture Organization. 2022. Available at https://www.fao.org/faostat/en/#home

21. Garlock, T., Asche, F., Anderson, J., Ceballos-Concha, A., Love, D.C., Osmundsen, T.C., and Pincinato, R.B.M. 2022. Aquaculture: The missing contributor in the food security agenda. *Glob. Food Sec.*, **32**: 100620.

22. Gupta, A. K., and Sangita, S. 2022. Impact of Food Standards on Patterns of International Trade in Marine Products. *Foreign Trade Rev.*, 00157325221121433.

23. International Trade Center. 2022. Available at https://www.trademap.org/

24. Iran Fisheries Organization. 2022. Available at https://www.fisheries.ir/

25. Kalirajan, K. 1999. Stochastic varying coefficients gravity model: an application in trade analysis. *J. Appl. Stat.*, **26(2)**: 185-193.

26. Kalirajan, K. 2007. Regional Cooperation and Bilateral Trade Flows: An Empirical Measurement of Resistance. *Int. Trade J.*, **21(2)**: 85–107.

27. Kareem, O.I. 2016. Food safety regulations and fish trade: Evidence from European Union-Africa trade relations. *J. Com. Mark.*, **2(1)**: 18-25.

28. Kim, C. M., Kim, D. E., and Lim, S. S. 2023. Assessing the Seafood Trade Diversion Arising from Economic Sanctions: Evidence from Russia and Western Countries. *Foods*, **12(21)**: 3934.

29. Krešić, G., Dujmić, E., Lončarić, D., Zrnčić, S., Liović, N., and Pleadin, J. 2022. Fish Consumption: Influence of Knowledge, Product Information, and Satisfaction with Product Attributes. *Nutrients*, **14(13)**: 2691.

30. Liu, Z., and Zhou, X. 2023. Can Direct Subsidies or Tax Incentives Improve the R&D Efficiency of the Manufacturing Industry in China? *Processes*, **11(1)**: 181.

31. Menozzi, D., Sogari, G., Simeone, C., Czajkowski, M., Zawadzki, W., Bazoche, P., ... and Aanesen, M. 2023. Positive versus negative information: What is really shifting consumers' intention to eat Norwegian salmon? Evidence from three European countries. *Food Qual. Prefer.*, **108**: 104871.

32. Mohammadi, H., Aminizadeh, M. and Aghasafari, H. 2020. Investigating the Iran's Export Efficiency in Pistachio Target Markets: Application of Stochastic Frontier Gravity Model. *Agric. Econ. Dev.*, **34(1)**: 1-18.

33. Mohammadi, H., Saghaian, S., Aminizadeh, M., and Aghasafari, H. 2020. Food Safety Standards and its effects on Iran's Fish Exports. *Iran. J. Fish Sci.*, **19(6)**: 3075-3085.

34. Natale, F., Borrello, A., and Motova, A. 2015. Analysis of the determinants of international seafood trade using a gravity model. *Mar. Policy*, **60**: 98-106.

35. Nguyen, D.D. 2022. Determinants of Vietnam's rice and coffee exports: using stochastic frontier gravity model. *J. Asian Bus. Econ. Stud.*, **29(1)**: 19-34.

36. Obeng, C. K., Boadu, M. T., and Ewusie, E. A. 2023. Deep preferential trade agreements and export efficiency in Ghana: Do institutions matter?. *Res. Glob.*, **6**: 100112.

37. Rafiee, H., Aminizadeh, M., Hosseini, E. M., Aghasafari, H., and Mohammadi, A. 2022. A cluster analysis on the energy use indicators and carbon footprint of irrigated wheat cropping systems. *Sustainability*, **14(7)**: 4014.

38. Ravishankar, G., and Stack, M.M. 2014. The Gravity Model and Trade Efficiency: A Stochastic Frontier Analysis of Eastern European Countries' Potential Trade. *World Econ.*, **37(5)**: 690-704.

39. Shepherd, B., and Wilson, N. L. 2013. Product standards and developing country agricultural exports: The case of the European Union. *Food Policy*, **42**: 1-10.

40. Shepotylo, O. 2016. Effect of non-tariff measures on extensive and intensive margins of exports in seafood trade. *Mar. Policy*, **68**: 47-54.

41. Stetkiewicz, S., Norman, R.A., Allison, E.H., Andrew, N.L., Ara, G., Banner-Stevens, G., Belton, B., Beveridge, M., Bogard, J.R., Bush, S.R., Coffee, P., Crumlish, M., Edwards, P., Eltholth, M., Falconer, L., Ferreira, J.G., Garrett, A., Gatward, I., Islam, F.U., Kaminski, A.M., Kjellevold, M., Kruijssen, F., Leschen, W., Mamun, A.A., McAdam, B, Newton, R., Krogh-Poulsen, B., Pounds, A., Richardson, B., Roos, N., Röös, E., Schapper, A., Spence-McConnell, T., Suri, S.K., Thilsted, S.H., Thompson, K.D., Tlusty, M.F., Troell, M.F., Vignola, R., Young, J.A., Zhang, W., and Little, D.C. 2022. Seafood in Food Security: A call for bridging the terrestrial-aquatic divide. *Front. Sustain. Food Syst.*, **504**.

42. Tandra, H., and Suroso, A.I. 2023. The determinant, efficiency, and potential of Indonesian palm oil downstream export to the global market. *Cogent Econ. Financ.*, **11(1)**: 2189671.

43. Tarakçı, D., Ölmez, F., and Durusu-Ciftci, D. 2022. Exchange rate volatility and export in Turkey: Does the nexus vary across the type of commodity?. *Cent. Bank Rev.*, **22(2)**: 77-89.

44. Tinbergen, J. 1962. Shaping the World Economy: Suggestions for an International Economic Policy (New York: Twentieth Century Fund).

45. Tveterås, S., Asche, F., Bellemare, M. F., Smith, M. D., Guttormsen, A. G., Lem, A., Lien, K., and Vannuccini, S. 2012. Fish is food-the FAO's fish price index. *PLoS One*, **7(5)**: e36731.

46. World Bank. 2022. World Bank Database. Available at https://databank.worldbank.org.

47. Xu, H., Nghia, D. T., and Nam, N. H. 2023. Determinants of Vietnam's potential for agricultural export trade to Asia-Pacific economic cooperation (APEC) members. *Heliyon*, **9(2)**.

48. Xu, J., Lu, C., Ruan, S., and Xiong, N.N. 2022. Estimating the efficiency and potential of China's steel products export to countries along the "Belt and Road" under interconnection: An application of extended stochastic frontier gravity model. *Resour. Policy*, **75**: 102513.

کاربرد الگوی جاذبه مرزی تصادفی برای تعیین صادرات غذاهای دریایی

چکیده

برآورد کارایی صادرات صنعت محور نقش حیاتی در شناسایی پتانسیل‌های صادراتی و استراتژی‌های بازاریابی مناسب دارد. هدف این مقاله بررسی عوامل تعیین کننده اصلی صادرات غذاهای دریایی ایران به 32 شریک تجاری خود از سال 2001 تا 2018 با استفاده از الگوی جاذبه مرزی تصادفی است. افزون بر این، این مقاله به تحلیل کارایی و پتانسیل صادرات غذاهای دریایی ایران به شرکای تجاری خود پرداخته است. یافته‌ها سازگاری تحلیل مرزی تصادفی را برای صادرات غذاهای دریایی ایران تأیید می‌کند. نتایج حاکی از آن است که تولید ناخالص داخلی ایران و شرکای تجاری آن اثرات مثبت و معناداری داشته است. در مقابل، نرخ ارز دوجانبه، مرز مشترک، مذهب مشترک، مسافت، بحران اقتصادی و تحریم ها اثرات منفی و معنی‌داری بر صادرات غذاهای دریایی ایران داشته است. همچنین نتایج کارایی صادرات نشان داد که ایران دارای پتانسیل صادراتی بالایی به شرکای تجاری خود به ویژه کشورهای همسایه است. آگاهی مردم از فواید غذاهای دریایی در کشورهای همسایه با مصرف کم می تواند باعث افزایش تقاضای آنها و افزایش صادرات ایران به این کشورها شود. افزون بر این، با توجه به پتانسیل بالای صادرات در کشورهای همسایه با تشابهات مذهبی و فرهنگی بالا، پیشنهاد می‌شود ایران روابط تجاری غذایی خود را با کشورهای همسایه مانند عراق، ترکمنستان، لبنان، کویت، امارات متحده عربی و افغانستان تقویت کند.

واژه‌های کلیدی: کارایی صادرات، پتانسیل صادرات، صادرات غذاهای دریایی، الگوی جاذبه مرزی تصادفی.