

**Application of Stochastic Frontier Gravity Model for Determining Seafood Export**Milad Aminizadeh<sup>1</sup>, Hosein Mohammadi<sup>1\*</sup>, Alireza Karbasi<sup>1</sup>, and Hamed Rafiee<sup>2</sup>**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

<sup>1</sup> Department of Agricultural Economics, Faculty of Agriculture, Ferdowsi University of Mashhad, Mashhad, Islamic Republic of Iran.

<sup>2</sup> Department of Agricultural Economics, Faculty of Agriculture, University of Tehran, Tehran, Islamic Republic of Iran.

\* Corresponding author; email: [hoseinmohammadi@um.ac.ir](mailto:hoseinmohammadi@um.ac.ir)

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

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

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

43 Iran emphasized policies to increase non-oil exports in several years. The agricultural sector  
 44 received special attention from policy-makers and planners due to its high capacity and climate  
 45 diversity. Despite the high potential in Iran's fisheries and aquaculture sectors, seafood products  
 46 have a low share in Iran's agricultural exports. Therefore, agricultural policy-makers have recently  
 47 reemphasized the development of fisheries and aquaculture sectors. The volumes of both seafood  
 48 production and exports have increased significantly in recent years. According to Table 1, seafood  
 49 production increased by 216% over the last two decades (from 399,000 tons in 2001 to 1,262,403  
 50 tons in 2018), and seafood exports increased by 3730.4% (from 8.2 million dollars in 2001 to 313.8  
 51 million dollars in 2018). In addition, Iran's seafood export competitiveness has also increased. The  
 52 value of the RCA index increased by 72.9% (from -0.830 in 2001 to -0.225 in 2018).

53  
 54 **Table 1: Production, consumption, and trade statistics of seafood products (2001-2018).**

Year	Production			Employment	Exports	Imports	Trade balance	RCA*
Unit	Captures Tons	Aquaculture Tons	Total 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	575,512	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

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

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

59  
60 Countries are seeking to increase the benefits of exports. However, there are questions about the  
61 export efficiency of the exporting countries and the export potential in front of them in the  
62 importing countries. Empirical studies used the stochastic frontier gravity model, a combination  
63 of the gravity model (Tinbergen, 1962) and the stochastic frontier model (Aigner et al., 1977), to  
64 determine export efficiency, export potential, and export gap. Export efficiency is defined as the  
65 export performance of a country in its importing countries. Export potential is defined as the  
66 maximum value of exports that can be achieved when there are no barriers to trade, which provides  
67 a clear picture for a country about the capacity of international markets (Ahmad Hamidi et al.,  
68 2022).

69 The literature confirms that there is inefficiency in exports of commodities (Kalirajan, 2007;  
70 Ravishankar and Stack, 2014; Atif et al., 2019; Xu et al., 2022; Liu and Zhou, 2023), particularly  
71 agricultural commodities (Atif et al., 2017; Mohammadi et al., 2020; Abdullahi et al., 2022;  
72 Ahmad Hamidi et al., 2022; Nguyen, 2022; Tandra and Suroso, 2023). For instance, Atif et al.  
73 (2017) found that the potential of Pakistan's agricultural exports is more than actual exports to  
74 importing countries, particularly neighboring, European, and Middle Eastern countries.  
75 Mohammadi et al. (2020) showed the technical inefficiency of Iran's pistachio exports. In addition,

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

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

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

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

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

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

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

136

## 137 **2. Materials and methods**

138 **2.1. Data**

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

146 **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

147

148 **2.2. Stochastic frontier gravity model**

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

$$155 \quad \text{Export}_{jt} = f(X_{jt}; \beta) \exp(\varepsilon_{jt} - u_{jt}) \quad (1)$$

156 where, “Export<sub>jt</sub>” is Iran’s seafood exports to trading partner j at year t,  $f(X_{jt}; \beta)$  represents factors  
 157 determining potential exports, and  $\beta$  is a vector of unknown parameters. The error term  $\varepsilon_{jt}$  denotes  
 158 measurement and specification errors, which are assumed to follow a normal distribution with zero  
 159 mean and variance  $\sigma_\varepsilon^2$ . The error term  $u_{jt}$  denotes export volume missing due to man-made trade  
 160 resistance and proxies the magnitude of the inefficiency of Iran exports with country j. The null  
 161 hypothesis ( $\sigma_e^2 = 0$ ) can be tested against the alternate hypothesis ( $\sigma_e^2 > 0$ ) to estimate technical

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

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

$$166 \quad E[\exp(-e_{jt}) | u_{jt} + e_{jt}] = \left[ \frac{1 - \phi[\sigma_\alpha + \gamma(u_{jt} + e_{jt}) / \sigma_\alpha]}{1 - \phi\gamma(u_{jt} + e_{jt}) / \sigma_\alpha} \right] \exp[\gamma(u_{jt} + e_{jt}) + \frac{\sigma_\alpha^2}{2}] \quad (2)$$

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

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

$$172 \quad \ln Export_{jt} = \beta_0 + \beta_1 \ln GDP_i + \beta_2 \ln GDP_p + \beta_3 \ln Dis + \beta_4 \ln BER + \beta_5 Border + \\
 173 \quad \beta_6 Religion + \beta_7 RTA + \beta_8 Region + \beta_9 High + \beta_{10} FC + \beta_{11} Sanc + \varepsilon_{jt} - u_{jt} \quad (3)$$

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

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

### 194 195 **2.3. K-means clustering algorithm**

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

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

$$206 \quad V^n = \frac{V - \min(V)}{\max(V) - \min(V)} \quad (4)$$

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

$$211 \quad \text{pseudo } F = \frac{SSE_B/g-1}{SSE_W/k-g} \quad (5)$$

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

## 215 216 **3. Results and Discussion**

### 217 **3.1. Gravity model results**

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



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

227 The results reveal that the coefficient of importing countries' GDP as a proxy of economic size  
228 is positive and statistically significant at 1 percent level, suggesting that trading partners' income  
229 influenced the flow of seafood exports in a positive direction. This means higher GDP of partners  
230 leads to a higher demand and, thereby, more seafood imports. This result is consistent with  
231 previous findings (Natale et al., 2015; Gupta and Sangita, 2022; Kim et al., 2023), revealing that  
232 seafood exports were positively and significantly influenced by importing countries' GDP. The  
233 Iran's GDP captures the supply capacity; it is positive and statistically significant at 1 percent  
234 level. This finding confirms the results of previous studies (Shepotylo et al., 2016; Kim et al.,  
235 2023), indicating that exporter's GDP positively affected the seafood exports.

236 The coefficient of distance carries the expected negative sign on its coefficient and is statistically  
237 significant at 1 percent level, revealing that geographical distance plays an impeding role in Iran's  
238 seafood exports to its importing countries. This result is similar to the findings in other studies  
239 (Kareem, 2016; Mohammadi et al., 2020; Dong and Truong, 2023), emphasizing the negative  
240 effect of distance on seafood exports. The coefficient of the bilateral exchange rate is negative and  
241 statistically significant at 1 percent level. This finding indicates that the devolution of the Iranian  
242 Rial decreased seafood exports. Bostan et al. (2018) demonstrated a significantly negative  
243 relationship between exchange rate and exports. Similarly, Beak (2013) found that Korean food  
244 exports to Japan were negatively influenced by the exchange rate in the short-term. However, there  
245 are empirical studies that emphasize the positive relationship between the exchange rates and  
246 exports (Atif et al. 2017). One of the most important reasons for the negative effect of exchange  
247 rate on Iran's seafood exports is that the increase in the exchange rate in Iran has been severe and  
248 with high fluctuations; as a result, creating uncertainty about future economic conditions among  
249 supply chain actors such as producers and exporters. Therefore, despite the increase in the  
250 exchange rate, Iran's seafood exports have not increased. For example, Chizari and Sadafi Abkenar  
251 (2020) showed that exchange rate fluctuations had a negative effect on Iran's pistachio supply.  
252 They recommended to maintain stability in the exchange rate. In addition, Tarakçı et al. (2022)  
253 demonstrated that Türkiye's exports were negatively affected by exchange rate volatility in the

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

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

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

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

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

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

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

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**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
$\mu$	2.802	0.551	0.000
$\lambda$	6.313	0.235	0.000
Log likelihood	-1085.138		
Wald	243.01		
	(0.000)		

293 Source: research findings  
 294 Note: Standard errors are robust, clustered by country.

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### 3.2. Export's efficiency and potential

297 The estimation of export's technical efficiency and export's potential for Iran's trading partners  
 298 has been shown in Tables 4 and 5. Considering the change in Iran's government in 2013 and also  
 299 the change in policymakers' view of international relations, it is important to interpret the  
 300 performance results in the period of 2013-2018 and compare it with the previous periods.  
 301 Therefore, for the sake of comparison, the whole period is divided into three sub-periods of 2001–  
 302 2006, 2007–2012, and 2013–2018 to estimate average technical efficiency. Our findings indicate  
 303 that Iran is not doing maximum exports with its trading partners, and there exists a huge potential  
 304 to increase exports with these countries. The results revealed a rapid reorientation of seafood  
 305 exports toward Asian countries. Iran's seafood export efficiency ranges from 0.27 in Turkmenistan  
 306 to 42.45 in UAE, with an average score of 12.97 during 2001-2018. The average efficiency of

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

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

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**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

321 Source: research findings.

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**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

329 Source: research findings.

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### 3.3. Clustering results

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

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

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

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

362  
 363 **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

364 Source: research findings.

365  
 366 **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	Sri Lanka	United Arab Emirates
			Germany	Turkmenistan	
			Italy		
			Luxembourg		
			Oman		
			Pakistan		
			Qatar		
			Spain		
			Switzerland		
			Türkiye		
			United Kingdom		
			United States		
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 Bělin 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

417 Source: research findings

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543 کاربرد الگوی جاذبه مرزی تصادفی برای تعیین صادرات غذاهای دریایی

چکیده

544 برآورد کارایی صادرات صنعت محور نقش حیاتی در شناسایی پتانسیل‌های صادراتی و استراتژی‌های بازاریابی مناسب دارد.  
545 هدف این مقاله بررسی عوامل تعیین کننده اصلی صادرات غذاهای دریایی ایران به 32 شریک تجاری خود از سال 2001 تا  
546 2018 با استفاده از الگوی جاذبه مرزی تصادفی است. افزون بر این، این مقاله به تحلیل کارایی و پتانسیل صادرات غذاهای  
547 دریایی ایران به شرکای تجاری خود پرداخته است. یافته‌ها سازگاری تحلیل مرزی تصادفی را برای صادرات غذاهای دریایی  
548 ایران تأیید می‌کند. نتایج حاکی از آن است که تولید ناخالص داخلی ایران و شرکای تجاری آن اثرات مثبت و معناداری داشته  
549 است. در مقابل، نرخ ارز دوجانبه، مرز مشترک، مذهب مشترک، مسافت، بحران اقتصادی و تحریم‌ها اثرات منفی و  
550 معنی‌داری بر صادرات غذاهای دریایی ایران داشته است. همچنین نتایج کارایی صادرات نشان داد که ایران دارای پتانسیل  
551 صادراتی بالایی به شرکای تجاری خود به ویژه کشورهای همسایه است. آگاهی مردم از فواید غذاهای دریایی در کشورهای  
552 همسایه با مصرف کم می‌تواند باعث افزایش تقاضای آنها و افزایش صادرات ایران به این کشورها شود. افزون بر این، با  
553 توجه به پتانسیل بالای صادرات در کشورهای همسایه با تشابهات مذهبی و فرهنگی بالا، پیشنهاد می‌شود ایران روابط تجاری  
554 غذایی خود را با کشورهای همسایه مانند عراق، ترکمنستان، لبنان، کویت، امارات متحده عربی و افغانستان تقویت کند.

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556  
557 واژه‌های کلیدی: کارایی صادرات، پتانسیل صادرات، صادرات غذاهای دریایی، الگوی جاذبه مرزی تصادفی.