1	ACCEPTED ARTICLE
2	Application of Stochastic Frontier Gravity Model for Determining Seafood Export
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### 5 Abstract

The efficiency estimation of industry-specific exports plays a vital role in identifying export 6 potentials and appropriate marketing strategies. This paper aimed to investigate the main 7 determinants of Iran's seafood exports to its 32 trading partners from 2001 to 2018, using the 8 stochastic frontier gravity model. Moreover, this paper analyzed the efficiency and export 9 potentials of Iran's seafood to its trading partners. The findings confirmed the consistency of 10 stochastic frontier analysis for Iran's seafood exports. The results indicated that the GDP of Iran 11 and its trading partners had significant positive effects. In contrast, the bilateral exchange rate, 12 common border, common religion, distance, economic crisis, and sanctions had significant 13 negative effects on Iran's seafood exports. In addition, the results of export efficiency revealed 14 that Iran has great export potential to its trading partners, particularly neighboring countries. 15 16 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 17 18 potential in neighboring countries with high religious and cultural similarities, it is suggested that 19 Iran should strengthen its food trade relations with neighboring countries such as Iraq, 20 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 30 benefits, seafood consumption shifted from local to international markets. Therefore, seafood 31 production and trade have increased significantly. In addition, trade liberalization and 32 improvements in logistics have contributed to an increase in the total supply and export markets 33 for seafood products (Tveteras et al., 2012; Asche et al., 2015). Seafood products are among the 34 most traded food commodities worldwide and are more important than poultry and pork combined 35 (Asche et al., 2015; Natale et al., 2015; Bellmann et al., 2016). For example, in 2022, the trade 36 value of seafood and poultry was approximately 295.5 billion dollars and 80 billion dollars, 37 respectively (International Trade Center, 2023). 38

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 43 received special attention from policy-makers and planners due to its high capacity and climate 44 diversity. Despite the high potential in Iran's fisheries and aquaculture sectors, seafood products 45 have a low share in Iran's agricultural exports. Therefore, agricultural policy-makers have recently 46 47 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 48 49 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 50 51 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). 52

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

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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

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

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

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.

Our main contribution in this paper is investigating the main determinants of seafood exports in 119 Iran. In the last two decades, much attention has been paid to Iran's fisheries sector, and today 120 policy-makers are looking to identify the factors affecting the increase and decrease of Iran's 121 seafood exports. Considering the different conditions of Iran and other countries, the findings of 122 this study can be of great help to Iranian policy-makers and planners in the field of seafood export. 123 124 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 125 126 performance of previous plans has been evaluated by calculating export efficiency, which can help policy-makers formulate future plans. 127 128 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 129

seafood exports. Second, in this study, for the first time, the clustering method has been used toidentify 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

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### 138 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).

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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

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### 148 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:

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

where, "Export<sub>jt</sub>" 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  $\varepsilon_{jt}$  denotes measurement and specification errors, which are assumed to follow a normal distribution with zero mean and variance  $\sigma_{\varepsilon}^2$ . 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 ( $\sigma_e^2 = 0$ ) can be tested against the alternate hypothesis ( $\sigma_e^2 > 0$ ) to estimate technical efficiencies. The rejection of the null hypothesis confirms the stochastic frontier model isappropriate.

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

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

where,  $\phi$  (.) denotes the density function. The technical efficiency from Eq. (2) for each countrypair 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.

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

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$$LnExport_{jt} = \beta_0 + \beta_1 LnGDP_i + \beta_2 LnGDP_p + \beta_3 LnDis + \beta_4 LnBER + \beta_5 Border + \beta_5 LnDis + \beta_4 LnBER + \beta_5 Border + \beta_5 LnDis + \beta_4 LnBER + \beta_5 Border + \beta_5 LnDis + \beta_4 LnBER + \beta_5 Border + \beta_5 LnDis + \beta_4 LnBER + \beta_5 Border + \beta_5 LnDis + \beta_4 LnBER + \beta_5 Border + \beta_5 LnDis + \beta_5 LnDis + \beta_6 LnBER + \beta_5 Border + \beta_5 LnDis + \beta_6 LnBER + \beta_5 Border + \beta_5 LnDis + \beta_6 LnBER + \beta_5 Border + \beta_5 LnDis + \beta_6 LnBER + \beta_5 Border + \beta_5 LnDis + \beta_6 LnBER + \beta_5 Border + \beta_6 LnBER + \beta_5 Border + \beta_6 LnBER + \beta_6 LnBER + \beta_5 Border + \beta_6 LnBER + \beta_6 LnBER$$

173  $\beta_6 Religion + \beta_7 RTA + \beta_8 Region + \beta_9 High + \beta_{10} FC + \beta_{11} Sanc + \varepsilon_{jt} - u_{jt}$  (3)

where, GDP of Iran and its trading partners has been applied as a renowned proxy for the market 174 size of a country. The market size of Iran and importers denotes the production and export capacity 175 of seafood and demand for Iran's seafood exports, respectively. Dis denotes the geographical 176 177 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 178 indicates a bilateral exchange rate between Iran and its trading partners. Trading partners with 179 common borders are expected to do more trade. Therefore, a dummy variable which is equal to 180 181 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 which is equal to unity for importing countries with similar religion with Iran, and zero otherwise. 183 184 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 same agreement, and zero otherwise. Region denotes the region of Iran's trading partners. A 186 187 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 188 189 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 in193 logarithmic form.

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### 195 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:

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

where, V<sup>n</sup> 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):

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

where SSE<sub>B</sub> denotes the between-cluster sum of squared error, and SSE<sub>w</sub> represents the withincluster 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

### 217 3.1. Gravity model results

Table 3 provides the results of the stochastic frontier gravity model. The results of Mu ( $\mu$ ) and Lambda ( $\lambda$ ) 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

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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 exporters, which has resulted in a decrease in Türkiye's long-term exports. 255 For qualitative dummy variables, the results show that the coefficient of the border dummy is 256 negative and significant at 1 percent level. This result contradicts Natale et al. (2015) and Gupta 257 and Sangita (2022), which confirmed that common borders and similar religions positively 258 affected seafood trade. In addition, the coefficient of the religion dummy is negative and 259 statistically significant at 1 percent level. One of the most important reasons is that the seafood 260 consumption in some importing countries with the same border and religion is very low. For 261 instance, seafood consumption in Afghanistan, a neighboring country with a common border and 262 similar religion, is very low and equal to 0.42 kg per person per year in 2018 (FAO, 2022). For 263 this reason, a large share of Iranian seafood products has been exported to non-border countries 264 265 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. 266 The coefficient of the RTA dummy is positive but statistically insignificant. This means Iran's 267 seafood exports were not significantly influenced by trade agreements between Iran and its trading 268 partners. Similarly, Shepherd and Wilson (2013) and Kareem et al. (2016) found that trade 269 agreements between countries had no significant effect on seafood exports. In contrast, studies by 270 271 Natale et al. (2015) and Dong and Truong (2023) demonstrated the significant positive effect of RTA on seafood exports. 272 273 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 274 275 with the findings of Dong and Truong (2023), who stated that the geographical region of importing countries had a significant effect on seafood exports. 276 277 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) 278 279 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. 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

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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292	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)			

#### 293 Source: research findings

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Note: Standard errors are robust, clustered by country. 295

#### 296 3.2. Export's efficiency and potential

The estimation of export's technical efficiency and export's potential for Iran's trading partners 297 298 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 299 300 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– 301 2006, 2007–2012, and 2013–2018 to estimate average technical efficiency. Our findings indicate 302 that Iran is not doing maximum exports with its trading partners, and there exists a huge potential 303 to increase exports with these countries. The results revealed a rapid reorientation of seafood 304 exports toward Asian countries. Iran's seafood export efficiency ranges from 0.27 in Turkmenistan 305 to 42.45 in UAE, with an average score of 12.97 during 2001-2018. The average efficiency of 306

307 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 308 309 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 310 of products such as pistachios and saffron, but in recent years, more attention has been paid to 311 other capacities of the agricultural sector, like seafood. 312

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

Countries Countries Years Years 2001-2007-2013-2001-2001-2007-2013-2001-2006 2012 2018 2018 2006 2012 2018 2018 Afghanistan 10.81 52.11 43.78 Luxembourg 23.68 42.87 1.20 19.38 35.57 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 2.97 2.79 Belgium 19.23 18.87 13.04 Pakistan 0.96 8.81 4.10 Canada 22.70 1.58 0.51 7.41 Oatar 6.65 0.24 3.31 3.21 Russian China 2.38 11.97 7.59 0.02 0.01 1.02 8.43 1.62 Federation Egypt 1.35 34.23 11.78 22.13 Spain 52.24 13.69 14.47 27.57 France 31.95 7.49 16.27 Sri Lanka 0.25 2.64 2.30 6.44 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 5.66 61.10 38.71 Türkiye 0.82 0.80 1.00 0.88 Iraq 49.37 Italy 5.07 5.54 2.41 4.34 Turkmenistan 0.13 0.20 0.47 0.27 0.10 Japan 3.04 0.30 1.33 UAE 28.55 44.06 54.72 42.45 Korea, 0.27 0.95 0.54 UK 0.02 0.59 7.44 1.72 4.23 Republic of 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

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

- 321 Source: research findings.
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- **Table 5:** The results of potential exports of Iran with its trading partners.
   Countries Potential Exports Countries Actual Exports Actual Potential exports exports exports exports gap gap Afghanistan 2183 4265 6138 -3955 Luxembourg 827 -3438 Azerbaijan 203 21589 -21386 Malaysia 450 2189 -1739 Bahrain 143 8245 -8102 Oman 647 5909 -5261 Belgium 8913 -7751 244 5955 -5711 1163 Pakistan Canada 207 2793 -2586 Qatar 528 16449 -15921 Russian China 5776 76070 -70294 794 78089 -77295 Federation 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 -91451 Thailand 7796 -43990 Hong Kong 14855 106307 51786 66669 172227 -105559 Türkiye 68 7789 -7721 Iraq Italy 1024 23585 -22561 Turkmenistan 143 52101 -51958 -84152 Japan 1134 85285 UAE 11742 27664 -15922 Korea, -107685 637 108322 UK 618 14612 -13994Republic of 8393 32303 -23910 USA 5990 -4808 Kuwait 1181 Lebanon 1539 56640 -55101 Viet Nam 40225 118201 -77976
- **329** Source: research findings.

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## 331 3.3. Clustering results

332 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 333 investigation in order to develop marketing plans and strategies to enter the market and develop 334 exports. The results of cluster analysis as a powerful tool in market segmentation can determine 335 the best destination countries for seafood exports based on Iran's trade objectives. Cluster analyses 336 are performed based on export efficiency, actual exports and export potential. The results indicated 337 that the number of four clusters is suitable for segmenting the trading partners of Iran's seafood 338 exports (Table 6). The four-group solution with a Calinski–Harabasz pseudo-F value of 74.26 is 339

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

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

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.

	Tabl	e 6: The res	sults of Calin	ski–Harał	oasz pseudo	-F.	
Number of clu	usters	3	4	5	6	7	8
pseudo-F		30.21	74.26	65.31	50.98	55.42	38.88
Source: researc	ch findings.						
		Ta	ble 7: Cluste	er solution	•		
Index	unit	Cluster	Cluster 2	Cluster 3 Cluster		Cluster 4	ļ
		1					
		Iraq	Azerbaijan	China	a	Afghanis	stan
		Vietnam	Bahrain	Japar	ı	Hong Ko	ong, China
			Belgium	Kore	a, Republic of	Kuwait	
			Canada	Leba	non	Malaysia	ì
			Egypt	Russi	an Federation	Thailand	l

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			France	Sri Lanka	United Arab Emirates
			Germany	Turkmenistan	
			Italy		
			Luxembourg		
			Oman		
			Pakistan		
			Qatar		
			Spain		
			Switzerland		
			Türkiye		
			United		
			Kingdom		
			United States		
Export	%	60.16	1 57	2.97	39.77
efficiency			<b>+.</b> J7		
Actual exports	1000\$	96055	455	2397	14432
Potential exports	1000\$	159144	12184	70277	36413

Source: research findings.

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**4. Conclusion** 

In this study, the main determinants and efficiency of Iran's seafood exports to its 32 trading 370 371 partners were estimated using the stochastic frontier gravity model during 2001–2018. The 372 findings of the stochastic frontier gravity model confirm that the economic size of Iran (GDP) and 373 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 374 375 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, 376 377 common border, common religion, and RTA could not contribute to Iran's seafood exports in our 378 analyses. Furthermore, Iran's seafood exports are negatively significantly affected by the 379 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 380 381 less than 50% in most trading partners, which had a downward trend in recent years. Further, 382 although Iran's seafood exports had a rapid reorientation towards Asian countries during the 2013-383 2108 period, there are huge export gaps for all importing countries, particularly neighboring countries with common borders and similar religions. 384 According to our analysis and discussion, some policy suggestions are proposed to boost Iran's 385 386 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 387

389	flexible long-term contracts has a great influence on limiting the adverse effects of sanctions (See
390	Bělín and Hanousek, 2021). Additionally, Iran should enhance political mutual with its trading
391	partners to reduce the effects of sanctions. Second, according to the regional effects, Iran should
392	focus on strengthening relations with Asian countries that import seafood. Third, stability in the
393	exchange rate can help supply chain actors improve their decision-making. Therefore, considering
394	the sharp increase in the exchange rate and its high fluctuations during the last decade, policy-
395	makers and decision-makers should formulate policies for the relative stability of the exchange
396	rate.
397	Fourth, since Iran's neighboring countries have high export potential, Iran should strengthen its
398	trade relations with neighboring countries with high religious and cultural similarities, such as Iraq.
399	Making people aware of the health benefits of seafood products can increase their seafood
400	consumption and, thereby, their demand for these products (Krešić et al., 2022; Menozzi et al.,
401	2023). Therefore, Iran should invest to create awareness among people in neighboring countries
402	with low seafood consumption. Fifth, considering the limited marketing budget, it is suggested
403	that the countries of the first cluster, particularly Iraq, which has the most efficiency and high
404	potential, should be prioritized for planning and policy-making. It is also suggested that
405	neighboring countries of the third and fourth clusters, such as Turkmenistan, Lebanon, Kuwait,
406	the United Arab Emirates, and Afghanistan, which have a higher average potential, should be
407	considered.
408	Finally, although this study tried to examine most influencing variables on Iran's seafood exports,
409	future studies can examine the possible effect of other variables such as institutional quality (Xu
410	et al., 2023), and logistic performance (Obeng et al., 2023). In addition, because the export
411	efficiency of different products in the destination markets may be different, it is suggested that in
412	future studies, the export efficiency should be done separately for each product (See Dong and
413	Truong, 2023).
414	

# 415 Appendix

Table	A1: Descriptive statisti	ics of the stu	dy variables	5	
Variable	Unit	Mean	Std. Dev	Min	Max
Seafood exports	Thousand dollars	<mark>5164</mark>	<mark>18411</mark>	0	150651
GDP Partner	<b>Billion dollars</b>	<mark>1430</mark>	<mark>3030</mark>	<mark>2.46</mark>	<mark>20500</mark>
GDP Iran	<b>Billion dollars</b>	<mark>362</mark>	<mark>143</mark>	<b>127</b>	<mark>599</mark>
Distance	Kilometer	<mark>3703</mark>	<mark>255</mark> 0	<mark>540</mark>	<b>10191</b>
Bilateral exchange rate		11364	18075	0.12	<u>13533</u> 2

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

- 417 Source: research findings
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543	کاربرد الگوی جاذبه مرزی تصادفی برای تعیین صادرات غذاهای دریایی
544	<mark>چکيده</mark>
545	بر آورد كار ايي صادر ات صنعت محور نقش حياتي در شناسايي پتانسيل هاي صادر اتي و استر اتژي هاي باز اريابي مناسب دارد.
546	<mark>هدف این مقاله بررسی عوامل تعیین کننده اصلی صادرات غذاهای دریایی ایران به 32 شریک تجاری خود از سال 2001 تا</mark>
547	2018 با استفاده از الگوی جاذبه مرزی تصادفی است. افزون بر این، این مقاله به تحلیل کارایی و پتانسیل صادرات غذاهای
548	دریایی ایران به شرکای تجاری خود پر داخته است. یافتهها سازگاری تحلیل مرزی تصادفی را برای صادرات غذاهای دریایی
549	ایران تأیید میکند. نتایج حاکی از آن است که تولید ناخالص داخلی ایران و شرکای تجاری آن اثرات مثبت و معناداری داشته
550	است. در مقابل، نرخ ارز دوجانبه، مرز مشترک، مذهب مشترک، مسافت، بحران اقتصادی و تحریم ها اثرات منفی و
551	معنیداری بر صادرات غذاهای دریایی ایران داشته است. <mark>همچنین نتایج کارایی صادرات نشان داد که ایران دارای پتانسیل</mark>
552	صادراتی بالایی به شرکای تجاری خود به ویژه کشور های همسایه است. آگاهی مردم از فواید غذاهای دریایی در کشور های
553	همسایه با مصرف کم می تواند باعث افزایش تقاضای آنها و افزایش صادرات ایران به این کشور ها شود. افزون بر این، با
554	توجه به پتانسیل بالای صادرات در کشور های همسایه با تشابهات مذهبی و فر هنگی بالا، پیشنهاد میشود ایر ان روابط تجاری
555	غذایی خود را با کشور های همسایه مانند عراق، ترکمنستان، لبنان، کویت، امارات متحده عربی و افغانستان تقویت کند.
556	

واژ دهاي كليدي: كارايي صادرات، پتانسيل صادرات، صادرات غذاهاي دريايي، الگوي جاذبه مرزي تصادفي.