

Original Research Articles

Strengthening the Resilience of Aquaculture Competitiveness in EU Economies: An empirical analysis

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The European Union (EU27) faces significant challenges in enhancing the global competitiveness of its aquaculture market, such as stagnant production, high production costs, competition from cheaper imports, focus on sustainability, and consumer preferences. Thus, the main goal of this research is to explore how factors related to global competitiveness influenced the growth of the aquaculture sector in the EU27 from 1990 to 2023. The methods of ordinary least squares (OLS), two-stage least squares (2SLS), and robust least squares (RLS) estimations were used to address the endogeneity problem to arrive at the most important results. The effect sizes indicate that the system of innovation and human capital have a greater influence on the development of the aquaculture sector in the highly developed EU14 countries compared to the developing EU13 nations. The exact outcomes of the applied methods, however, demonstrate that the aquaculture market's expansion in EU13 developing nations is more influenced by market size, institutional quality, and economic growth compared to EU14 members. This study recommends that the EU27 region emphasize policy adjustments to balance sustainability with competitiveness, which includes streamlining regulations, improving access to financing, and fostering innovation in aquaculture technologies.

INTRODUCTION

The EU's aquaculture sector faces the challenge of balancing domestic production with the need for imports to meet consumer demand. While the EU exports some high-value products, it remains a net importer of aquaculture. Addressing sustainability and trade challenges will be crucial for the future of the EU's aquaculture sector. The EU region's reported consumption during 2021 was 10.6 million tons of live weight equivalent (LWE), or 24 kg LWE per person.^{1,2} Aquaculture production is a growing sector in the EU, but it still represents a small share of total seafood production. In 2022, EU aquaculture production was estimated at 1.1 million tonnes, worth €4.8 billion. This amounts to slightly more than two-fifths of the overall value of fisheries goods produced in the EU.^{1,3} The EU is also a major importer of fish and seafood products. In 2021, the EU imported 6.2 million tonnes of fish and seafood products, worth €22.6 billion. The main suppliers of fish and seafood products to the EU are Norway, China, and the United States.^{1,4}

The EU is a significant player in the global seafood market but with a complex balance between aquaculture imports and exports. The EU imports a substantial amount of aquaculture products to meet domestic demand from major suppliers including Norway (salmon), China (various species), and other countries in Asia and South America. The import driving factors are (1) growing consumer demand for seafood; (2) Limitations on EU aquaculture production due to environmental regulations and space constraints; (3) Competitive pricing from foreign producers.⁵ On the other hand, the EU exports a range of aquaculture products, particularly high-value species like salmon, trout, and some shellfish, to neighbouring countries within Europe that are major destinations, along with some Asian and North American markets. EU aquaculture often emphasizes high-quality, sustainable production methods, which can command premium prices in export markets.⁶

The European Union (EU27) faces significant challenges in enhancing the global competitiveness of its aquaculture sector. For example: (1) Stagnant Production, despite substantial EU funding, aquaculture production within the bloc has remained relatively static. This contrasts sharply with

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the rapid growth observed in global aquaculture production⁷; (2) High Production Costs, EU27 aquaculture producers often grapple with higher production costs compared to their global competitors. Factors contributing to this include stringent environmental regulations, higher labor costs, and access to more expensive feed⁸; (3) Competition from Cheaper Imports, the EU market is heavily reliant on seafood imports, particularly from countries with lower production costs and less stringent regulations. This intense competition puts significant pressure on European producers^{2,9}; (4) Focus on Sustainability, while a commendable goal, the EU's strong emphasis on sustainability can sometimes create additional hurdles for producers. Meeting stringent environmental and social standards can increase production costs and complexity; (5) Consumer Preferences, European consumers often favor high-value, high-quality seafood, driving the market towards less intensive and more expensive production methods. This can further limit the competitiveness of EU producers^{10,11}; (6) Market Access and Trade Barriers, international trade disputes and tariffs can hinder market access for EU aquaculture products in key export markets. Moreover, Sanitary and phytosanitary (SPS) measures and technical trade barriers can create obstacles for EU exporters; (7) Consumer Demand for Sustainability, growing consumer awareness of environmental issues like overfishing, pollution, and habitat destruction is driving demand for sustainably produced seafood. Moreover, the EU has stringent environmental regulations, which can increase production costs and limit expansion opportunities.

Hernandez-Arzaba et al.⁷ examined how market competitiveness works in Mexico to demonstrate how aquaculture regions are created as a result of several factors that provide them a competitive advantage in the global marketplace, which is essential to grow the aquaculture industry. According to research by Marsal and colleagues⁸ on the opportunities and challenges related to the growth of aquaculture on Brunei Island, human resources and competitiveness are the two key elements for the industry's evolution. Many other studies have demonstrated the importance of market competitiveness in the development of aquaculture, such as those conducted by Rowan,⁹ and Little and Mackenzie.¹ The scales required for *Salmo Salar* stocking to achieve the marketplace at new aquaculture areas with high temperatures in Canada were probably computed by Dempsey et al.,¹² who concluded that the stocking strategy typically reduces risks and speeds up the period it requires for harvested fish to attain distribution channel in an eco-friendly method

Similarly, previous research evaluated the size growth of the aquaculture business in China both historically and nowadays, indicating that the development of national as well as global aquaculture industries is the primary cause of global competitiveness.¹³ Similarly, papers by Laine et al.,¹⁴ Ababouch et al.,¹⁵ and Péter et al.¹⁶ showed a similar relationship between market size and aquaculture market development. The most significant factors for the growth and competitiveness of the aquaculture sector are effectiveness and technical efficiency as stated in previous Nor-

wegian studies.¹⁷⁻¹⁹ These papers demonstrate how developments have impacted the aquaculture marketplace over the years besides the ecosystem of innovation that promotes these developments. According to studies on novel approaches to management for the aquaculture industry's sustainability performed in Bangladesh and India, stating that the creative ecosystem is critical for the aquaculture market, changing the climate, and profitable growth.^{20,21}

According to Tiutiunnyk and Iermakova²² and Damonte et al.,²³ differences in materials, climate, management, technologies, markets, social circumstances, and aquaculture policies and governing organizations may be the source of growth inequities. According to Naylor et al.,²⁴ government policies have significant impacts on the types of groups, innovation, strategies, and infrastructures that are used in different areas, along with the geographical distribution of aquaculture development. The sustainability condition of ponds aquaculture in Tambakbulusan village was evaluated by Agry et al.,²⁵ which concentrated on the enabling environment dimensions and recommended that stakeholders, in specific, take advantage of possessing access to comprehensive data. All shareholders need to be involved in the processes of assuring aquaculture sustainable development and outgrowth, particularly the creation of an enabling environment, according to Jolly et al.,²⁶ who most likely studied the dynamics of aquatic governance.

In Indonesia, the management of aquaculture resources and the path toward resource sustainable development management were also examined by Yuniarti et al.²⁷ They concluded that managing cage aquaculture and its impacts on the environment and livelihoods depend extensively on the establishment of an enabling environment. The manufacturing power and enabling environment of developing nations are challenged to ensure compliance with the increasingly high standards and regulations for customer protection, and cultural and sustainable development, according to Haj²⁸ and Ababouch et al.,¹⁵ who additionally investigated the current situation and issues facing aquaculture supply chains, as well as the primary forces, implications, and future potential of the aquaculture market. According to research done in African countries by Omoregie²⁹ which exposed the macro-economic elements that maintain aquaculture species, strong public institutions are important for obtaining sustainable development.

According to Neis et al.,³⁰ population losses in marine fisheries aquaculture may cause some negative effects, including human casualties, damaged infrastructure, and a significant decline in fish populations or well-being. However, Williams³¹ clarified the significance of following environmental and human health regulations, highlighting the need to protect human resources in all industry operations, concentrating on the avoidance of accidents and the reduction of dangerous substances, diseases, and other health risks. Similarly, research on the environmental and human issues associated with growing prawns in Asia, claims that physical, chemical, biological, practical, and psycho-social issues remained significant.³²⁻³⁴ Accordingly, Kim et al.³⁵ support these conclusions in their research on marine incidents affecting South Korean fishing industry ships.

The relationship among aquaculture productivity, emissions of greenhouse gases, and economic conditions across Africa was examined.^{36,37} According to their results, there is a complex relationship between greenhouse gas emissions and GDP, with aquaculture output consistently having a favorable impact on short- and long-term growth in the economy. In their investigation of the mutually advantageous connection between sustainable fish farming and economic growth in India's coastal areas, Swarna et al.³⁸ and Ignatius³⁹ identified the importance of enhanced leadership, aquaculture procedures, seafood sectors, policy structures, and capability developing in expanding the countries objectives for a developing blue growth. According to earlier researchers who conducted extensive research following the advancement of the Chinese aquaculture market from 1985 to 2020, there was a period of explosive development followed by consistent but slow expansion patterns that are probable to endure for an extended time.^{40,41}

Similarly, Yu and Mu⁴² focused on oyster aquaculture and investigated the sustainable growth trend in aquaculture. Their innovative strategy encompasses the green economy's fundamentals with the distinctive features of aquaculture, creating a system of assessment that is based on "yield & area + green economy + green progress." Research performed by Whyte et al.⁴³ and Silvestri et al.,⁴⁴ offer extensive insight into the aquaculture, blue growth, and related regulations of landscapes on a global scale, including both pre-and post-pandemic periods. As an essential sector that stimulates auxiliary employment possibilities in the process, propagation, and export industries, these evaluations emphasize the critical function that aquatic companies perform in enhancing economic sustainable development in coastal cities and countries all over globally.

Several studies are being carried out on the subject of global competitiveness, the aquaculture marketplace, progress economics, and its reasons; nevertheless, there is discussion over the elements that have the most impact on the aquaculture industry's green development and worldwide competitiveness. The findings of several studies conducted by different companies and industries using a variety of approaches indicate that the elements that formerly significantly impacted a firm's or industry's global competitiveness are now considered irrelevant for other companies and industries. This may be because of the distinct features of the data that was utilized, or because of the specific influence or character of a company or sector. Second, previous research examined the determinants influencing global competitiveness using methods including Pooled Ordinary least squares, random impact fixed effect theories, the Tobin model, etc. Since these methods might not completely account for the bias of the fixed-effect estimation, they might yield less trustworthy results. Previous studies did not take into account the endogeneity issue related to the global competitiveness of the aquaculture sector.

The current research objective is to examine the aquaculture markets' worldwide competitive aspects from 1990 to 2023 from an economic perspective. Additionally, to compare the aquaculture markets' global competitiveness

footprints in EU13 developing nations as well as EU14 developed nations. To address the gap, this research addresses the following queries: What changes have been made to the EU27 aquaculture markets' global competitiveness factors between 1990 and 2023? Additionally, whether aspects of global competitiveness in EU14 members versus EU13 members have a greater impact on the aquaculture market's expansion? In this research, studying global competitiveness factors and the aquaculture market in the EU can offer several novel contributions: (1) Focus on circular economy principles within aquaculture, minimizing waste and maximizing resource efficiency, (2) Investigate social equity within the aquaculture sector, including fair labor practices, community engagement, and the impact on local livelihoods, (3) Explore the potential of emerging technologies like AI, big data analytics, and biotechnology to enhance aquaculture productivity and efficiency, (4) Conduct an in-depth analysis of global market trends, competitive landscapes, and consumer preferences, and (5) Develop evidence-based policy recommendations to boost the green outgrowth of the EU aquaculture sector.

There are three stages to the scientific significance of this study. Employing a two-stage least squares (2SLS) model, to look at how global competitiveness determinants impact the outgrowth of the aquaculture market in the EU27. Second, the current research uses the 2SLS approach to analyze the effects on the aquaculture market's overall global competitiveness in EU13 members versus the EU14 members markets. Finally, applying the 2SLS model, this research evaluates how global competition determinants affect the aquaculture market in the EU13 members market versus the EU14 members market. The aforementioned three phases will make it abundantly evident how closely global competitiveness factors and aquaculture market expansion are related in the European Union zone (EU27), EU14 members, and EU13 members. The structure of the remaining sections of the document is as follows: Section two reviews the earlier research on the influence of different determinants and variables of aquaculture in shaping global competitiveness. Section three outlines the two-stage least squares (2SLS) method process. Section four shows and regresses the outcomes. Section five summarizes the key findings and offers relevant policy recommendations.

The present study depends on multi-year data to explore the correlation between aquaculture output and global competitiveness characteristics across different stages of economic growth in EU nations. To achieve this research goal, the present research expanded the period starting from 1990 up to 2023. To deal with the endogeneity challenges, the current study additionally applies the statistical techniques of Robust Least Square (RLS) and Two-Stage Least Squares (2SLS). As a result, the influence on global competitiveness factors is more robust and the estimations more consistent. Because of the European Union's ambitious regulations and goals for the aquaculture sector, this study examines the global competitiveness of the aquaculture industries across the EU27 member states. The study's findings will expand on what was previously understood re-

garding aquaculture, blue development, and the economics of the marine ecosystem overall.

DATABASE AND METHODOLOGY

THEORETICAL BACKGROUND

The method of Porter Diamond is a framework used to analyze the competitive advantage of nations or industries. When applied to aquaculture, it helps understand the factors that contribute to the success or failure of a country's aquaculture industry. The four key determinants of the model are: (1) Factor Conditions: these are the inputs necessary for production, such as natural resources, human resources, infrastructure, and knowledge resources. (2) The size and character of the domestic aquaculture product market, as well as demand conditions. Innovation and quality enhancement might be stimulated by a sizable and demanding home market. (3) Related and Supporting Industries: The existence of related and supporting industries, such as producers of feed, suppliers of equipment, and processing facilities, may promote innovation and offer affordable inputs. (4) The nature of competition in the domestic market, as well as company strategy (structure and rivalry). Efficiency and creativity can be stimulated by fierce competition. (5) Two additional factors influence the diamond: (A) Government, policies can significantly impact the aquaculture industry, such as regulations, subsidies, and trade policies. (B) Chance, unforeseen events, such as natural disasters or technological breakthroughs, can also impact the industry.

Global competitiveness theory provides a valuable framework for understanding the factors that contribute to the success of a nation's industries. The Norwegian salmon industry serves as a successful case study, demonstrating how a combination of favorable factors can lead to global dominance. By analyzing these factors, other countries can identify areas for improvement in their aquaculture sectors. This example illustrates how Porter's Diamond Model can be applied to analyze the global competitiveness of aquaculture in a specific country. By understanding the interplay of these factors, countries can develop strategies to enhance their competitiveness in the global seafood market. According to the diagram below, aquaculture growth should follow this pattern to increase global competitiveness. The three major contributions to this novel framework are the human resources measure, the focus on creativity, and the significance of governance. According to Porter's diamond model, this revised model has certain characteristics with the models developed by Dwyer and Kim⁴⁵ and Crouch and Ritchie.⁴⁶ First, it significantly affects the competitiveness of the aquaculture market in both EU14 and EU13 developing nations. One of the primary factors in the sustainable expansion of aquaculture must be considered as governance. Although all of the cluster's competitiveness components are interlinked, it is important to identify and demonstrate the type and scope of connections that connect. The following model was developed as a result of a recent study by Wang et al.^{2,3};

$$AC_{it} = f(ENB_{it}, INN_{it}, MRK_{it}, GDP_{it}, HCI_{it})$$

ECONOMETRIC METHODOLOGY

Using Porter's diamond approach as a structure, the study examines how global competition affected the aquaculture sector in the EU27 at the duration between 1990 towards 2023. The current paper, which applies the two-stage least squares approach to evaluate how global competition affects the sector's sustainability throughout this time, is supported by data from the EUROSTAT database and the World Development Indicators. Further, the research differentiates the EU region's developed and developing nations for comparable analysis, establishing three distinct sections: the EU27, EU14, and EU13 as developed and developing countries, respectively. Employing a dynamic panel regression methodology along with data from Porter's diamond method, the study examines the complex link between aquaculture market sustainability and global competitiveness control factors between 1990 and 2023. Between 1990, when only a small number of European nations started aquaculture sustainability programs, and 2023, when all EU nations are involved in similar projects, bound together toward a rigid conceptual work intended to promote sustainability and economic growth, this paper examines a considerable progression. As a consequence, the study model illustrates the various elements impacting the outgrowth of the aquaculture market and environment in the European countries during the designated frame time.

$$Y_{it} = \beta_0 + \beta_1 X_{it} + \varepsilon_{it} \quad (1)$$

The developed method is therefore extended and revised in the current study as follows, per Wang et al.⁴⁷: if ε is the error term, then X is the vector with potential global competitiveness driver and Y is the aquaculture market; instead, the symbols i and t refer to the relevant nations and periods.

$$AQ_{it} = \beta_0 + \beta_1 ENB_{it} + \beta_2 INN_{it} + \beta_3 MRK_{it} + \beta_4 GDP_{it} + \beta_5 HCI_{it} + \varepsilon_{it} \quad (2)$$

In the equation, "aquaculture" (AQ) points to the production of aquatic animals, including fish, mollusks, crustaceans, and aquatic organisms. In aquaculture, produce specially to the outputs of aquaculture activities (small, medium, and larger size farms) that are eventually collected according to consumer demand. The following are independent factors: The Enabling Environment (ENB), which measures the effectiveness of the government, is taken based on the recognized European database website (Europa, 2023). The new research includes precise per capita considerations of each statistic using data on economies across the European Union from 1990 to 2023. The factor (INN), which refers to the innovation environment as well as intellectual property protection actions, was incorporated in the dataset of the European Union website. According to MRK, the market size is determined by PPP's current international (Purchasing Power Parity in currently international the US dollar) GDP. A measure of an ecosystem's average lifespan for education and learning is the Human Capital Development Indicator (HCI). According to Eurostat (2023), the European Commission's database is used to source GDP,

Table 1. Key variables of the study.

Variables	Abbreviated	Source of Data	Measurement Units
Aquaculture Production	AQ	WDI	Metric tons
Economic Growth	GDP	Eurostat	Gross domestic product (constant USD)
Innovation Ecosystem	INN	Eurostat	Trademark applications, direct nonresident
Enabling Environment	ENB	WDI	Percentage of confidence in governance
Market Size	MRK	WDI	GDP per purchasing power parity (current international USD)
Human Capital	HCI	Eurostat	Average years of education (in years)

or gross domestic product, which is computed in constant US dollars.

The research gathered its yearly data based on three trustworthy sources: Europa, the website for European statistics, the Eurostat database, and the World Bank's Index of World Development Indicators (WDI). Because of its nature, this study needed to aggregate data from a wide variety of nations to achieve its goals. A complete overview of the data, indicating its modification, resources, and methods of evaluation, is given in Table 1, which is essential to our investigation. Particularly, as Table 1 explains, all measurements used in this research have been exponentially modified. The error term (represented by ε), an intercept (expressed by β_0), and the co-efficient matrices (expressed by β_1 , β_2 , β_3 , β_4 , and β_5) are important variables in the model. The subscripts i as well as t , respectively, denote time and country.

The approach used in this research aims to calculate a longitudinal model of the aquaculture market's growth while accounting for as many global competitiveness-influencing factors as possible. Referring to Wen et al.,⁴⁸ Lupu and Tiganasu,⁴⁹ Fomba (2023), and Khan et al.,⁵⁰ the econometric analysis of the aquaculture market's worldwide competitiveness variables at different levels of economic development is as follows:

$$Y_{it} = \beta_0 + \beta_1 Y_{it-1} + \beta_2 X_{it} + \mu_{it} + \varepsilon_{it} \quad (3)$$

Where, $i = 1, \dots, N$, $t = 1, \dots, T$.

Regression analysis is performed on (Y_{it}) using the exogenous independent factors (X_{it}) and the lagged dependent factor. The error term is composed of the individual-specific effects (μ_{it}) as well as the white noise error term (ε_{it}). This study uses an econometric model to analyze the link between the aquaculture market and the factors that influence global competitiveness. To examine the data from chosen nations and assess the underlying hypothesis, the study specifically uses a panel data regression model.

H: Global competitive factors boost significantly the aquaculture market development and growth

These models are especially well-suited for this kind of analysis because they take into consideration the longitudinal and time-series distinctions of the data, which allows for the assessment of possible effects that are particular over periods and countries as well as preserving variations throughout countries. This demonstrates why it is so important to incorporate outcomes from relative research with the cross-sectional panel data estimation to theoretically and practically explore the impact of global

competitiveness elements on the growth of the aquaculture marketplace. In this section, "aquaculture production" serves as an explanatory variable for human activities, while "growth in the aquaculture market" represents the blue economy indicator for an EU member i at specific period t . To create a theoretical standard for analysis, this research applies the Ordinary Least Squares (OLS) method with fixed effects for a particular EU member and a specific frame time. The relationship among the aquaculture market and factors influencing global competitiveness should be impacted by specific period-related impacts and unidentified differences across the EU members.

By considering various time- and country-specific effects, the authors could mitigate potential biases and offer more punctual estimates of the influence of global competitiveness variables on the expansion of the aquaculture sector. To further address the possible variability problem and determine a causal relationship among global competitiveness variables and the development of the aquaculture economy, this study also employs robustly predicted endogenous issues using the Two-Stage Least Squares (2SLS) estimation and Robust Least Square (RLS) methods. The 2SLS and RLS models are common and successful statistical and economically computable methods that assist in mitigating endogeneity difficulties. They make use of instrumental factors described by Greene⁵¹ and Kennedy,⁵² that are employed in previous related work, including Cooray⁵³ as well as Khan et al.⁵⁴ To mitigate endogeneity issues in the model, the 2SLS approach uses instrumental variables that are linked to the macroeconomic aquaculture market but do not have a direct impact on sustainable blue farming practices.

This study initially evaluates the global competitiveness factors on the instrumented variables to get the predicted amounts of the global competitiveness components. Using these predicted values from the second regression stage, this article regresses the correlation among the aquaculture market's growth and the examined global competitiveness parameters. The authors employed the economic growth level, they had obtained from the EUROSTAT dataset, as a baseline to assess the state of economic outgrowth.⁵⁵ Because it measures the likelihood of 2 structure levels of underdeveloped (developing) and developed members, this segregation seems to be essential for determining a nation's level of economic structure outgrowth.⁵⁶ The standard deviations are organized at the global level, and the model created for the current paper includes the period

Table 2. Outcomes of key variables statistical test

Variable	Obs.	Mean	Standard Deviation	Minimum	Maximum
ENB	837	1.857	0.699	1.421	1.843
MRK	837	4.409	0.229	3.673	5.321
AQ	837	4.127	0.858	1.643	5.638
GDP	837	4.378	0.395	3.129	5.253
HC	837	1.888	0.190	1.832	1.982
INN	837	3.678	0.331	2.456	4.654

Source: Author estimations

and county-fixed effects. As a result, the 2SLS and RLS approaches are used in the current research to enhance the integrity of the evaluation used here by addressing endogeneity issues. It helps ensure that results on the impact of global competitiveness variables on aquaculture market expansion are more probable to reflect causal connections as compared to deceptive associations.

RESULTS AND DISCUSSION

BASELINE REGRESSION RESULTS

Because every variable in [Table 2](#) has a natural logarithm, the logarithmic transformation is required to lower the variation among the variables and produce reliable estimations. Along with descriptive data, [Table 2](#) shows general statistics that show the variables' normal distributions. The correlation test findings are displayed in [Table 3](#). The results indicate that there is no substantial relationship between the explanatory factors, demonstrating the absence of a multicollinearity problem. Therefore, there is a small probability of multicollinearity developing during parameter evaluation within an identical approach. Also, [Table 3](#) shows a positive and computable significant relationship (0.567) among aquaculture results and global competitiveness elements, with positive coefficients indicating that in EU countries, aquaculture market expansion is associated with higher human resources investment; all of the human resources indices show positive correlations, but the aquaculture market growth is significantly greater.

A variety of common tests are used in the initial stage of parameter estimation to ascertain the variables' time series characteristics, as shown in [Table 4](#). The study starts by examining if cross-sectional dependence (CD), a component that may affect the precision of coefficient predictions, is present in the panel. According to Phillips and Sul,⁵⁷ neglecting CD might seriously reduce the advantages gained from panel examination of data, especially when it results from hidden common factors. Therefore, the CD must be addressed to maintain the integrity of coefficient estimations. The panel's CD is assessed using the Pesaran⁵⁸ CD test, and [Table 4](#) shows clear cross-country dependencies across a range of quantitative metrics. Using unit root and cointegration tests in conjunction with a cross-sectional panel approach that incorporates reliable procedures

to counteract the influences of CD, the study attempts to mitigate potential size distortions.

[Table 5](#) shows the application of cross-sectional panel non-stationarity analysis, to ensure an unbiased assessment of the integration characteristics of the used factors. The Breitung⁵⁹ test, along with the Breitung and Das⁶⁰ test, assumes a uniform autoregressive coefficient for each panel unit, whereas the IPS (2003) test allows for varying autoregressive parameters across the panel. As indicated in [Table 5](#), for a large cross-sectional panel database as same as the one applied in the current research, the Breitung⁵⁹ test demonstrates higher power compared to similar unit root tests. Additionally, a modified approach of the Breitung and Das⁶⁰ test, that built on cross-sectional dependence (CD), is employed to examine its impact on each unit root test. The results indicate that the variables were non-stationary at the mentioned scales but became stationary after first-differencing, as confirmed by the applied unit-root analysis in [Table five](#), suggesting an estimator that applied has considered variables of order I(1).

This study employs two-panel cointegration tests to identify long-term correlations among the factors: the Pedroni panel co-integration analysis and the Bootstrapped panel co-integration analysis introduced by Westerluns⁶¹ (see [Table 6](#)). Like the two-step Engle and Granger procedure, Pedroni⁶² offers an overall approach for cross-sectional panel co-integration analysis. It's interesting to note that Pedroni's method addresses heterogeneity by eliminating short-term characteristics and individual-specific deterministic tendencies in the first analytical stage. Pedroni generates seven distinct test statistics using estimated residuals. A common approach is assumed by "pooled" and "within-dimension" testing, whereas an individual procedure is assumed by "grouped" and "between-dimension" tests. The presumption of no cointegration is removed by Westerluns⁶¹ by including four additional tests, which favor structural dynamics over residual ones. The effectiveness of this approach is increased by lessening the restrictions that residual-based testing places on common components. According to Kremers et al.,⁶³ the incapability to highlight share determinant limits may significantly reduce the efficacy of residual-based co-integration studies, requiring the inclusion of structural dynamics. To address the distortion brought on by cross-sectional dependence, the study employs the bootstrap technique created by Westerluns⁶¹ to obtain strong thresholds. The outputs of the Pedroni analysis and Westerluns analysis for co-inte-

Table 3. Results of Correlation test.

Vari.	AQ	GDP	HC	INN	IQ	MRK
AQ	1.000					
GDP	0.132	1.000				
HC	0.455	0.482	1.000			
INN	0.338	0.818	0.742	1.000		
IQ	0.209	0.644	0.615	0.138	1.000	
MRK	0.396	0.649	0.847	0.491	0.647	1.000

Source: Alsaleh et al.⁵**Table 4. Results of Cross-Sectional Dependency**

Variables	GDP	AQ	INN	HC	MRK	ENB
Pesaran ⁵⁸	(83.55)***	(50.95)***	(43.28)***	(19.71)***	(67.99)***	(31.30)***

Note: *** denotes significance on a scale of 1%.

Source: Author estimations

Table 5. Outcomes of Unit-Root Analysis

Factors	Difference		First-Difference	
	LLC	IPS	LLC	IPS
INN	7.818***	11.923***	16.282***	26.894***
ENB	10.912***	13.684***	18.011***	25.581***
AQ	3.884***	10.385***	15.406***	28.510***
MRK	6.894***	10.492***	14.303***	20.001***
GDP	21.531***	15.596***	60.124***	61.758***
HC	11.914***	14.911***	23.571***	30.112***

Note: *** denotes significance on a scale of 1%.

Table 6. Panel Co-integration Analysis

Test	Without-Trend	With-Trend
A) Pedroni Cointegration Test with Residuals:		
Alternative hypothesis: Basic Autoregressive Coefficients (within dimension):		
Panel v-statistics	1.064*** (0.856)	1.983*** (0.976)
Panel rho-statistics	3.250 (0.999)	2.446 (0.992)
Panel PP-statistics	7.563*** (0.000)	7.666*** (0.000)
Panel ADF-statistics	5.176*** (0.206)	5.120*** (0.039)
Alternative hypothesis: Basic Autoregressive Coefficients (between dimensions)		
Group rho-statistics	4.255	0.997
Group PP-statistics	9.945***	(0.000)
Group ADF-statistics	3.344***	(0.010)

Note: Significant for the 1%, 5%, & 10% levels are denoted by ***, **, and *, respectively.

P-values are given in parenthesis.

Source: Alsaleh and Abdul-Rahim⁶

gration provide strong support for bootstrapped co-integration, as seen in [Table 6](#).

A variance inflation factor, or VIF, test is necessary to examine multicollinearity or any interaction among the

Table 7. Results of the Regression test

Variable	Coefficient	Prob.	VIF
GDP	1.673***	0.000	2.32
HC	2.259***	0.000	1.12
INN	0.852***	0.000	1.51
ENB	1.641***	0.000	2.12
MRK	1.591***	0.000	1.03
C	1.215***	0.000	

Note: Significant for the 1%, 5%, & 10% levels are denoted by ***, **, and *, respectively.

variables that are independent in [Table 7](#). The goal of this preventative step is to avoid any deceptive regression results that can bias findings. In this study, a linear regression analysis was performed before the VIF (variance inflation factor) evaluation; the findings are shown in [Table 7](#). Interestingly, the table presents that multicollinearity is not present. A commonly used guideline is that if the VIF is less than 5, multicollinearity is not present. As a result, [Table 7](#) shows that INN, IQ, GDP, HC, and MRK do not correlate.

CHECKING THE ROBUSTNESS OF THE RESULTS

The estimators 2SLS and RSL are used in the current research to examine the robustness of the results from the second level of analysis while keeping the same distinct control parameters. The study's first part focuses on how the variables are correlated. An OLS regression evaluation is then conducted, adding the aquaculture market to the study. This methodical technique guarantees a thorough comprehension of the data and its consequences in the topic of research. The worldwide competitive component is assumed to be exogenous by the OLS regression technique, which estimates the results below. However, it is conceivable that two of the explaining factors—for example, ecosystem innovation development and human capital—are determined together, as several authors have pointed out. It might be the cause of endogeneity. To address this issue, the two estimators 2SLS and RLS are utilized. Tables eight, nine, and ten refer to the study period from 1990 up to 2023. Additionally, in [Tables 9](#) and [10](#), the authors incorporate the economic development structure, as well as developed and developing countries, in their respective 2SLS and RLS regression analyses.

The baseline regression results in Model 1 using the OLS, 2SLS, and RLS estimations in the EU27 region are shown in [Table 8](#). The 2SLS and RLS results largely corroborate the OLS regression's conclusions. However, the EU27 Region frequently has greater coefficient dimensions in the estimator-based 2SLS or RLS regressions. The human resources input is the most dependable of the three specifications concerning statistical importance and coefficient magnitude. The expansion of the aquaculture industry is positively affected by a one percent increase in human resources, resulting in a 1.69% growth according to the RLS model, 1.98% growth for the 2SLS method, and 1.61% growth for the OLS method. This result is aligned with the recent papers by Williams et al.,³¹ Saha et al.,³⁴ and Neis

et al.,³⁰ who contend that encouraging information sharing between experts and the next generation is essential to the sector's long-term survival.

Furthermore, the favorable impact of the innovation environment is shown, which is significant for the description of the OLS estimator as well as the 2SLS and RLS. An increase in the growth of the system for Ordinary Least Squares, Two-Stage Least Squares, and Robust Least Squares of 0.30%, 1.06%, and 1.17%, respectively, has a positive effect on the expansion of the aquaculture market in the EU27 Region. Ordinary Least Squares approach and Two-Stage Least Squares approach requirements give compelling computable favorable facts in favor of the Porter Diamond conceptual framework. This outcome is in line with the core idea of the DPSIR hypothesis (Driving, Response, Influence, State, Pressure), which postulates that the technological ecosystem for aquaculture in the EU is a complex network of players and initiatives working to advance competitive and economically viable aquaculture practices.¹⁸⁻²⁰ For instance, the EU's primary financing initiative for aquaculture research and innovation is called Horizon Europe.

Encouraging surroundings significantly contributes to the aquaculture market's expansion. This means that for the EU27 Region, a 1% rise in the enabling environment raises aquaculture market development by 0.622, 1.698, and 1.678%, respectively, according to the Ordinary Least Squares, Two-Stage Least Squares, and Robust Least Squares estimation methods. The group of nations that produce aquatic production is supported by this in terms of the global competitiveness hypothesis. The output of Damonte et al.,²³ Tiutiunnyk and Iermakova,²² and Naylor et al.²⁴ are aligned with the output of this research, which demonstrates that the EU has created a framework for the growth of aquaculture in a sustainable manner through the implementation of laws such as the Common Fisheries Policy and the Marine Strategy Framework Directive.

Furthermore, a favorable impact of market size is demonstrated, which is significant for both the OLS estimate specifications and 2SLS and RLS. In the EU27 Region, a rise in the market value as a percentage provides a favorable effect on aquaculture industry growth of 0.80% for OLS, 0.62% for 2SLS, and 0.59% for RLS. The worldwide competitiveness hypothesis is well supported by statistically significant data from both the RLS estimator specification as well as the 2SLS specification. Hernandez-Arzaba et al.,⁷ Little and Mackenzie,¹ and Marsal et al.⁸ claim that the market is developing as a result of rising consumer knowl-

Table 8. Cross-Sectional Estimation Results for the Europe Union Region

Factors	Ordinary Least Squares		Two-Stage Least Squares		Robust Least Squares	
	Coefficients	Standard Error	Coefficients	Standard Error	Coefficients	Standard Error
ENB	0.622*	0.034	1.698***	0.035	1.678***	0.030
MRK	0.808***	0.026	0.621**	0.025	0.595***	0.023
GDP	0.268***	0.099	0.118	0.099	0.093	0.087
HC	1.611***	0.027	1.987***	0.026	1.699***	0.024
INN	0.304***	0.053	1.061***	0.086	1.177***	0.046
Constant	3.680	0.448	3.307***	0.462	4.014***	0.871
R^2	0.214		0.347		0.304	
Adjusted- R^2	0.209		0.343		0.490	

Note: Significant for the 1%, 5%, & 10% levels are denoted by ***, **, and *, respectively.

edge of sustainable food sources and the global need for seafood. This result is in line with the main idea of marine developmental governance as well as the findings of Alsaleh et al.⁶⁴

Table 9 shows the results of baseline estimation employing the three techniques OLS, 2SLS, as well as RLS. It is interesting to note that the Ordinary Least Squares estimation results are boosted by the Two-Stage Least Squares and Robust Least Squares techniques. The majority of the coefficient magnitudes for the 2SLS as well as RLS regressions employing these estimators are significantly larger for the advanced EU14 nations, albeit this is still significant (Model 2). The improvement of human capital stands out as the most resilient of the three criteria in terms of both coefficient magnitude and statistical significance. The OLS estimator indicates that a 1.29% boost to human resources has a positive impact on the aquaculture market's development. In the EU14 advanced economies, this impact is somewhat magnified in the RLS estimator (1.44%) and the 2SLS estimate (1.70%). This output is aligned with earlier papers by Aruna and Kumar,³³ Sharma et al.,³² and Kim et al.,³⁵ which discovered that funding university courses and vocational education and training in aquaculture could help in the development of the competencies required by employees.

Furthermore, there is a beneficial and statistically significant correlation between the revolutionary ecosystem and the aquaculture market's growth. For the EU14 advanced countries, the coefficient of this association, however, varies among parameters. For example, according to the OLS, 2SLS, as well as RLS estimators, the aquaculture market grows by 0.46%, 0.13%, and 0.94%, respectively, as the innovation ecosystem's proportion increases. According to Bunting et al.,²⁰ Mitra et al.,²¹ and Afewerki et al.,¹⁸ this outcome supports their results and emphasizes the importance of developing a novel ecosystem to increase aquaculture output while reducing environmental effects. The European Maritime and Fisheries Fund (EMFF), for instance, offers funding for innovative initiatives as well as the development of sustainable aquaculture.

The EU14 advanced nations' aquaculture market development is also greatly influenced by the enabling envi-

ronment. For the Ordinary Least Squares, Two-Stage Least Squares, and Robust Least Squares, each additional percentage in the enabling environment improves aquaculture market expansion by 0.84%, 1.22%, and 1.90%, respectively. This finding aligned with the international competitiveness hypothesis for nations that produce aquatic products, which is consistent with the previous research for example; Jolly et al.,²⁶ Agry et al.,²⁵ and Yuniarti et al.,²⁷ which state that the demand for responsibly farmed products is being driven by increasing awareness among consumers of the significance of sustainable seafood usage.

In the industrialized nations of the EU14, market size also significantly improves all estimating parameters. A specific increase in market size by one percent results in a growth of 0.85%, 0.99%, and 0.17% in the aquaculture market for the Ordinary Least Squares, Two-Stage Least Squares, and Robust Least Squares models, relatively. This pattern, most noticeable in the RLS and 2SLS models, supports the hypothesis of global competitiveness. This was in line with other studies that highlighted the continually rising market value of aquaculture output in the EU, including You,¹⁵ Dempsey et al.,¹² and Ababouch et al.¹⁵ When compared to prior years, it increased significantly to €4.87 billion in 2022.

The results of standard estimation for the EU13 developing nations applying Ordinary Least Squares, Two-Stage Least Squares, and Robust Least Squares methods are shown in Table 10. The Two-Stage Least Squares, and Robust Least Squares results largely corroborate the Ordinary Least Squares regression's conclusions. However, the coefficient magnitudes are frequently greater in the estimator-based 2SLS or RLS regressions.

The economic growth indicator is the most dependable of the three criteria among the EU13's members showing a positive and favourable correlation with the aquaculture sector. A 1% raise in GDP has a favorable influence on the growth of the aquaculture sector. In particular, the Ordinary Least Squares method indicates an enhancement of 0.27%, the Two-Stage Least Squares estimate of 0.29%, and the Robust Least Squares method of 0.28%. This finding is consistent with the results of different previous research. Ignatius,³⁹ and Ngarava et al.^{36,37} have shown that aqua-

Table 9. Cross-Sectional Estimation Results for the Developed Europe Union Members

Factors	Ordinary Least Squares		Two-Stage Least Squares		Robust Least Squares	
	Coefficients	Standard Error	Coefficients	Standard Error	Coefficients	Standard Error
ENB	0.842**	0.040	1.224**	0.051	1.909***	0.513
MRK	0.855**	0.022	0.997***	0.027	0.171***	0.171
GDP	0.698	0.013	0.228	0.035	0.231	0.365
INN	0.462**	0.020	0.130**	0.053	0.941***	0.507
HC	1.291***	0.031	1.706***	0.039	1.444***	0.354
Constant	2.701***	0.222	3.559***	0.676	2.195***	0.659
R^2	0.952		0.954	0.264	0.264	
Adjusted- R^2	0.950		0.952	0.530	0.530	

Note: Significant for the 1%, 5%, & 10% levels are denoted by ***, **, and *, respectively.

culture sustains a sizable number of employments along the value chain, from agriculture and processing to transportation and retail. Additionally, by offering economic possibilities, they may significantly contribute to the revitalization of rural and coastal areas. For the developing nations of the EU13, exporting high-value aquaculture products can result in substantial foreign exchange profits.

This sector includes employment and operations in the maritime and coastal sectors as well as training, retraining, and upgrading initiatives implemented by EU13 developing nations. Of the three specifications, the human capital input is consistent and shows a favorable strong correlation, although its co-efficient is seen to be a little different based on the used method. The OLS, 2SLS, and RLS estimation techniques show that the same enhancement portion in human capital has a positive effect on the development of the aquaculture market by 0.95%, 1.03%, and 1.06%, respectively. Consistent with previous work for example; Soykan⁶⁵ and Ngajilo et al.,⁶⁶ the sector needs to attract young individuals and recent graduates with relevant skills, such as engineering, marine science, and aquaculture-specific subjects.

Additionally, the innovation environment has a favorable influence, which is noteworthy in the EU13 developing nations' Ordinary Least Squares estimate specification in addition to the Two-Stage Least Squares and Robust Least Squares. A rise in the eco-system digitalization (INN) by 1% has an advantageous development influence of 0.10%, 0.80%, and 0.92% on the aquaculture market expansion for OLS, 2SLS, and RLS, respectively. The current output is in line with the outcomes of previous papers, such as Wang and Alsaleh⁶⁷ and Afewerki et al.,^{17,18} which are based on the global competitiveness hypothesis. These studies assert that many research institutions carry out state-of-the-art research in fields like genetics, nutrition, disease prevention, and environmental impact to overcome the challenges of sustainable growth in the aquaculture sector.

In the aquaculture sector, an enabling atmosphere has a beneficial effect on the quantity of expansion. This means that for the EU13 developing nations, a percentage improvement in the enabling environment leads to an increase in aquaculture market growth of 1.76%, 2.20%, and

1.70% for the Ordinary Least Squares, Two-Stage Least Squares, and Robust Least Squares methods, relatively. For the EU13 members with high volume production of aquaculture output and well-developed work environment, this lends credence to the global competitiveness argument. It is aligned with earlier papers like Ababouch et al.,¹⁵ Haj,²⁸ and Omoregie²⁹ that aquaculture growth might be difficult to get societal approval, especially in coastal areas. Furthermore, long-term sustainability depends on aquaculture enterprises being financially viable.

Additionally, it appears that market size has a positive effect, which is important in 2SLS and RLS in addition to the OLS estimate specification. Growing aquaculture markets in EU13 developing countries are positively impacted by market size increases of 0.41%, and 1.13%, as well as 0.04% of OLS, 2SLS, as well as RLS, respectively. The global competitiveness hypothesis is well supported by statistically significant data from each of the RLS estimator specifications as well as the 2SLS specification. The essential of maritime commercial and transportation law development, which was discovered in earlier papers by Laine et al.,¹⁴ Ababouch et al.,¹⁵ and Péter et al.,¹⁶ is aligned with this conclusion. The research findings that investigating new species and markets for aquaculture products from the EU also increases the competitiveness of EU aquaculture in the global market are corroborated by these studies.

Employing the methods of the OLS panel, the panel 2SLS, as well as RLS techniques, the estimates are consistent, which increases the reliability of the results. The panel's OLS coefficient together with those for Panel 2SLS and RLS exhibit comparable signs along with degrees of significance, highlighting the robustness and use of a cross-sectional database of Two-Stage Least Squares and Robust Least Squares for drawing sound conclusions. The similar signals of the Ordinary Least Squares coefficients along with those for panel Two-Stage Least Squares and Robust Least Squares reinforce the reliability of the outcomes, even though their significant thresholds varied somewhat. Panel 2SLS estimates are particularly noteworthy for their robustness and lack of serial association and variability issues.

The EU 27 countries were split into two categories, the EU13 emerging countries as well as the EU14 developed

Table 10. Cross-Sectional Estimation Results for the Developing Europe Union Members

Factors	Ordinary Least Squares		Two-Stage Least Squares		Robust Least Squares	
	Coefficients	Standard Error	Coefficients	Standard Error	Coefficients	Standard Error
ENB	1.768**	0.033	2.206***	0.039	1.702***	0.034
MRK	0.411***	0.044	1.138***	0.030	0.040	0.046
GDP	0.270***	0.065	0.290***	0.099	0.283***	0.067
HC	0.956***	0.0204	1.037***	0.039	1.006***	0.098
INN	0.100***	0.046	0.804***	0.015	0.924*	0.048
Constant	1.055***	0.357	1.831***	0.674	1.417***	3.667
R^2	0.204		0.151		0.202	
Adjusted- R^2	0.192		0.137		0.228	

Note: Significant for the 1%, 5%, & 10% levels are denoted by ***, **, and *, respectively.

countries, according to their economic growth phases. A detailed examination of how international competitive factors impact the growth of the aquaculture industry is made simpler by this section. While Table 10 outlines the expected effects within the EU13 members, Table 9 details the anticipated effects of competitiveness determinants pressures on the aquaculture business in the EU14 members. The findings in Tables 8 and 10 demonstrate how the aquaculture business has expanded dramatically due to factors related to global competition. A significant difference is observed among EU13 members and EU14 members with the influence of economic growth on aquaculture sector expansion. According to the magnitude impact of 2.290 for EU13 countries and 0.228 for EU14 members, it is evident that EU13 developing nations have the potential to overcome the EU14 members in aquaculture market outgrowth by adopting more effective strategic approaches.

The results also demonstrate that the enabling environment has a different impact on the expansion of the aquaculture sector in EU13 members compared to EU14 developed countries. With impact scales of 2.205 or 1.224 for EU13 or EU14 economies, relatively, it is evident that EU13 developing countries can significantly accelerate the growth of the aquaculture industry by implementing maritime policy and marine tax policies. Furthermore, compared to EU14 developed nations, EU13 developing countries show a stronger effect of market size on the expansion of the aquaculture industry. By using global competitive market strategies, EU13 countries that are developing are on track to overtake EU14 developed economies in the expansion of the aquaculture industry, with impact scales of 1.831 as well as 0.997 for EU13 members and EU14 members, relatively.

The development of human capital appears to have a greater negative impact on the outgrowth of the aquaculture market in the EU14 members than in the EU13 members. For EU13 versus EU14 nations, the exact impact magnitudes are 1.037 and 1.706, respectively. This concludes that if EU14 nations adopt cutting-edge strategies for quickening the development of human resources inside aquaculture institutions, they may considerably surpass EU13 nations in aquaculture production growth. The re-

sults show that the aquaculture industry's growth in EU14 developed nations is substantially more impacted by the implementation of innovative ecosystem applications than in EU13 members. The EU13 as well as EU14 members have distinct influence magnitudes of 0.804 and 0.130, correspondingly. This includes that EU14 industrialized nations, rather than EU13 ones, may significantly speed up the aquaculture sector's growth by utilizing environmentally friendly innovations and patents inside the business.

CONCLUSION AND IMPLICATIONS

In this study, panel data from the EU27 nations for the period between 1990 and 2023 is empirically examined using Ordinary Least Squares, Two-Stage Least Squares, and Robust Least Squares methods. According to the outcomes, determinants associated with global competitiveness have a considerable and favorable influence on the expansion of the aquaculture sector. For Ordinary Least Squares, Two-Stage Least Squares, and Robust Least Squares regression techniques, most of these results are valid across all parameters. This article also points out that elements of global competitiveness have varying effects on the country's local aquaculture market development level. This study specifically finds that human capital and the innovation ecosystem have a bigger role in propelling the aquaculture market's expansion in EU14 advanced economies than in EU13 developing nations. This suggests that reaching higher rates of aquaculture market expansion in EU14 developed nations requires improving macroeconomic aquaculture variables, human capital as well as innovation environment, effectiveness, and sustainable growth across different situations.

The authors found that the aquaculture market development in EU13 members is more reliant on market size, economic development, and enabling conditions than in EU14 members. This illustrates that to attain higher scales of aquatic market expansion from the perspective of global competitiveness, EU13 developing countries must enhance administrative effectiveness, aquatic advancement, and access to markets in a range of scenarios. The outputs support the hypothesis that the aquaculture market is crucial to en-

hancing blue farming's efficacy and sustainability as well as the safety of blue food. Even after performing numerous reliability tests, for example, setting further controlling variables, applying different approaches, evaluating the aquaculture industry's sustainability and competitiveness on a global scale using some metrics, and applying split analysis to samples, these results are still valid.

The EU27 aquaculture sector's global competitiveness depends on its ability to balance economic viability with environmental sustainability and social responsibility. To succeed, the EU needs to: (1) Enhance productivity and efficiency, improve production methods, optimize resource use, and reduce costs. (2) Promote innovation and diversification, invest in research and development, explore new species and technologies, and develop value-added products. (3) Strengthen market access, negotiate favorable trade agreements, reduce trade barriers, and promote EU aquaculture products in international markets. (4) Ensure sustainability and social responsibility, adhere to high environmental and social standards, promote animal welfare, and ensure responsible sourcing of feed. (5) Address consumer preferences, and cater to evolving consumer demands by offering a diverse range of high-quality, sustainable products.

The authors recommend policymakers and decision-makers to address these challenges as follows; (1) investing in human capital development, the EU13 aquaculture sector can enhance its competitiveness, contribute to food security, and support development of sustainable economics in coastal and rural communities. (2) The aquaculture market in the EU14 presents a promising opportunity for economic growth, but it requires a concerted effort to address the challenges and capitalize on the potential. By focusing on sustainability, innovation, and consumer engagement, the EU14 can develop a thriving and competitive aquaculture sector that contributes to food security, economic development, and environmental protection. (3) The EU14 aquaculture innovation ecosystem is constantly evolving, with ongoing efforts to strengthen collaboration, foster innovation, and ensure aquaculture green efficiency. (4) The EU14 aquaculture market has the potential for significant growth, but it faces enabling environmental challenges that need to be addressed. By focusing on sustainable practices, innovation, and addressing social and environmental concerns, the EU14 can develop a thriving and competitive aquaculture sector.

To foster a green and competitive aquaculture sector in the EU27 region, This study provides key recommendations including (1) adopting sustainable farming practices like recirculating aquaculture systems (RAS); (2) prioritizing low-impact species, optimizing feed efficiency; (3) utilizing renewable energy sources; (4) implementing robust environmental monitoring (5) promoting research and innovation in sustainable technologies; (6) and ensuring strong regulatory frameworks with clear sustainability

standards to guide the industry towards environmentally responsible operations while maintaining market competitiveness. One of the disadvantages of the current research is its not theoretical analysis of only a few macro-economic elements associated with the influence of the aquaculture sector on its expansion. Therefore, by examining other aquaculture microeconomic aspects including pricing, supply, and demand, future research might build on this work. These elements can increase the influence of domestic market and microeconomic variables on the aquaculture market's sustainability and sustainable development.

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AUTHORS' CONTRIBUTIONS

M.A. (Mohd Alsaleh) gathered the data and estimated the panel cointegration model and the competitive advantage of the external factors on the fishery industry in the EU27 region; A.A. (A.S. Abdul-Rahim) presented the EU27's health environment and fishery industry and put together all the numerical results; M.A. and A.A. contributed with conclusions and recommendations as well as with the limitations of the study and further research; M.A. conducted the literature review; and was responsible for the overall writing process.

COMPETING INTEREST

The author declares that they have no competing interests.

ETHICAL CONDUCT APPROVAL

The authors declare that the manuscript does not report studies involving human participants, human data, or human tissue.

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Data is available upon request.

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