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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

Aquaculture as an engine of economic growth: Evidence from second-generation panel and causality estimations on global aquaculture dynamics

Ekonomik büyümenin itici bir gücü olarak su ürünleri yetiştiriciliği: Küresel su ürünleri yetiştiriciliği dinamiklerine ilişkin ikinci nesil panel veri ve nedensellik analizlerinden elde edilen kanıtlar

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Abstract: This study investigates the impact of aquaculture production on economic growth across the top twenty aquaculture-producing countries for the 2001–2024 period. Accounting for cross-sectional dependence and slope heterogeneity, the study employs second-generation CIPS panel unit root tests, panel VAR Granger causality analysis, and fixed-effects estimation with Driscoll–Kraay robust standard errors. A dynamic panel specification is also employed to assess the robustness of the findings. A dynamic panel specification is also applied for robustness. The empirical findings confirm a strong Granger causality running from aquaculture to economic growth. Panel estimates indicate that a 1% increase in aquaculture output is associated with about 0.14% higher per-capita GDP, while CPI is also positively and significantly associated with GDP. These associations remain robust in the dynamic specification. Overall, the findings highlight aquaculture's vital macroeconomic role and emphasize the need to integrate circular economy principles into sustainable growth strategies.

Keywords: Aquaculture production, economic growth, panel data econometrics, Driscoll-Kraay estimation, panel VAR Granger causality

Öz: Bu çalışma, 2001–2024 dönemi için dünyanın en fazla su ürünleri yetiştiriciliği üretimi gerçekleştiren yirmi ülkesinde yetiştiricilik üretiminin ekonomik büyüme üzerindeki etkisini incelemektedir. Yatay kesit bağımlılığı ve eğim katsayılarının heterojenliği dikkate alınarak, çalışmada ikinci nesil CIPS panel birim kök testleri, panel VAR Granger nedensellik analizi ve Driscoll–Kraay dirençli standart hatalarına dayalı sabit etkiler tahmin yöntemi kullanılmıştır. Ayrıca, bulguların sağlamlığını sınamak amacıyla dinamik panel veri modeli de uygulanmıştır. Sağlamlık kontrolü amacıyla ayrıca dinamik panel spesifikasyonu uygulanmıştır. Ampirik bulgular, su ürünleri yetiştiriciliğinden ekonomik büyümeye doğru güçlü bir Granger nedenselliğinin bulunduğunu göstermektedir. Panel tahminleri, su ürünleri yetiştiriciliği üretimindeki %1'lik artışın kişi başına GSYH'de yaklaşık %0,14'lük artışla ilişkili olduğunu, ayrıca Tüketici Fiyat Endeksi'nin (TÜFE) de GSYH ile pozitif ve istatistiksel olarak anlamlı bir ilişki gösterdiğini ortaya koymaktadır. Bu ilişkiler dinamik model spesifikasyonunda da sağlamlığını korumaktadır. Genel olarak bulgular, su ürünleri yetiştiriciliğinin makroekonomik açıdan önemli rolünü ortaya koymakta ve döngüsel ekonomi ilkelerinin sürdürülebilir büyüme stratejilerine entegre edilmesi gerekliliğini vurgulamaktadır.

Anahtar kelimeler: Su ürünleri yetiştiriciliği üretimi, ekonomik büyüme, panel veri ekonometrisi, Driscoll-Kraay tahmini, panel VAR Granger nedenselliği

INTRODUCTION

This paper uses panel data methodology, which permits comparisons both across countries and over time. There are a number of studies in the empirical literature that demonstrate the impact of aquaculture production on economic growth. For instance, Ahammed et al. (2025) finds that total fisheries production, aquaculture production, agriculture/forestry/fishing value added, capital, and trade all have statistically significant positive long-run effects on China's per-capita GDP. Ngarava et al. (2023) finds that aquaculture production has a positive effect on GDP in both the short and long run, while its relationship with GHG emissions is negative and asymmetric. Eyüboğlu and Akmermer (2024) find a positive long-run relationship between fisheries production and GDP — directly. Subasinghe et al. (2009) emphasize that aquaculture is the fastest growing food production sector in the world and makes direct and indirect contributions to national income, especially in developing economies.

The aquaculture sector increases total added value by establishing strong forward and backward linkages with input-providing sectors such as feed industry, logistics, processing, and packaging technologies. The increasing demand for aquatic products due to the global limits of natural fishing is met through aquaculture. Exports of processed aquaculture products are expected to positively impact the current account balance, particularly in developing countries, and thus GDP growth by providing net foreign exchange earnings. Furthermore, employment created in coastal and rural areas through aquaculture increases household incomes, boosting consumption expenditures and contributing to macroeconomic stability by reducing regional development disparities.

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This paper specifically estimates the impact of aquaculture production on GDP for 20 countries (China, Philippines, Norway, Japan, Indonesia, India, Egypt, Bangladesh, Vietnam, Korea, Türkiye, Iran, Chile, Ecuador, Myanmar, Thailand, Brazil, Malaysia, United States of America, Russian Federation) during the period 2001-2024 using appropriate panel data methods. These countries were selected because they have the highest aquaculture volumes in the world in 2024. This approach was chosen because, while many countries engage in aquaculture, not all have significant trade volumes; limiting the study to 20 countries ensured clearer, more reliable results. Since these countries are located across various geographical regions and span the globe, it was possible to derive results that reflect the global situation. To avoid missing variable errors, the Consumer Price Index has been added to the model as control variables. In econometric models, the CPI serves as a proxy or control variable to capture these cost pressures; it is a significant variable with high explanatory power. In aquaculture, the gap between farm-gate prices and final consumer prices is influenced by general economic inflation. The CPI also helps model general market pricing behaviors and market integration. Moreover, while traditional growth frameworks focus primarily on capital accumulation and labor inputs, modern economic paradigms emphasize the critical role of specialized sectoral dynamics and environmental resource integration. Labor force specifically refers to the workforce employed in this particular sector. Such data could not be obtained because countries do not fully share these figures, and the sector involves unpaid family labor as well as informal employment. As global wild-catch fisheries reach biological limits, aquaculture has emerged not only as a vital alternative for food security but also as a structural driver of regional economic diversification and export-led growth. Despite its growing economic prominence, empirical literature often overlooks the complex interdependencies and cross-country spillovers characterizing major aquaculture-producing nations. This study addresses this gap by departing from standard first-generation econometric models, explicitly incorporating cross-sectional dependence and slope heterogeneity into the analytical framework. By doing so, it provides robust, unbiased estimates of how aquaculture production interacts with macroeconomic aggregates while controlling for demand-side pressures via the consumer price index.

MATERIALS AND METHODS

Panel data analysis provides both unit and time variation, thus increasing the efficiency of predictions (Baltagi, 2005), ensuring low multicollinearity, and enabling the estimation of complex behavioral models (Kennedy, 1998). Since panel data presents similar problems to time series, the primary focus should be on investigating whether the variables have unit roots. Panel unit root tests are divided into two types: first-generation and second-generation unit root tests. First-generation unit root tests consider the assumption of homogeneity, while second-generation unit root tests consider the presence of heterogeneity and cross-sectional dependence. Therefore, to select the correct unit root test, the homogeneity and cross-sectional dependence of the variables must be tested first.

The study sample comprises the 20 leading aquaculture-producing countries in 2024, which were selected based on their aquaculture production volumes and are listed in Table 1.

Table 1. Countries included in the study

Country Code	Country Name
1	China
2	Philippines
3	Norway
4	Japan
5	Indonesia
6	India
7	Egypt, Arab Rep.
8	Bangladesh
9	Vietnam
10	Korea, Rep.
11	Türkiye
12	Iran, Islamic Rep.
13	Chile
14	Ecuador
15	Myanmar
16	Thailand
17	Brazil
18	Malaysia
19	United States
20	Russian Federation

Pesaran and Yamagata (2008) developed the delta homogeneity test. The hypotheses for this test are as follows:

H_0: $\beta_i = \beta$ (The slope parameters are homogeneous among the cross-sectional units.)

H_1: $\beta_i \neq \beta_j$ (Slope parameters are heterogeneous among cross-sectional units.)

If p-value<0.05=>H_0 is rejected (Slope parameters are heterogeneous)

p-value>0.05=>H_0 cannot be rejected (Slope parameters are homogeneous)

The homogeneity of the slope coefficients was examined using the delta test. The null hypothesis (H_0) assumes equal slope coefficients across cross-sectional units, whereas the alternative hypothesis (H_1) allows the slope coefficients to differ. The slope homogeneity test developed by Pesaran and Yamagata (2008) was applied to determine whether the coefficients are constant across panel units.

H_0: No cross-sectional dependency

H_1: Cross-sectional dependency exists

Cross-sectional dependence was examined using the Pesaran (2004) CD test based on pairwise correlations of the

panel regression residuals. This test evaluates whether the cross-sectional units share common shocks or unobserved common factors.

In addition to testing the homogeneity and cross-sectional dependence of the series, it has been decided to use the CADF (Cross-sectionally Augmented ADF) test developed by Pesaran (2007) and the CIPS (Cross-sectionally Imputed Panel Stationarity / CADF) test, which is derived by averaging these tests. This is because the CIPS test can be used successfully and reliably even in panel data with homogeneous slope coefficients.

Fisher (1932)'s meta-analysis comes into play in the analysis of causal relationships between variables. Fisher developed a formula that statistically combines probability values obtained from independent tests under a single framework. Since cross-sectional means (common shocks) are integrated in the model's regressions, spurious causalities arising from cross-country movements are prevented. The purified *p*-values are combined with Fisher's formula to arrive at the final panel decision. Sometimes, causality may be found in some countries but not in the others. Fisher test allows clearly see the weighted common trend of the entire panel (e.g., the overall panel effect of aquaculture on growth). If there is cross-sectional dependence between countries, the *p*-values obtained from those countries become interdependent. In this case, applying Fisher's formula directly will cause the test statistic to become biased and produce incorrect results. In modern analysis, Fisher test is not applied directly. The process is carried out in two stages: Firstly, the correlation between countries is eliminated beforehand by adding cross-sectional averages to the equations or by removing common factors in the error terms, and then removing cross-sectional correlation from the model, the equation for each country is now estimated based on independent residuals. The normalized probability values are then subjected to Fisher meta-analysis. Choi (2001) developed the Choi Z-statistic to prevent bias in Fisher-type tests when cross-sectional dependence cannot be completely eliminated. These methods modify the Fisher formula by taking into account the correlation structure between them. Two key panel metric results testing the common movement of these cleaned *p*-values across the panel.

In an economy, private consumption expenditure constitutes the largest expenditure item. Therefore, in this growth analysis model, the Consumer Price Index variable, which has a significant impact on consumption decisions, has been included in the analysis on the demand side, while the aquaculture variable has been added on the supply side. Modern endogenous growth models state that the impact of human capital on economic growth is very significant. However, while this paper selected the countries with the highest aquaculture rates as of 2024, complete data on the number of people employed in this sector for the period 2001-2024 was not available for all of these countries. As is known, in balanced panel data models, if there is missing data for any given year that country cannot be included in the analysis. The sample size used in this paper is sufficient to obtain accurate long-term estimators in terms of both the number of countries and the time interval. The Consumer Price Index (CPI) dataset for Türkiye was retrieved from the Central Bank of the Republic of Türkiye (2026) EVDS database. All remaining macroeconomic variables utilized in the analysis were obtained from the World Bank's World Development Indicators (WDI) database. Therefore, aquaculture and CPI were used as explanatory variables.

To examine the impact of aquaculture production and Consumer Price Index on economic growth while controlling for demand-side macroeconomic pressures, the baseline panel regression model is specified as follows in Equation (1):

$$GDP_{it} = \beta_0 + \beta_1 AQUACULTURE_{it} + \beta_2 CPI_{it} + u_{it} \quad (1)$$

In Equation (1), i and t denote the cross-sectional unit (country) and time period (year), respectively. The dependent variable represents Gross Domestic Product (per-capita GDP) of country i in year t. β_0 is constant term, β_1 and β_2 are slope terms. $AQUACULTURE_{it}$ stands for the aquaculture production volume/output of country i in year t. To account for general market pricing behaviors and inflation-driven cost pressures, the Consumer Price Index (CPI_{it}) is incorporated as a control variable on the demand side. Finally, u_{it} captures the composite error term including country-specific fixed effects.

Given the overall evidence of level stationarity, the panel relationship was estimated directly using a fixed-effects specification with Driscoll-Kraay standard errors. The Driscoll and Kraay (1998) estimator was selected because it provides standard errors robust to cross-sectional dependence and other forms of panel error dependence. The fixed-effects framework was used to control for time-invariant country-specific heterogeneity. As a robustness check, the lagged value of the dependent variable was added to the model to evaluate whether the estimated associations remain stable in a dynamic panel specification.

RESULTS

The empirical analysis begins with diagnostic tests of slope homogeneity and cross-sectional dependence, which determine the appropriate econometric framework for the subsequent panel estimations. The results of the Pesaran and Yamagata (2008) delta homogeneity test are presented in Table 2.

Table 2. Delta test results

Test Statistic	Value	*p*-Value	Result (1% significance level)
Δ	4.8748	0.0000	The homogeneity hypothesis rejected
Adjusted Δ	5.3188	0.0000	The homogeneity hypothesis rejected

Given the sample dimensions (N=20, T=24), both the Δ and adjusted Δ statistics are statistically significant ($p<0.01$). Therefore, the null hypothesis of slope homogeneity is rejected, indicating that the slope coefficients are heterogeneous across countries.

The CDLM statistic based on the panel regression residuals was 6.5597 with a p-value of 0.000 ($p<0.01$). Thus, the null hypothesis of no cross-sectional dependence was rejected at the 1% significance level, confirming strong cross-sectional dependence across the panel units.

Comparing the calculated CIPS statistic of −4.0582 with the critical values tabulated by Pesaran (2007) for N=20 and T=24 (approximately −2.20 to −2.36 at the 5% and 1% significance levels, respectively; CADF individual values approximately -2.80 to -2.35) the absolute value of the test statistic well exceeds these thresholds. Consequently, we reject the null hypothesis of non-stationarity, confirming that the series is stationary at level (I(0)). Only Bangladesh and Thailand's series are I(1). Consequently, the empirical evidence confirms that the dependent variable GDP is stationary at level I(0) under cross-sectional dependence for the panel-level (only two countries have unit roots but it doesn't change the panel-level result), ensuring that subsequent estimations are free from spurious regression issues.

Table 3 presents the CADF test results for the dependent variable GDP for each country. CADF test results for the independent variables of the model when comparing the calculated CIPS statistic of the critical values tabulated by Pesaran (2007), the absolute value of the test statistic exceeds these thresholds. Only China and the Philippines' aquaculture data are I(1) (China and the Philippines' first difference CADF t-statistics are 4.3441 and 4.4153, respectively.). All other series are I(0). Bangladesh and Myanmar's CPI data only has unit root (first difference CADF t-statistics are 4.4193 and 3.9681, respectively.). All other series are I(0). Since the panel-level series is I(0), it is necessary to proceed directly to dynamic panel estimations which take into account cross-sectional dependence and homogeneity without proceeding to conventional panel cointegration analysis.

Table 3. CADF test results for dependent variable GDP

Country Code	Level CADF t-Statistic	First Difference CADF t-Statistic
1	-4.0532	-6.6766
2	-5.1191	-7.2138
3	-4.7378	-8.8161
4	-5.0818	-6.3644
5	-6.5215	-12.0615
6	-2.8712	-6.2754
7	-5.2933	-6.4589
8	-1.1482	-4.9123
9	-3.9352	-6.8677
10	-2.5341	-5.9457
11	-5.1162	-5.6331
12	-3.7573	-7.2744
13	-3.0620	-5.1703
14	-3.7069	-6.8984
15	-4.9046	-7.0942
16	-2.0793	-8.0471
17	-4.0099	-5.4750
18	-2.6939	-7.2461
19	-3.8956	-5.9870
20	-6.6427	-10.2761
CIPS Statistics	-4.0582	-7.0347

Table 4 presents CADF test results for the independent variables at the level. Within the country-by-country estimation framework preceding the meta-analysis, the optimal lag length for each individual country's VAR / Granger causality model was determined using standard information criteria (Akaike Information Criterion - AIC and Schwarz Bayesian Information Criterion - SIC). To ensure model parsimony and eliminate residual serial correlation in the individual country equations, maximum lag lengths were tested, and the lag order minimizing the respective information criteria for each specific cross-section unit was selected, and the country-specific Wald statistics were re-estimated across all replications to derive robust empirical-values, ensuring that the final meta-analytic synthesis is immune to small-sample distributional distortions. Following Fisher (1932), these individual *p*-values were aggregated into a unified panel test statistic. As reported in Table 5, the resulting Fisher statistic is 1,703,014 with a corresponding Chi-Square *p*-value of 0.0000, strongly rejecting the null hypothesis of no panel causality. As presented in Table 5, Choi's Z-statistic is 42,113 with a normal distribution *p*-value of 0.0000, confirming the robustness of the finding across alternative meta-analytic pooling methods. After controlling for cross-sectional dependence and strengthening with bootstrap simulations, both Fisher and Choi (2001) Z panel statistics were statistically significant at the 1% level. This situation demonstrates that the aquaculture is a strong Granger cause of economic growth across the panel. On an individual basis, Bangladesh, Myanmar, Indonesia, Japan, Türkiye and Brazil stand out as the units where this causality is strongest. Wald statistics for these countries are 73.0656, 24.3162, 16.3039, 15.3646, 9.2813, 8.9103, respectively.

Table 4. CADF test results for the independent variables

Country Code	Level CADF t-Statistic (Aqua)	Level CADF t-Statistic (CPI)
1	-2	-4.73
2	-1.9021	-3.5025
3	-6.8621	-5.9588
4	-5.3216	-6.0863
5	-8.7289	-3.6958
6	-6.6448	-5.0636
7	-5.5017	-5.966
8	-5.7822	-1.8488
9	-4.0201	-4.1506
10	-5.3116	-9.1168
11	-4.3357	-5.0221
12	-4.5881	-5.4542
13	-4.3588	-4.686
14	-3.1341	-5.1256
15	-4.7547	-2.1349
16	-7.8096	-3.6524
17	-10.1982	-4.9161
18	-3.4598	-4.3677
19	-4.0947	-5.9549
20	-4.1935	-4.2995
CIPS Statistics	-5.1501	-4.7866

Table 5. Panel VAR Granger causality analysis

AQUACULTURE → GDP	χ
Fisher (1932) combined χ^2 statistic	1,703,014
Chi-Square *p*-value	0.0000
Choi (2001) Z-Statistic (Panel Normalized Correction)	42,113
Normal Distribution *p*-value	0.0000

Statistical significance is evaluated at the 1% level (p < 0.01).Significant at 1% level.

Table 6 presents the panel coefficient estimates and Driscoll and Kraay (1998)'s standard error-corrected fixed effects estimator adapted from Stock and Watson (2008). The aquaculture coefficient is positive and statistically significant at the 1% level. The elasticity estimate indicates that a 1% increase in aquaculture production is associated with approximately 0.14% higher GDP, holding other model factors constant. The coefficient of CPI is also positive and statistically significant at the 5% level (p=0.016), although its estimated magnitude is comparatively small.

Table 6. Driscoll and Kraay (1998) standard error corrected fixed effects model

Variable	Mean coefficient	Standard Error	t-Statistic
AQUACULTURE	0.1450	0.022	6.524
CPI	0.0045	0.002	2.419

The dynamic panel specification incorporating lagged GDP was estimated using the Pooled Mean Group (PMG) autoregressive distributed lag (ARDL) approach. This estimator allows short-run coefficients and error variances to differ across countries while constraining long-run coefficients to be homogeneous, ensuring robust dynamic adjustments. As reported in Table 7, the estimated coefficient for the lagged dependent variable is statistically significant (*p*=0.000), confirming significant persistence in output growth and justifying the dynamic panel specification. The mean coefficients, robust standard errors, and corresponding t-statistics reflect the asymptotic efficiency properties of the chosen estimator. Therefore, the positive association between aquaculture production and GDP remains statistically significant after adding lagged GDP, supporting the robustness of the baseline estimates.

Table 7. Dynamic panel model estimation results

Variable	Mean coefficient	Standard Error	t-Statistic
GDP_{t-1}	0.2972 (*p*=0.000)***	0.047	6.324
AQUACULTURE	0.1008	0.022	4.613
CPI	0.0031 (*p*=0.079)*	0.002	1.759

*** and * show 1% and 10% significance level, respectively.

DISCUSSION

The empirical findings provide robust evidence that aquaculture production is positively associated with economic growth across the major aquaculture-producing countries. The baseline Driscoll-Kraay estimation indicates that a 1% increase in aquaculture production is associated with approximately 0.14% higher per-capita GDP, while the positive association remains statistically significant in the dynamic specification after controlling for lagged GDP. This consistency suggests that the observed relationship is not merely a feature of the static specification. Moreover, the panel Granger causality results provide strong evidence of predictive causality running from aquaculture production to GDP. Nevertheless, Granger causality should not be interpreted as structural causality, but rather as evidence that past changes in aquaculture production contain significant information for explaining subsequent changes in economic activity.

These findings are broadly consistent with previous empirical evidence. Ngarava et al. (2023) reported a positive relationship between aquaculture production and economic growth in Sub-Saharan Africa, while Rehman et al. (2019) found that both aquaculture and capture fisheries production positively contributed to economic growth in Pakistan. Similarly, Eyüboğlu and Akmermer (2024), using an ARDL framework for Türkiye, identified a positive long-run relationship between fisheries production and economic growth. More recent evidence also indicates that aquaculture and other blue-economy components can make significant contributions to economic growth when considered alongside broader economic factors, including labor, capital, renewable energy, and green innovation (He et al., 2025). Thus, despite differences in geographical coverage, periods, and econometric techniques, the predominantly positive evidence in the literature is consistent with the direction of the relationship identified in the present multi-country panel.

Several economic mechanisms may explain this association. Aquaculture generates value not only through primary production but also through backward and forward linkages involving feed production, processing, transportation, cold-chain logistics, marketing, and international trade. Commercial aquaculture may consequently contribute to income generation, employment, foreign-exchange earnings, and broader value-chain development (Hishamunda et al., 2009). These channels are particularly relevant for countries capable of transforming increasing aquaculture output into higher-value processed products and competitive exports. However, these mechanisms should be regarded as plausible transmission channels rather than directly tested mediators in the present model, since employment, trade, processing capacity, and capital formation were not explicitly included as explanatory variables.

The positive CPI coefficient in the baseline model requires more cautious interpretation. Although CPI is positive and statistically significant in the Driscoll-Kraay specification, its statistical significance weakens in the dynamic model. Therefore, the CPI result should not be interpreted as evidence that inflation itself promotes economic growth. Rather, it may reflect heterogeneous macroeconomic conditions and demand dynamics across the countries included in the panel. In contrast, the aquaculture coefficient remains positive and statistically significant across both specifications, providing stronger evidence for the robustness of the central aquaculture-growth relationship.

Finally, the significant slope heterogeneity identified in the panel indicates that the magnitude of the aquaculture-growth relationship differs across countries. Such heterogeneity is economically plausible because countries differ substantially in production scale, technological capacity, export orientation, value-chain development, and institutional conditions. Accordingly, the findings support aquaculture as an important component of economic development, while also suggesting that its economic contribution depends on country-specific structural conditions. Policies aimed at expanding aquaculture should therefore combine productivity and value-chain development with environmental sustainability, resource efficiency, and circular-economy principles to ensure that economic gains remain sustainable over the long term.

CONCLUSION

This study primarily aims to examine the impact of aquaculture activities on economic growth. In countries with extensive coastlines and abundant freshwater resources, aquaculture creates significant economic value. However, economic benefits that may seem advantageous in the short term, pose significant risks to sustainable development. Therefore, more planned economic activities are needed. This provides significant advantages not only in terms of generating income, but also in terms of expanding high value-added fishing activities and creating employment. Because the ultimate goal in an economy is to achieve sustainable economic development, this study therefore examined the impact of aquaculture on GDP using causality analysis and performed Panel VAR Granger Causality Analysis. The results from this 20-country panel dataset showed a causal relationship from aquaculture to GDP. When looking at individual countries, the top five countries where causality was significant and high were found to be Bangladesh, Myanmar, Indonesia, Japan, Türkiye, and Brazil. These countries have been able to increase their economic growth rate with the help of aquaculture. However, it is crucial that circular economy and waste management sensitivities are considered while planning aquaculture activities, and that development is carried out within this context. Prioritizing the transition to a circular economy and adopting an environmentally protective approach are important when developing aquaculture.

From a policy perspective, the empirical findings carry profound implications for policymakers and industry stakeholders across top aquaculture-producing economies. Given the robust positive elasticity estimate and evidence of Granger causality from aquaculture production to GDP, governments should prioritize targeted public investments in sustainable aquaculture infrastructure, cold-chain logistics, and advanced disease-management technologies. However, intensive aquaculture expansion can exacerbate environmental pressures, future policy frameworks must strictly mandate the adoption of circular economy models. Ensuring regulatory alignment between export competitiveness and environmental sustainability will secure the long-term viability of the sector as a resilient engine of macro-development.

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AUTHORSHIP CONTRIBUTIONS

Gülçin Güreşçi: Conceptualization, Data analysis, Data curation. Mehmet Yunus Çelik: Investigation, Data curation, writing – Original draft, Writing – Review & editing. Adem Yavuz Sönmez: Investigation, Methodology, Formal analysis, Writing – Review & editing all authors read and approved the final manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ETHICAL APPROVAL

Ethics approval was not required because the study is based on country-level secondary economic and aquaculture data and did not involve human participants or experimental animals.

DECLARATION OF AI USE

ChatGPT (OpenAI) was used to assist with the general organization and linguistic refinement of selected parts of the manuscript. The authors reviewed and verified all AI-assisted content and take full responsibility for the final manuscript.

DATA AVAILABILITY

The country-level aquaculture, GDP, and CPI data used in this study were obtained from publicly available international databases. The underlying dataset is available from the corresponding author upon reasonable request.

REFERENCES

Ahammed, S., Rana, M. M., Uddin, H., Majumder, S. C., & Shaha, S. (2025). Impact of blue economy factors on the sustainable economic growth of China. *Environment, Development and Sustainability, 27*(6), 12625–12652. https://doi.org/10.1007/s10668-023-04411-6

Baltagi, B. H. (2005). *Econometric Analysis of Panel Data* (3rd ed.). John Wiley & Sons.

Central Bank of the Republic of Türkiye, (2026) https://www.tcmb.gov.tr/wps/wcm/connect/EN/TCMB+EN/Main+Menu/Statistics/Inflation+Data, Retrieved from 25.07.2026

Choi, I. (2001). Unit root tests for panel data. *Journal of International Money and Finance*, *20*(2), 249272. https://doi.org/10.1016/S0261-5606(00)00048-6

Driscoll, J. C. & Kraay, A. C. (1998). Consistent covariance matrix estimation with spatially dependent panel data. *The Review of Economics and Statistics*, *80*(4), 549–560.

Eyüboğlu, S., & Akmermer, B. (2024). The relationship between economic growth and fisheries production in Turkey. *Aquaculture Studies, 24*(2), Article AQUAST1017. https://doi.org/10.4194/AQUAST1017

Fisher, R. A. (1932). *Statistical methods for research workers*. Oliver & Boyd.

He, S., Alhamdi, F. M., Paramaiah, C., Hanif, S., & Nawaz, M. A. (2025). Role of blue economy and green economy in economic growth: Evidence from Pakistan. *Natural Resources Forum*, *49*(3), 3280-3291. https://doi.org/10.1111/1477-8947.70009

Hishamunda, N., Cai, J., & Leung, P. (2009). *Commercial aquaculture and economic growth, poverty alleviation and food security: Assessment framework*. FAO Fisheries and Aquaculture Technical Paper No. 512. Food and Agriculture Organization of the United Nations.

Kennedy, P. (1998). A Guide to Econometrics. Oxford: Blackwell Publishing

Ngarava, S., Zhou, L., Nyambo, P., Chari, M.M., & Bhungeni, O. (2023). Aquaculture production, GHG emission and economic growth in Sub-Sahara Africa. *Environmental Challenges, 12*, Article 100737. https://doi.org/10.1016/j.envc.2023.100737

Pesaran, M.H., 2004. General Diagnostic Tests for Cross Section Dependence in Panels, *Cambridge Working Papers in Economics,* 0435, Faculty of Economics, University of Cambridge.

Pesaran, M.H., (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics*, *22*(2), 265–312. https://doi.org/10.1002/jae.951

Pesaran, M.H., & Yamagata, T. (2008). Testing slope homogeneity in large panels. *Journal of Econometrics*, *142*(1), 50-93. https://doi.org/10.1016/j.jeconom.2007.05.010

Rehman, A., Deyuan, Z., Chandio, A.A., Hussain, I., Luan, J., & Iqbal, M.S. (2019). Do fisheries and aquaculture production have dominant roles within the economic growth of Pakistan? A long-run and short-run investigation. *British Food Journal, 121*(8), 1926-1935. https://doi.org/10.1108/BFJ-01-2019-0005

Stock, J. H., & Watson, M. W. (2008). Heteroskedasticity-robust standard errors for fixed effects panel data regression. *Econometrica*, *76*(1), 155–174. https://doi.org/10.1111/j.0012-9682.2008.00821

Subasinghe, R., Soto, D., & Jia, J. (2009). Global aquaculture and its role in sustainable development. *Reviews in Aquaculture*, *1*(1), 2-9. https://doi.org/10.1111/j.1753-5131.2008.01002.x