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Research Article **Araştırma Makalesi**

Capital-Labor-Output Nexus in Türkiye's Fisheries Sector: Panel ARDL Analysis

Türkiye Balıkçılık Sektöründe Sermaye-Emek-Üretim İlişkisi: Panel ARDL Analizi

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Abstract: This study analyzes the relationship between production, labor force and capital investments in the fisheries sector in the Marmara, Aegean, Mediterranean, Western Black Sea and Eastern Black Sea regions of Türkiye and examines their effects on sectoral growth and employment. In the study, total fish production, number of employees in the sector and capital investments (number of vessels) variables are used in the panel data analysis covering the period 2006-2023. According to the results of the analysis, the labor force has a positive and significant effect on production, but the effect of capital on production is negative. This shows that capital investments in the Turkish fisheries sector have not been able to provide the expected productivity growth. Moreover, capital investments are found to support employment by increasing labor demand. The long-run cointegration results reveal a strong equilibrium relationship between the variables. This study contributes to the existing research in the literature and provides strategic recommendations for the development of sustainable growth and productivity policies in Türkiye's fisheries sector. In particular, supporting aquaculture activities, modernizing capital investments and taking regional differences into account are critical for the long-term sustainability of the sector.

Keywords
- Fisheries sector
- Aquaculture
- Panel data
- Türkiye

Özet: Bu çalışma, Türkiye'nin Marmara, Ege, Akdeniz, Batı Karadeniz ve Doğu Karadeniz bölgelerinde balıkçılık sektöründe üretim, işgücü ve sermaye yatırımları arasındaki ilişkiyi analiz etmekte ve bunların sektörel büyüme ve istihdam üzerindeki etkilerini incelemektedir. Çalışmada 2006-2023 dönemini kapsayan panel veri analizinde toplam balık üretimi, sektörde çalışan sayısı ve sermaye yatırımları (tekne sayısı) değişkenleri kullanılmıştır. Analiz sonuçlarına göre, işgücünün üretim üzerinde pozitif ve anlamlı bir etkisi vardır, ancak sermayenin üretim üzerindeki etkisi negatiftir. Bu durum, Türk balıkçılık sektöründe sermaye yatırımlarının beklenen verimlilik artışını sağlayamadığını göstermektedir. Ayrıca, sermaye yatırımlarının işgücü talebini artırarak istihdamı desteklediği tespit edilmiştir. Uzun dönem eşbütünleşme sonuçları değişkenler arasında güçlü bir denge ilişkisi olduğunu ortaya koymaktadır. Bu çalışma, literatürdeki mevcut araştırmalara katkıda bulunmakta ve Türkiye'nin balıkçılık sektöründe sürdürülebilir büyüme ve verimlilik politikalarının geliştirilmesi için stratejik öneriler sunmaktadır. Özellikle su ürünleri yetiştiriciliği faaliyetlerinin desteklenmesi, sermaye yatırımlarının modernize edilmesi ve bölgesel farklılıkların dikkate alınması sektörün uzun vadeli sürdürülebilirliği için kritik önem taşımaktadır.

Anahtar kelimeler
- Balıkçılık sektörü
- Su ürünleri yetiştiriciliği
- Panel veri analizi
- Türkiye

1. INTRODUCTION

The fisheries sector plays a key role in ensuring food security and providing employment worldwide (FAO, 2020). However, in the context of Türkiye, the sector holds unique importance due to the country's rich marine resources and strategic geographical location. Surrounded by seas on three sides, Türkiye has access to diverse ecosystems including the Black Sea, the Aegean Sea, and the Mediterranean Sea.

These ecosystems support both national food supply and economic activity in coastal regions (TurkStat, 2024).

In Türkiye, the fisheries sector plays an important role in coastal economies by contributing to employment, regional development, and foreign trade. According to 2022 data, approximately 100 thousand people are directly employed in the fisheries sector, and related activities support broader economic growth (Ministry of Agriculture and Forestry, 2019). Türkiye produces various fish species for both domestic consumption and export markets, with trout and sea bass being particularly important for increasing international competitiveness (FAO, 2023).

Despite its potential, the sector faces significant structural and environmental challenges. Overfishing, marine pollution, climate change, and the decline of fish stocks threaten sustainability (Hekimoğlu and Altındeğer, 2012). These problems have made it clear that the limits of capture-based production have been reached, prompting a shift towards aquaculture as a more sustainable alternative (FAO, 2020). Aquaculture not only increases total production but also enhances employment opportunities in coastal areas.

Türkiye has made notable progress in aquaculture, particularly in the Aegean and Mediterranean regions, supported by government incentives and modern production technologies. The increasing share of aquaculture in total production reduces reliance on traditional fishing methods (TurkStat, 2024). This transformation is supported by technological investments aimed at boosting export capacity and international competitiveness. As a result, the fisheries sector remains central to Türkiye's efforts toward achieving sustainable economic and environmental development goals.

The aim of this study is to reveal the dynamics of sectoral growth and employment by analyzing the relationships between production, labor, and capital in the fisheries sector across the Marmara, Aegean, Mediterranean, Western Black Sea, and Eastern Black Sea regions. The analysis covers the 2006–2021 period and uses key variables such as fish production (catch and aquaculture), registered labor force, and capital investment (vessel count). Employing panel data methods, the study investigates both regional characteristics and national trends. Unlike most previous studies that focus on either production or capital, this paper offers a more comprehensive view by incorporating labor and its interaction with capital. The findings aim to guide sectoral policy formulation and support strategies for sustainable fisheries management.

In the literature, the fisheries sector is recognized for its multifaceted contributions to economic development, food security, and employment (FAO, 2020). Carlson et al. (2020) emphasized the role of capital investment and modern technology in enhancing production capacity. Similarly, Triezenberg et al. (2020) highlighted the productivity gains from adopting modern infrastructure. On the labor side, Teh and Sumaila (2011) explored how employment in the fisheries sector contributes to socio-economic sustainability. Garza-Gil (2017) examined how regional disparities influence employment, suggesting that infrastructure investments stimulate job creation.

Region-specific productivity differences are also widely acknowledged. Hekimoğlu and Altındeğer (2012) noted the relatively high productivity in the Black Sea Region but pointed to infrastructure shortcomings as a barrier to growth. In regions such as Marmara and the Aegean, tourism competes with fisheries, affecting sector performance (Samsun Directorate of Agriculture and Livestock, 2012).

Recent studies suggest that improving capital efficiency through innovative policies can positively affect both production and employment (Ainsworth et al., 2023). Liu et al. (2018) stressed the role of spatial management tools in balancing output and employment. Oyakhilomen and Zibah (2013), in their study on Nigeria, argued that inefficiencies and reliance on imports limited the sector's contribution to GDP — a challenge also seen in Türkiye, where fish consumption remains low and trade deficits persist (FAO, 2023).

Several Türkiye-specific studies have explored the links between infrastructure, energy costs, and regional production (Garza-Gil, 2017; Carlson et al., 2020). These findings underline the importance of region-sensitive and technology-driven investment strategies to improve sectoral performance. Arslan and Yıldız (2021) emphasized the sector's untapped potential due to low per capita consumption and insufficient infrastructure. Gün and Kızak (2019) supported this view with statistical evidence of declining capture fisheries and rapid growth in aquaculture. Sarıözkan (2016) found that despite this growth, the sector's share in GDP remains limited, calling for increased public support and effective marketing strategies. Similarly, Tolon (2019) provided a historical account of fisheries policy and its economic evolution, underscoring the role of strategic investment and sustainability planning.

Other scholars have examined financial, trade, and labor dimensions of the sector. Kekül (2024) used CBRT sectoral balance sheets in a panel data framework and concluded that financial leverage hampers profitability, whereas equity turnover enhances it. Ukav (2023) analyzed foreign trade data and found that aquaculture exports have quadrupled in the past decade, driven by rising demand from Europe. On the labor side, Öztürk and İbik (2023) identified mismanagement and declining profitability as major drivers behind the migration of Turkish fishermen to Mauritania. These studies provide critical insights into the sector's financial sustainability, export potential, and labor challenges, reinforcing the importance of region-specific strategies for long-term resilience and growth.

In summary, existing literature confirms the complex and regionally diverse interplay between production, capital, and employment in the fisheries sector. A detailed country-specific analysis of these dynamics is essential for effective policy design. This study contributes to the literature by jointly analyzing the impact of labor and capital on production, as well as how production and capital influence employment. By integrating a regional perspective focused on five key coastal regions of Türkiye, it addresses a significant gap in the empirical literature and offers valuable insights for both the academic community and policy-makers.

2. MATERIAL and METHODS

2.1. Fisheries sector in Türkiye

This study was conducted seasonally in 2016. Figure 1 provides a comparative annual comparison of the total catch and landings in the Marmara, Aegean, Mediterranean, Western Black Sea and Eastern Black Sea regions of Türkiye, as well as the total fish production in Türkiye as a whole. These are of great importance for understanding the structural and environmental changes in the fisheries sector over the years. Approximately 400,000 tons of fish caught in 2006 exceeded 500,000 tons in 2007 but showed a significant downward trend from 2008 onwards. This decline can be explained by factors such as overfishing, deterioration in marine ecosystems and depletion of fish stocks (Hekimoğlu and Altındeğer, 2012). This decline until 2014 shows that the sector faces serious structural problems in terms of sustainability. The period after 2014 reveals that despite short-term recoveries, the overall downward trend in the amount of fish caught has continued. This can be attributed to intense fishing pressure in the Black Sea and increasing pollution in the Marmara Sea (Samsun Directorate of Agriculture and Livestock, 2012).

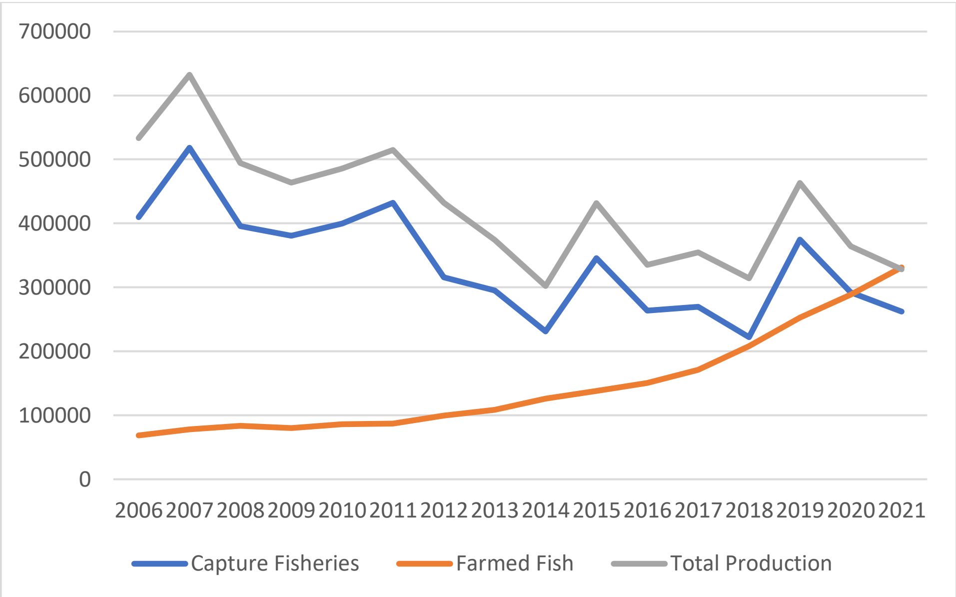

Figure 1. Capture, farmed and total fish production in Türkiye by years (2006-2021).

The increase in the amount of farmed fish has shown a remarkable trend. Approximately 70,000 tons of farmed fish production in 2006 exceeded 300,000 tons by 2021. This continuous increase is attributed to technological investments and government incentives in aquaculture (FAO, 2020). The spread of modern aquaculture facilities, especially in the Aegean and Mediterranean regions, has been one of the most important reasons for this increase (TEPGE, 2023). In addition, infrastructure improvements and modern production techniques supported by government policies have also accelerated the growth in the aquaculture sector.

The green line representing the total fish production in Türkiye followed a stable course between 2006 and 2010, and this balance was maintained thanks to the increase in the amount of farmed fish despite the decline in the amount of fish caught since 2011. However, in 2021, the sharp decline in the amount of fish caught led to a decline in total production. This suggests that the limits of capture-based production have been reached and aquaculture activities are becoming even more important for the sustainability of the sector. Liu et al. (2018) emphasized the contribution of aquaculture to economic and ecological sustainability and highlighted the benefits of investments in this area to regional economies.

This reveals that production dynamics in Türkiye's fisheries sector are shaped on two different bases: capture fisheries and aquaculture. While the decline in the amount of fish caught emphasizes the need for more effective policies to protect marine ecosystems, the growth in aquaculture offers great potential for the future development of the sector. FAO (2020) stated that aquaculture plays a critical role in meeting the growing demand for food worldwide, while Ainsworth et al. (2023) stated that this growth should be supported by capital efficiency and innovative policies. In this context, Türkiye needs to prioritize aquaculture investments to increase total fish production in a sustainable manner, while at the same time implementing effective management policies to protect marine resources.

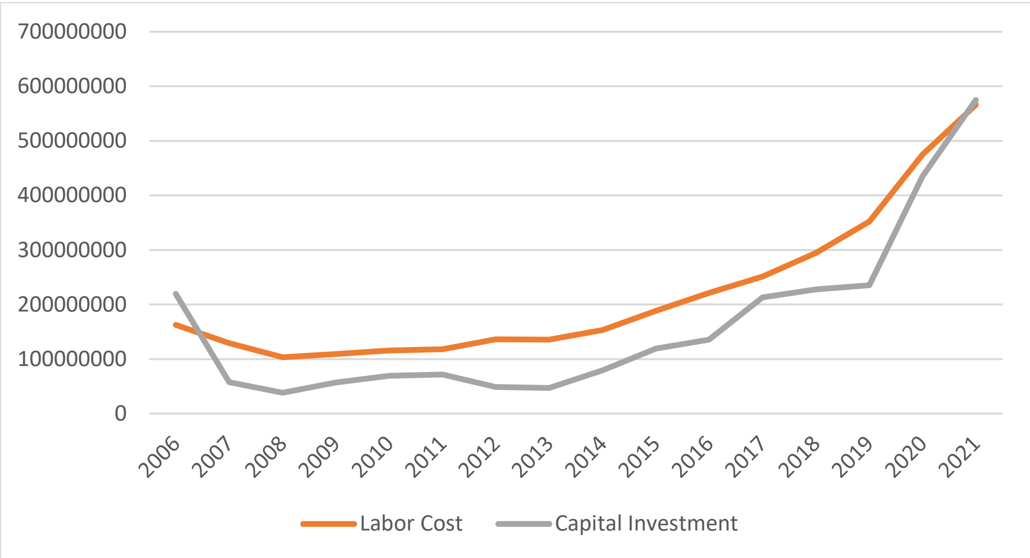

Figure 2. Labor cost and capital investment of the fisheries sector in Türkiye.

Figure 2 shows the annual changes in labor costs and capital investments in the Turkish fisheries sector between 2006 and 2021. The graph provides important information for understanding the growth dynamics of the sector and the evolution of the two key inputs over the years.

In 2006, capital investments started at a higher level than labor costs. However, in 2007, labor costs surpassed capital investments, and this difference became more pronounced in the following years. This reflects the labor-intensive production structure in the fisheries sector and the impact of the increase in labor costs on the sector, especially after 2010. In particular, as stated in the Samsun Directorate of Agriculture and Livestock (2012) report, high labor costs in fishing activities in regions such as the Black Sea and Marmara have increased pressures on sectoral productivity.

While labor costs remained flatter between 2010 and 2013, capital investments decreased during the same period. This reflects a period of decline in new vessel purchases and modernization investments in the fishing sector. This decline can be attributed to capital constraints following the global economic crisis (Garza-Gil, 2017). At the same time, the recession and decline in production in the sector during this period reduced the rate of return on capital investments, making it difficult to encourage new investments.

Since 2014, a significant increase in capital investments has been observed. A rapid increase is especially noticeable in 2018 and beyond. This increase can be explained by the adoption of modern fishing technologies and government incentive policies for the aquaculture sector (Triezenberg et al., 2020). This increase in capital investments indicates a growth trend in Türkiye's fisheries sector that is in line with investments in aquaculture.

Labor costs, on the other hand, have increased steadily in the post-2014 period, with a particularly sharp rise in 2020. This can be attributed to both inflationary pressures and increased labor demand in the sector. Moreover, this increase in labor costs was also affected by labor market regulations and wage increase policies (Teh and Sumaila, 2011).

Overall, the chart shows how the dynamics between capital investments and labor costs in the fisheries sector have changed over time. In 2020 and 2021, capital investments and labor costs approach the same level, indicating that a capital-intensive structure is developing in the sector. FAO (2020) emphasizes that capital-intensive production models provide higher productivity in the long run and contribute to a more sustainable structure, especially in aquaculture activities.

In conclusion, the graph clearly shows the increasing importance of labor costs in the Turkish fisheries sector and the impact of the growth in capital investments on production capacity in the sector. These trends call for a balanced focus of sectoral policies on both labor and capital investments. This presents important opportunities to optimize resource utilization at the regional and national levels.

The dynamics presented in figures 1 and 2 clearly demonstrate the accelerating shift from capture-based production to aquaculture in Türkiye's fisheries sector and the impact of labor and capital investments on the sustainability of the sector. While Figure 1 highlights the increasing role of aquaculture in total fish production, Figure 2 reflects the changing balance between capital investments and labor costs. The decline in landings and the growth of aquaculture indicate which components need to be focused on more for the sector's future growth and sustainability goals. The importance of capital-intensive activities in terms of long-term sustainability and productivity is a finding frequently emphasized in the literature (FAO, 2020; Ainsworth et al., 2023).

In this context, the importance of our study comes forward once again. In addition to analyzing the impact of the amount of fish caught and farmed in the Marmara, Aegean, Mediterranean, Western Black Sea and Eastern Black Sea regions of Türkiye on production, our analysis of the role of labor and capital on sectoral growth provides a strategic guide for sectoral policies. Considering the data in the graphs, our study will contribute not only to academic knowledge but also to the development of sustainable growth and productivity policies in Türkiye's fisheries sector. These findings provide a critical foundation for understanding regional dynamics and designing more effective policies on the national scale.

2.2. Data

The dataset used in this study is based on annual data on the fisheries sector covering the Marmara, Aegean, Mediterranean, Western Black Sea and Eastern Black Sea regions of Türkiye. These data, collected between 2006 and 2023, aim to examine fishing activities in each region in detail. The data set includes variables such as the total amount of saltwater fish produced (sum of the amount of fish caught (tons) and the amount of fish farmed (tons)), the number of vessels used in the fishing sector and the number of people working in the sector. This comprehensive dataset allows for the analysis of both the production and employment dimensions of the fisheries sector. It also allows for a detailed examination of the differences between regions. The dataset provides a solid basis for analyzing sectoral growth, productivity and sustainability by reflecting temporal and regional changes in production activities based on both traditional fishing methods and aquaculture. The wide time span and regional disaggregation make the dataset highly valuable for examining long-term trends and regional comparisons in the fisheries sector. The present study used this comprehensive dataset to conduct quantitative analyses on the production and employment dimensions of the sector.

The variables used in this study represent production and production inputs in the Turkish fisheries sector:

- lnQ is total production (in tons),
- lnL is the total number of employees employed in the sector, and
- lnK is capital investments (number of vessels).

In order to analyze the relationship between the variables and to obtain a more appropriate scale, the natural logarithms of all variables are taken. In this way, the wide range of values of the variables is homogenized and better represents a linear relationship in the analysis. The data were compiled from official statistics provided by the Turkish Statistical Institute (TurkStat) and harmonized with the dataset covering 2006-2023 used in the study.

Table 1. Descriptive statistics.

Variables	Obs	Mean	Std. Dev.	Min	Max
lnQ	90	11.110	0.9547	9.1942	12.749
lnL	90	8.8594	0.3316	8.0536	9.4003
lnK	90	7.9509	0.3449	7.3746	8.6898

When the descriptive statistics are analyzed, it is seen that the average value of the lnQ variable (production) is 11.11. This value indicates that the average production in the Turkish fisheries sector is quite high. However, with a standard deviation value of 0.9547, it is understood that production values vary significantly across time and regions. lnL has a lower standard deviation (0.3316) compared to the production value with a mean of 8.8594. lnC has a mean of 7.9509 and a standard deviation of 0.3449, indicating that capital investments have a similar distribution to labor. The minimum and maximum values emphasize that there are significant differences in terms of production, labor force and capital in the analyzed period and regions. Overall, the descriptive statistics reflect the regional and temporal diversity of the Turkish fisheries sector in terms of production and inputs. This diversity provides an important basis for the study to provide a deeper understanding of sectoral dynamics.

Figure A1 shows in detail the yearly variation in the catch and landings in the Marmara, Aegean, Mediterranean, Western Black Sea and Eastern Black Sea regions of Türkiye. In general, the Aegean and Mediterranean regions present a picture where aquaculture activities are growing rapidly, while the Marmara and Black Sea regions are more dominated by capture-based production. The Aegean Region is noteworthy for its rapid increase in aquaculture activities, especially since 2010. This growth can be explained by the geographical advantages of the region and the spread of modern aquaculture facilities. While a similar increase is observed in the Mediterranean Region, it is observed that production based on fishing is relatively limited. This can be attributed to the limited fishing potential in the region and the growth of aquaculture to fill this gap.

The amount of fish caught in the Marmara and Western Black Sea regions follows a relatively fluctuating course, and it is observed that aquaculture is quite limited in these regions. While fishing activities in Marmara had stronger potential in the past, they have shown a slightly decreasing trend in recent years. The Western Black Sea presents a stable outlook in terms of catches despite periodic fluctuations. The Eastern Black Sea Region stands out with high levels of fish catches. However, it is noteworthy that aquaculture activities are also limited here. Increasing aquaculture capacity in these regions offers an important opportunity to ensure sustainable growth in the sector. Regional differences highlight the need to diversify Türkiye's fisheries policies and develop strategies tailored to the potential of each region.

2.3. Methodology

In this study, the panel ARDL (Autoregressive Distributed Lag) model was employed to analyze the long-run and short-run relationships between production, labor, and capital across different regions of Türkiye’s fisheries sector. This model is particularly suitable for datasets with a relatively small time dimension and larger cross-sections, which aligns with the structure of this study (2006–2021 across five regions). One of the main advantages of the panel ARDL approach is its flexibility in handling variables with mixed levels of integration (i.e., I(0) and I(1)), unlike traditional cointegration methods that require all variables to be integrated in the same order. Additionally, the model captures heterogeneous dynamics across cross-sectional units, allowing for region-specific short-run variations while imposing a common long-run structure. Compared to fixed or random effects models, panel ARDL provides a more robust framework for studying dynamic interactions and adjustment processes, making it ideal for sectoral analyses with regional focus. Furthermore, the inclusion of lags in both dependent and independent variables helps account for delayed effects, which are common in sectors such as fisheries where policy or investment changes influence outcomes over time.

2.3.1 Panel Unit Root Tests

In panel data analysis, testing whether the variables are stationary is critical for the accuracy of the methods to be applied. In this study, IPS (Im, Pesaran and Shin, 2003) and Breitung (2000) tests are used as panel unit root tests. While the IPS test assumes different autoregressive structures for each unit in heterogeneous panel data, it tests the first difference stationarity assumption. The flexibility provided by this test is important since Türkiye exhibits different economic and environmental structures in five different regions. The test statistic is expressed as follows:

$$t_{IPS} = \frac{1}{N}\sum_{i=1}^{N} t_i \qquad (1)$$

Where t_i is the test statistic for the null hypothesis of stationarity of the autoregressive parameters for each cross-section. The Breitung test assumes that the series in the panel have a common autoregressive parameter, which leads to more robust results, especially in small samples. Moreover, it can more accurately detect the stationarity of the series under the assumption of a common autoregressive parameter. It is determined that the variables in our panel data set do not contain unit roots and should be stationary.

2.3.2. Panel Cointegration Tests

Panel cointegration tests were applied to examine the long-run relationships between the variables. Pedroni (1999) and Kao (1999) cointegration tests are used in this study. The Pedroni cointegration test is an approach that allows for heterogeneity across cross-sectional units and is based on multiple regression equations. The test was conducted within the framework of the following model:

$$y_{it} = \alpha_i + \delta_i t + \beta x_{it} + \epsilon_{it} \qquad (2)$$

where y_{it} represents the dependent variable and x_{it} represents the independent variables. The Pedroni test tests for cointegration by checking whether the error term is stationary. According to the results of this test, which are analyzed with various statistics, it is determined that there is a long-run relationship between the variables (Pedroni, 1999).

The Kao test is applied under the assumption of homogeneous cross-section to verify whether there is cointegration between the series. The test is based on the stationarity analysis of the following error terms:

$$\epsilon_{it} = \rho\epsilon_{it-1} + u_{it} \qquad (3)$$

A coefficient ρ less than one indicates the presence of cointegration. The Kao test assumes that all units in the panel have common autoregressive parameters. This test offers a simpler structure compared to the Pedroni method and is used as a supportive tool for cointegration results. The test results confirmed a strong cointegration relationship between the variables (Kao, 1999).

2.3.3. Panel ARDL Model

The econometric model constructed using the variables defined earlier is as follows:

$$lnQ_{it} = \beta_0 + \beta_1 lnL_{it} + \beta_2 lnK_{it} + u_{it} \qquad (4a)$$

$$lnL_{it} = \beta_3 + \beta_4 lnQ_{it} + \beta_5 lnK_{it} + e_{it} \qquad (4b)$$

The Pooled Mean Group (PMG) estimator developed by Pesaran et al. (1999) is used to estimate long-run and short-run coefficients. The panel autoregressive distributed lag (panel ARDL) model restricts the long-run coefficients to be the same but allows the short-run coefficients and error variances to differ across groups (Pesaran et al., 1999). In addition to dynamic identification, the ARDL approach also allows for testing cointegration. The cointegrated time series system can be estimated as an ARDL model with the advantage of being I(0) or I(1) without the need to specify which of the variables in the cointegration relationship are I(0) at level or I(1) at first difference. However, the variables should not be I(2) stationary in the second difference. At the same time, the ADRL model allows the estimation of both short-term and long-term relationships between the dependent and independent variables. Since the ARDL technique works well with small samples, it is highly recommended to use it with a small data sample. The specification form of the ARDL (p, q) approach with lag p for the dependent variable and lag q for the independent variables is as follows:

$$Y_t = \delta + \sum_{k=1}^{p} \theta Y_{t-k} + \sum_{j=1}^{q} \gamma W_{t-j} + e_t \tag{5}$$

In this equation, Y is the dependent variable, W is the explanatory variables, δ, θ and γ are the estimated coefficients of the model and e_t is the error term.

When equation (4a) is adapted to the ARDL model, it can be written as follows (Equation 6):

$$\Delta lnQ_{it} = a_0 + \emptyset_i \sum_{j=1}^{p} \Delta lnQ_{i,t-j} + \theta_i \sum_{j=1}^{q} \Delta lnL_{i,t-j} + \beta_i \sum_{j=1}^{q} \Delta lnL_{i,t-j} + \pi ECT_{t-1} + \varphi_1 lnQ_{i,t-1} + \varphi_2 lnL_{i,t-1} + \varphi_3 lnK_{i,t-1} + u_{it} \tag{6}$$

In this equation, Δ is the difference operator, $\emptyset_i$, θ_i and $\beta_i$are the short-run coefficients, ECT is the error correction term explained from the long-run equilibrium relationship, φ_i is the long-run coefficients and u_{it} is the error term.

3. RESULTS

Before applying the ARDL method, the variables should be tested for unit root tests. Table 2 analyzes the stationarity of the variables used in the study with IPS and Breitung unit root tests. These tests are an important method to determine whether the variables used in panel data analysis have a constant mean and variance over time (Baltagi, 2008). The results of whether the variables are stationary at I(0) and at first difference I(1) are reflected in the table. The IPS and Breitung panel unit root test results have been summarized. Although the level values of the series contain unit roots, they are stationary at a 1% significance level when the first differences are taken.

Table 2: Unit root tests.

Variables	IPS		Breitung	
	I(0)	I(1)	I(0)	I(1)
lnQ	-0.862 (0.194)	-4.086 (0.000)	-2.051 (0.020)	-2.898 (0.002)
lnL	0.179 (0.571)	-6.579 (0.000)	-0.582 (0.281)	-5.168 (0.000)
lnK	-0.475 (0.318)	-5.578 (0.000)	-1.557 (0.059)	-7.291 (0.000)

Note: The values in parentheses are probability values.

Table 3 presents the results of Pedroni and Kao cointegration tests. Pedroni and Kao tests are common methods used in panel data analysis to assess whether there is a long-run relationship between variables. In this context, the test results are critical to understand whether the hypotheses of the study are supported or not.

According to the Pedroni test results, the p-values for Panel PP, Panel ADF, Group PP and Group ADF statistics are less than 0.01. This indicates the existence of a long-run cointegration relationship between the variables. The consistent significance of both panel and group statistics of the Pedroni test strongly supports the existence of a long-run equilibrium relationship between the variables used. The results of the Pedroni test provide a reliable framework for assessing cointegration relationships, especially in heterogeneous panels.

The results of the Kao test indicate that the ADF statistic is -2.798 and the corresponding p-value is 0.0026. This result again supports the cointegration hypothesis at the 0.01 significance level. The Kao test is used for cointegration analysis, especially in less complex panels, as it offers a simpler structure. These results support the findings from the Pedroni test.

Table 3. Panel Cointegration Test.

	Statistic	**Prob.**
Pedroni Test		
Panel PP	-4.685	0.0000
Panel ADF	-5.211	0.0000
Group PP	-3.455	0.0003
Group ADF	-4.196	0.0000
Kao Test		
	t-stat	**Prob.**
ADF	-2.798	0.0026

In general, the results of both Pedroni and Kao tests reveal the existence of a long-run relationship between the analyzed variables. This finding suggests that the model provides a solid basis for making forecasts and developing policy recommendations based on long-run relationships. As noted in the literature (Pedroni, 1999; Kao, 1999), such cointegration tests are critical for understanding long-run dynamics in panel data models.

Table 4 presents the results of the panel ARDL model estimated separately for two dependent variables: lnQ (output) and lnL (labor). The analysis distinguishes between long-run equilibrium relationships and short-run dynamic adjustments. In the first model, where lnQ is the dependent variable, the ARDL (3,2,2) specification reveals that labor has a statistically significant and positive impact on output at the 1% level. Specifically, a 1% increase in the labor force leads to an approximate 1.8% increase in output, highlighting the labor-intensive nature of the fisheries sector in Türkiye. Conversely, capital investment exerts a negative long-run effect on output, also significant at the 1% level. This result suggests that capital accumulation, in its current form, may not be aligned with productivity-enhancing outcomes.

The negative impact of capital in both the short and long run can be attributed to several sector-specific inefficiencies. In Türkiye, capital investments in fisheries are often channeled into outdated or inefficient assets, such as aging vessels and insufficiently modernized infrastructure. These may fail to enhance production capacity and, in some cases, even generate cost burdens. Furthermore, regional mismatches in capital allocation, combined with weak strategic planning and limited technological integration, reduce the productivity of capital. The dominance of small-scale enterprises, coupled with restricted access to finance and expertise, may also hinder the transformation of capital into effective output. Environmental constraints—such as overfishing, marine pollution, and diminishing fish stocks—further suppress the marginal return on capital investments. Collectively, these factors underscore the need for coordinated, region-specific investment strategies to ensure capital contributes positively to production growth.

In the second model, where lnL is the dependent variable and the ARDL (1,2,2) specification is used, both output and capital are found to have positive and statistically significant effects on employment in the long run. This finding indicates that production growth fosters labor demand, while capital investments play a supportive role in job creation within the sector. Notably, the error correction term is negative and highly significant (-0.7885), indicating a strong and rapid adjustment toward long-run equilibrium following short-run deviations. While some short-run coefficients are not statistically significant in either model, the presence of a significant error correction mechanism suggests that sectoral imbalances are eventually corrected over time.

In summary, the ARDL analysis offers valuable insights into the dual dynamics of labor and capital in Türkiye's fisheries sector. Labor emerges as a consistently productive input in terms of enhancing output, while capital contributes meaningfully to employment but not directly to production. These asymmetric impacts highlight the importance of restructuring capital investments and fostering labor efficiency as complementary strategies for sustainable sectoral development.

Table 4. Panel ARDL Results.

lnQ dependent – ARDL (3,2,2)		lnL dependent – ARDL (1,2,2)	
Variables	**Coefficient**	**Variables**	**Coefficient**
Long Run Equation		**Long Run Equation**	
lnL	1.7989***	lnQ	0.2224***
lnK	-1.1838***	lnK	1.8125***
Short Run Equation		**Short Run Equation**	
COINTEQ01	-1.1902	COINTEQ01	-0.7885***
D(LNQ(-1))	0.6059	D(LNQ)	-0.2511*
D(LNQ(-2))	0.4986*	D(LNQ(-1))	-0.0993*
D(LNL)	-0.8549	D(LNK)	0.0962
D(LNL(-1))	-2.1406**	D(LNK(-1))	-0.0428
D(LNK)	2.0339	C	-6.2826***
D(LNK(-1))	2.3728*		
C	6.0587		

4. DISCUSSION

This study investigates the dynamic interactions between production, labor, and capital in Türkiye's fisheries sector, with a particular focus on their effects on output and employment. The results reveal both parallels and divergences from the international literature and highlight country-specific dynamics that warrant closer policy attention. Notably, the first model indicates a negative and statistically significant relationship between capital and output. While prior studies generally report a positive association between capital investments and production efficiency (Carlson et al., 2020; Triezenberg et al., 2020), the findings of this study align more closely with the Türkiye-specific challenges emphasized by Kekül (2024) and Gün and Kızak (2019). These challenges include inefficient capital allocation, the use of outdated technologies, and ecological degradation, all of which collectively reduce the productivity of capital.

One of the critical structural explanations for this outcome is the imbalance in capital distribution across regions. Particularly in the Marmara and Western Black Sea regions, declining fish stocks and industrial pollution have undermined the effectiveness of vessel-based investments. Instead of improving infrastructure or investing in sustainable production systems, capital expenditures in these areas have disproportionately targeted vessel numbers, which do not necessarily enhance output. While Ainsworth et al. (2023) emphasize that capital effectiveness depends on technological modernization and spatial planning, this study shows that such strategic planning remains limited in Türkiye's fisheries sector.

In contrast, the second model demonstrates that capital positively affects employment, indicating that investments—albeit structurally limited—still generate labor demand. This finding is consistent with studies that highlight the labor-intensive nature of modernized equipment used in fisheries (Teh & Sumaila, 2011; Öztürk & İbik, 2023). Moreover, the positive and significant impact of labor on output reinforces the observation that Türkiye's fisheries sector continues to rely on labor-driven production dynamics. These outcomes suggest that the transition to a capital-intensive model has not yet materialized, and that growth continues to be supported primarily by human capital.

From a policy perspective, these findings underline the importance of region-specific and functional capital planning. Policymakers should prioritize investments in sustainable infrastructure, such as cold chain systems, harbor modernization, eco-friendly aquaculture facilities, and fish processing centers. In underperforming regions, public funding should be directed toward upgrading logistics, energy efficiency, and ecosystem restoration, particularly where overfishing and pollution have reduced natural resource availability.

To implement regional incentive policies more effectively, differentiated support mechanisms should be developed based on local needs and resource capacities. For instance, in the Marmara region, where environmental degradation limits productivity, incentives should focus on pollution control infrastructure and transitioning to aquaculture. In contrast, in the Eastern Black Sea region, where labor remains highly productive, support should target training programs, cooperative formation, and improved vessel maintenance. National fisheries policy should be restructured to include a regional performance-based investment framework, where subsidies and credits are allocated in line with ecological carrying capacity, labor absorption potential, and technological innovation.

Moreover, policy design should involve multi-stakeholder platforms that include fishers' cooperatives, local authorities, universities, and NGOs to ensure that investment decisions reflect on-the-ground realities. Performance monitoring systems should be integrated into these programs to evaluate the long-term impact of public support on productivity, sustainability, and employment. The success of such policies will depend on administrative coordination, targeted financing, and clear long-term strategies that link sectoral investment to national development goals.

In summary, this study contributes to the literature by offering an empirical explanation for why capital investments in Türkiye's fisheries sector have failed to yield the expected production gains. It also confirms the continued relevance of labor as a growth driver and offers concrete, context-specific policy recommendations. These include restructuring capital allocation strategies, designing regionally differentiated incentives, and enhancing human capital development—all of which are crucial for achieving long-term sustainability and competitiveness in the sector.

5. CONCLUSION

In light of the findings of the study, a number of policy recommendations can be offered to support sustainable growth and increase the efficiency of capital investments in Türkiye's fisheries sector. First, capital investments should be directed towards more efficient and modernized equipment. Replacing outdated technologies with modern fishing equipment can both increase production capacity and reduce costs. Secondly, it is important to implement region-based incentive policies to address the imbalances in capital allocation across regions. Increasing infrastructure investments, especially in regions with low production capacity such as Marmara and the Western Black Sea, can increase productivity in the sector.

Thirdly, increasing incentives for aquaculture can offset the sustainability problems experienced in fisheries-based production. It is stated in the literature that aquaculture activities offer significant opportunities in terms of both production and employment in the fisheries sector (FAO, 2020). In this context, technology and infrastructure investments should be prioritized, especially in regions with high aquaculture potential such as the Aegean and Mediterranean. In addition, the implementation of sector-specific training and certification programs to increase the quality of the workforce can contribute to sustainable growth in production and employment. However, the feasibility of these policies is directly related to the effective use of financial resources and the development of solutions that are in line with local dynamics. It is critical that policymakers develop strategies that are sensitive to local needs, considering regional differences.

This study has several important limitations. First, the dataset used focuses only on Türkiye's fisheries sector and does not include international comparisons. This may limit the general validity of the results. Second, the variables used in the analysis focus only on the capital and labor dimensions of the effects on sectoral growth and employment. However, other important variables such as energy costs, environmental factors and government policies are not considered in this study. Future studies can provide a more comprehensive analysis by including these variables.

In addition, although regional disparities were analyzed in the study, the causes of these disparities were not examined in detail. By examining the causes of interregional disparities in more depth, future research can reveal how sectoral policies can be more effective at the regional level. Moreover, the use of different methods (e.g. structural equation models or spatial econometric analyses) may be useful to assess the relationships between variables in a broader framework. Further studies in line with these recommendations will provide a stronger and more comprehensive knowledge base for the sustainable growth of the fisheries sector.

CONFLICTS OF INTEREST

The authors affirm that there are no identifiable financial or personal conflicts that could impact the research.

ETHICS APPROVAL

The study did not require any specific ethical approval.

DATA AVAILABILITY

For inquiries for datasets, please contact the corresponding author.

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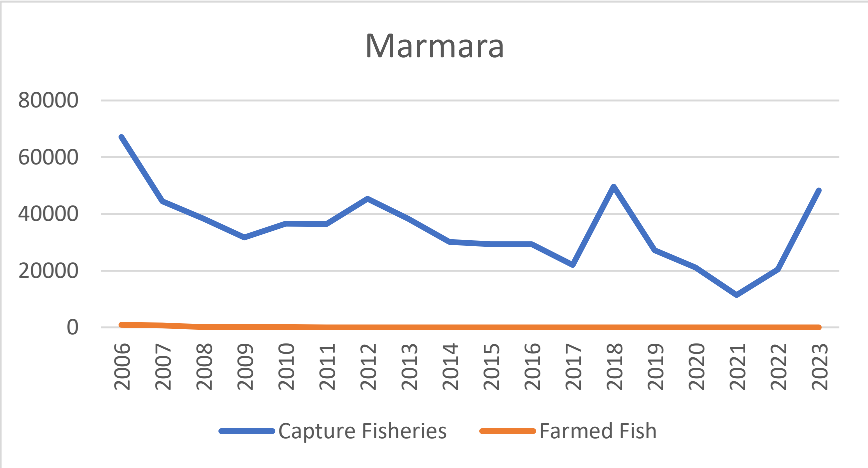
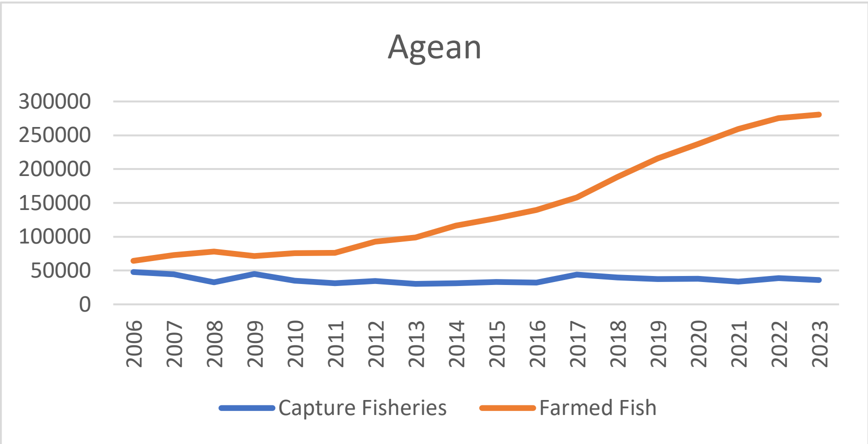
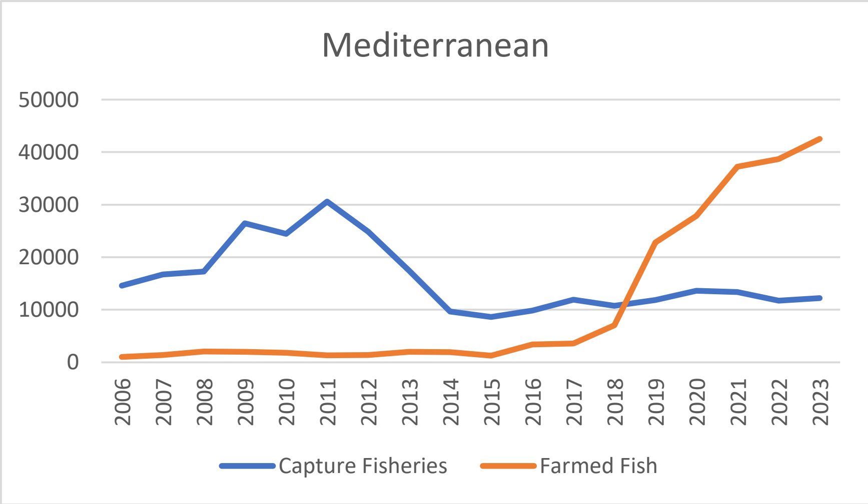
APPENDIX

Figure A1.



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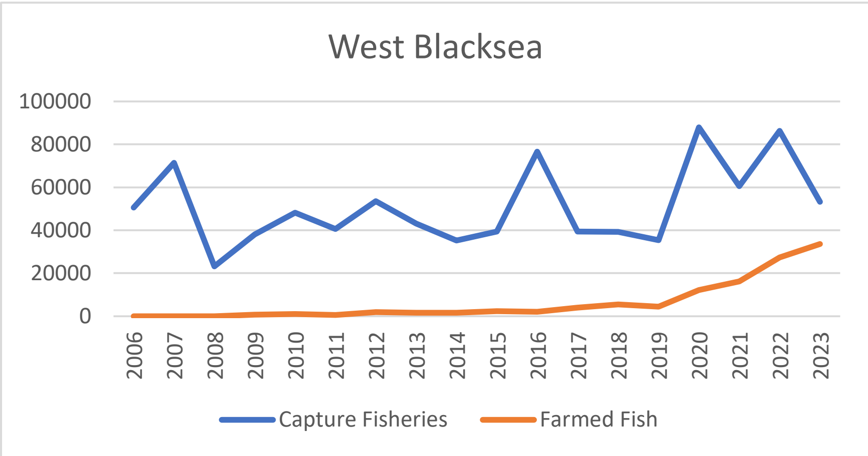
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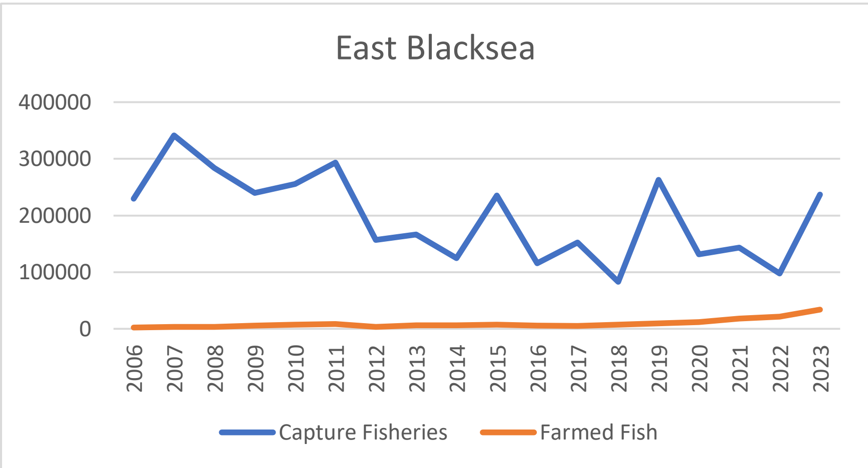
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