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Regional Specialization and Economic Impacts of Aquaculture in Korea: An Analysis of Key Species

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Abstract

Purpose: This study aims to assess the current state of aquaculture in Korea and evaluate regional competitiveness for major aquaculture species: flounder, rockfish, sea bream, and yellowtail. It seeks to identify the unique characteristics of aquaculture across various regions to enhance understanding of regional dynamics and industry trends. **Research design, data and methodology:** It utilizes Location Quotient, Shift Share Analysis, and combined analysis of the two methods to investigate regional specialization and growth factors in the farming of major aquaculture species. Data from the Fishery Aquaculture Trend Survey for 2018 and 2023 were analyzed, covering 30 administrative districts with detailed production values. **Results:** The analysis reveals varying regional specializations in aquaculture across Korea, with the East Coast showing high specialization in yellowtail but low in other species, and the South Coast demonstrating diverse specialization patterns depending on the region. It highlights that while the East Coast excels in sea bream and yellowtail, and the West Coast in rockfish, regional competitiveness for other species varies. **Conclusions:** It provides insights into regional variations in aquaculture specialization and competitiveness, identifying key regions for each species and offering a basis for targeted policy development. It suggests more frequent assessments to accurately monitor regional trends.

Keywords : Aquaculture, Regional Specialization, Location Quotient, Shift Share Analysis

JEL Classification Code: C25, C51, D12

1. Introduction

Aquaculture has been continuously growing, and since 2022, farmed aquatic products have accounted for more than half of the world's seafood production. It is estimated that by 2032, production will increase by 17% compared to current levels, with farmed seafood expected to make up 60% of the total seafood consumed by humans (FAO, 2024). As such, aquaculture is being recognized as a critical industry that will sustain future food supplies, with its role being highlighted from a food security perspective as well. From the 1970s through the 1990s, global fish catch steadily increased. However, due to population growth, overfishing, climate change, environmental pollution, and eutrophication, there has been a consistent decline throughout the 2000s and 2010s (Hardy, 2003; IPCC, 2014; Rice & Garcia, 2011;

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Sibley & Strickland, 1985). In 2020, during the COVID-19 pandemic, there was a significant decrease in fish catch (FAO, 2022). Amidst these conditions, the increase in aquaculture production has helped offset the decline in fish catch, thereby contributing to the stabilization of overall seafood production. Additionally, advancements in technology have improved aquaculture production efficiency, and the expansion of farmable species is expected to contribute to food security (Subasinghe et al., 2009).

In response, South Korea has recognized the importance of aquaculture and is making various efforts to promote its development. The government has established a legislative foundation for the growth and sustainable development of aquaculture by separating it from the Fisheries Act and enacting the Aquaculture Industry Development Act (Choi, 2022). Additionally, the government formulates the "Basic Plan for Aquaculture Industry Development," which assesses the current status and prospects of the industry and outlines policy directions, on a five-year cycle (Ministry of Oceans and Fisheries, 2023).

In Korea, most fish aquaculture production is consumed in the form of raw fish, making the management of the distribution system a critical issue. However, the current distribution relies heavily on non-systematic shipment through local collectors, leading to complex distribution channels and difficulties in management (Ministry of Oceans and Fisheries, 2023). Therefore, understanding the production areas is essential for establishing and managing an efficient distribution network.

As interest in aquaculture continues to grow, there is an increasing need to approach the industry from an economic perspective, assess its competitiveness, and conduct targeted research. Therefore, it is meaningful to focus on the regional aspects of aquaculture and evaluate their status. This study aims to review the current state of aquaculture in South Korea, analyze regions specialized in major aquaculture species, and ultimately present the unique characteristics of aquaculture in each area.

2. Literature Review

Aquaculture is mainly categorized into land-based tank aquaculture and offshore cage aquaculture, and it has been found that technical efficiency varies depending on the species in Korea (Park, 2012). Land-based tank aquaculture has shown significant advantages in spatial efficiency and productivity due to its capability to farm fish at high densities, with the removal of harmful substances and management of overstock being critical for maintaining productivity (Eh, 2014). Offshore cage aquaculture, on the other hand, allows for large-scale production, providing benefits in terms of economies of scale (Kam et al., 2003). In Korea, most farms using the offshore cage method practice mixed-species farming to capitalize on economic benefits (Jung & Jin, 1997).

Research on the productivity of different fish species in aquaculture has mainly focused on Flounder and Rockfish (Hong et al., 2016; Jwa et al., 2020; Kim et al., 2021; Son et al., 2014; Song, 2011). The form of feed can significantly impact the profitability of aquaculture, with Flounder showing a strong relationship between survival rate and profitability (Hong et al., 2016). Specifically, live feed is advantageous in terms of growth rates, making it more favorable overall compared to cheaper formulated feeds (Song, 2011). Regionally, Jeju Island has strengths in terms of stocking density per unit area (Jwa et al., 2020), while the Wando area is noted for its high survival rates (Kim et al., 2021). In studies on Rockfish aquaculture, feed costs and labor costs were identified as the largest expenses. It was found that medium-sized farms operate most efficiently and have the highest return on investment, suggesting that medium size is the optimal scale (Son et al., 2014).

To comprehensively understand the aquaculture industry from the perspective of industrial competitiveness, it is important to consider regional specialization. While there are studies on the regional productivity of aquaculture in areas such as the South Coast (Kim & Kim, 2021), Jeju Island (Jwa et al., 2020), and Wando (Kim et al., 2021), there are few studies focused on the degree of regional specialization in aquaculture. Some research has analyzed production efficiency and specialization in the Jeonnam region (Kim, 2017), but these studies are limited to specific areas. This study examines regional specialization in Korean fish aquaculture, focusing on major aquaculture species across the entire country.

3. Research Methods and Materials

3.1. Methods

3.1.1. Location Quotient

In this study, the Location Quotient (LQ) was used to examine the regional specialization of major live fish species farming. LQ is one of the representative methods for assessing the concentration of a specific industry within a region. It compares the proportion of a particular industry in a region to the proportion of that industry at the national level, indicating how specialized a region is in that particular industry (Choi & Lee, 2021).

In this study, LQ for species w in region z (LQ_{wz}) is calculated using the formula provided in Equation (1).

$$LQ_{wz} = \frac{\frac{TP_{wz}}{TP_z}}{\frac{TP_w}{TP}} \quad (1)$$

In this context, TP denotes the total production value of the national fish farming industry, while TP_w represents the production value of fish farming for species w at the national level. TP_z refers to the production value of fish farming in region z, and TP_{wz} indicates the production value of species w in region z. Generally, if the LQ is 1 or higher, the region is considered to be specialized in that particular industry (Carroll et al., 2008; Hendayana, 2003; Miller et al., 1991).

3.1.2. Shift Share Analysis

Shift Share Analysis, along with LQ, is one of the most widely used methods for analyzing regional industries. It identifies growth factors based on the assumption that growth occurring between two specific points in time is closely related to the regional industrial structure (Ryu, 2022). The factors influencing industrial growth within a region are divided into three components: National Growth Effect (NGE), Industrial Mix Effect (IME), and Regional Share Effect (RSE) (Esteban-Marquillas, 1972; Kim & Kim, 2014).

The NGE quantifies the impact of national economic growth on regional economic growth and is represented by NGE_{wz} as follows:

$$NGE_{wz} = TP_{wz}^{2018} \times \left(\frac{TP^{2023}}{TP^{2018}} - 1\right) \quad (2)$$

where TP_{wz} denotes the production value of species w in region z, and TP signifies the total production value of the national fish farming industry, with the superscript indicating the respective year. A positive NGE suggests that the regional industry has experienced growth consistent with national economic trends.

The IME captures the influence of the structural characteristics and growth rates of a specific industry at the national level on regional industries and is represented by IME_{wz} as follows:

$$IME_{wz} = TP_{wz}^{2018} \times \left[\left(\frac{TP_w^{2023}}{TP_w^{2018}}\right) - \left(\frac{TP^{2023}}{TP^{2018}}\right)\right] \quad (3)$$

where TP_w represents the national production value for aquaculture of species w, with the superscript indicating the corresponding year. If the IME is positive, it indicates that the industry has structural competitiveness.

RSE represents the growth effects due to regional production environment and locational conditions, and RSE is defined by RSE_{wz} as follows:

$$RSE_{wz} = TP_{wz}^{2018} \times \left[\left(\frac{TP_{wz}^{2023}}{TP_{wz}^{2018}}\right) - \left(\frac{TP_w^{2023}}{TP_w^{2018}}\right)\right] \quad (4)$$

If the RSE is positive, it indicates that the region has competitiveness in a particular industry (Joo, 2023). TCE represents the overall rate of change in production value from 2018 to 2023 and is defined by TCE_{wz} as follows:

$$TCE_{wz} = NGE_{wz} + IME_{wz} + RSE_{wz} \quad (5)$$

TCE is equal to the sum of the NGE, IME, and RSE, and if TCE shows a high value, it indicates that the overall competitiveness of the industry has improved, regardless of regional factors (Houston, 1967; Sihag & McDonough, 1989).

3.2. Data

In this study, data from the Fishery Aquaculture Trend Survey provided by Statistics Korea were utilized for the analysis (KOSTAT, 2024). It provides information on the status of aquaculture, production volume, and production value by region, aquaculture method, and species on an annual basis. Four major aquaculture species— flounder, rockfish, sea bream, and yellowtail—were selected based on their popularity as preferred raw fish among the public (Kim et al., 2024). The analysis focuses on the years 2018 and 2023. During this period, the aquaculture of the four major species occurred in the following regions: Busan (1 region: Gijang), Ulsan (1 region: Ulju), Gangwon (2 regions: Gangneung, Samcheok), Chungnam (4 regions: Boryeong, Seosan, Taean, Dangjin), Jeonbuk (1 region: Buan), Jeonnam (8 regions: Yeosu, Goheung, Jangheung, Gangjin, Haenam, Wando, Jindo, Shinan), Gyeongbuk (4 regions: Pohang, Gyeongju, Yeongdeok, Uljin), Gyeongnam (7 regions: Tongyeong, Sacheon, Geoje, Goseong, Namhae, Hadong, Changwon), and Jeju Island (2 regions: Jeju, Seogwipo). In total, 30 administrative districts were included in the analysis.

The production values of aquaculture species for live fish used in sashimi in Korea is shown in Table 1. The total production value of fish farming increased by 20.5%, rising from 929,167 million KRW in 2018 to 1,119,367 million KRW in 2023. Specifically, the production value of flounder farming grew by 30.5%, from 495,391 million KRW in 2018 to 646,430 million KRW in 2023. Conversely, the production value of rockfish farming decreased by 24.0%, falling from 192,448 million KRW in 2018 to 146,240 million KRW in 2023. The production value of sea bream farming increased by 10.8%, from 106,789 million KRW in 2018 to 118,351 million KRW in 2023. Additionally, the production value of yellowtail farming nearly doubled, with

a substantial increase of 98.6%, rising from 5,265 million KRW in 2018 to 10,456 million KRW in 2023.

Table 1: The production value of live fish by species in Korea

Species	2018	2023	% Change
Flounder	495,391	646,430	30.5%
Rockfish	192,448	146,240	-24.0%
Sea Bream	106,789	118,351	10.8%
Yellowtail	5,265	10,456	98.6%
Total	929,167	1,119,367	20.5%

Source: KOSTAT, (2024). *Fishery Aquaculture Trend Survey*
Note: The unit of production value is million KRW

4. Results

4.1. Location Quotient

The LQ for each fish species and region was calculated based on production values from 2018 and 2023. The results of the LQ calculation for flounder farming are represented in Figure 1. The analysis revealed that the LQ values for flounder farming ranged from a minimum of 0.02 to a maximum of 1.88 in 2018, and from a minimum of 0.00 to a maximum of 1.73 in 2023. The range of LQ values slightly decreased in 2023 compared to 2018. For the East Coast, Ulsan (Ulju) exhibited an LQ of 1 or higher in 2018 but fell below 1 in 2023. Conversely, Gangwon (Gangneung) and Gyeongbuk (Pohang, Gyeongju, Uljin) consistently had LQ values below 1 in both years, indicating lower specialization in flounder farming in these regions.

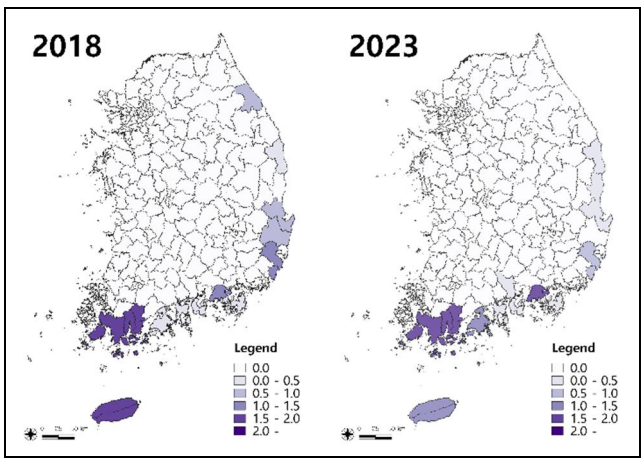

Figure 1: LQ for Flounder Aquaculture (Production Value)

On the South Coast, Busan (Gijang) had an LQ of 1 or higher in 2018 but decreased to below 1 in 2023, reflecting a reduction in specialization. In Gyeongnam, Goseong maintained an LQ of 1 or higher in both years, whereas other Gyeongnam regions (Tongyeong, Geoje, Namhae, Hadong) had LQ values below 1 in both 2018 and 2023, suggesting a lower level of specialization in flounder farming in these areas. In Jeonnam, Goheung's LQ increased from below 1 in 2018 to above 1 in 2023, indicating a rise in specialization. In contrast, Yeosu's LQ remained below 1 in both years. The remaining Jeonnam regions (Jangheung, Gangjin, Haenam, Wando, Jindo) consistently had LQ values above 1 in both years, demonstrating high specialization in flounder farming in Jeonnam. On Jeju Island, both Jeju and Seogwipo had Location Quotient (LQ) values exceeding 1 in 2018 and maintained values above 1 in 2023, indicating a high level of specialization in flounder farming in these regions.

The LQ values for rockfish farming ranged from a minimum of 0.00 to a maximum of 4.83 in 2018, and from a minimum of 0.01 to a maximum of 7.65 in 2023 (see Figure 2). Regionally, on the East Coast, Pohang in Gyeongbuk had LQ values below 1 in both 2018 and 2023, while Gyeongju had an LQ above 1 in 2018 but below 1 in 2023. This indicates that the East Coast generally exhibits low specialization in rockfish farming.

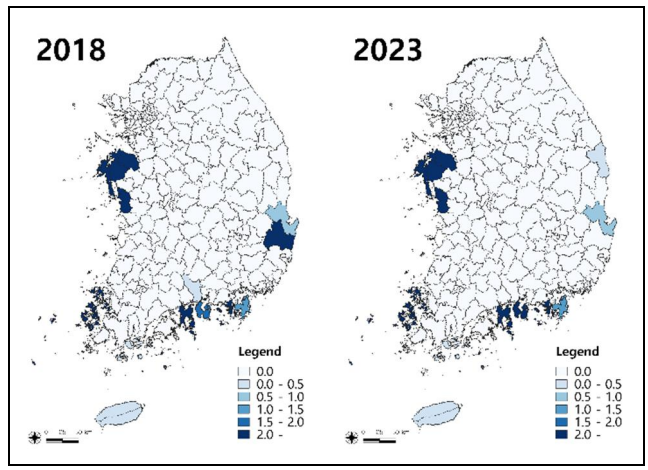

Figure 2: LQ for Rockfish Aquaculture (Production Value)

On the South Coast, within Gyeongnam, Hadong had LQ values below 1 in both 2018 and 2023, whereas Tongyeong, Geoje, and Namhae consistently had LQ values above 1 in both years. Consequently, Gyeongnam is identified as a region with high specialization in rockfish farming. In Jeonnam, Yeosu had LQ values above 1 in both 2018 and 2023, whereas Wando had LQ values below 1 in both years. On Jeju Island, both Jeju and Seogwipo exhibited LQ values below 1 in 2018 and remained below 1 in 2023, indicating low specialization in rockfish farming on the island. On the West Coast, Chungnam (Boryeong, Seosan, Taean, Dangjin) and Jeonnam (Shinan) had LQ values exceeding 1 in both 2018 and 2023, suggesting that the West Coast has high specialization in rockfish farming.

In 2018, the LQ range for the sea bream aquaculture industry was from a minimum of 0.04 to a maximum of 7.09, and in 2023, it ranged from a minimum of 0.08 to a maximum of 9.46 (see Figure 3). By region, in the East Coast area, the LQ of Gyeongbuk (Pohang) was below 1 in both 2018 and 2023. Therefore, the East Coast can be considered a region with a low degree of specialization in the sea bream aquaculture industry.

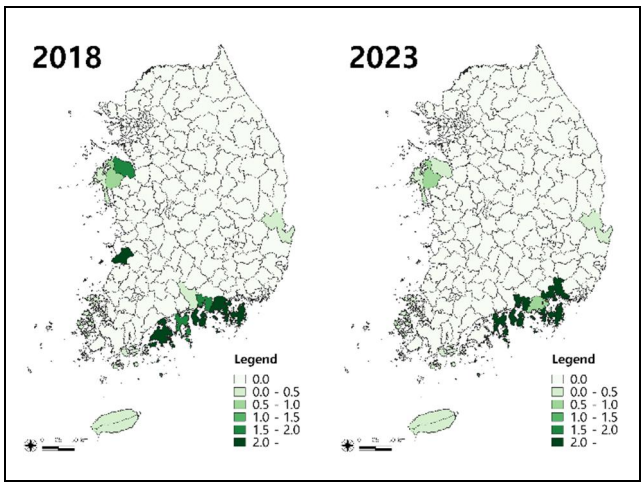

Figure 3: LQ for Sea Bream Aquaculture (Production Value)

In the South Coast area, within Gyeongnam, Tongyeong, Sacheon, Geoje, and Namhae had LQs above 1 in both 2018 and 2023, while Goseong had an LQ above 1 in 2018 but below 1 in 2023. Conversely, Changwon had an LQ below 1 in 2018 but above 1 in 2023. Hadong had LQs below 1 in both 2018 and 2023. Therefore, Gyeongnam is considered a region with a high degree of specialization in the sea bream aquaculture industry. In Jeonnam, Yeosu had LQs above 1 in both 2018 and 2023, while Wando had LQs below 1 in both years. In the Jeju region, both Jeju and Seogwipo had LQs below 1 in both 2018 and 2023, indicating that Jeju Island can be considered a region with a low degree of specialization in the sea bream aquaculture industry. In the West Coast area, Jeonnam (Shinan) had LQs below 1 in both 2018 and 2023. In Chungnam, Dangjin, Buan, and Goheung had LQs above 1 in 2018 but below 1 in 2023, while Seosan and Taean had LQs below 1 in both years. Therefore, the West Coast region can be considered to have a low degree of specialization in the sea bream aquaculture industry.

In 2018, the LQ range for the yellowtail aquaculture industry was from a minimum of 0.14 to a maximum of 176.48, and in 2023, it ranged from a minimum of 0.13 to a maximum of 107.06 (see Figure 4). The LQ values for the yellowtail aquaculture industry showed a very large variation, likely because yellowtail aquaculture is conducted in only a very few regions, and the production areas for yellowtail generally do not produce other species or produce very little of them. By region, in the East Coast area, within Gangwon, Samcheok had an LQ above 1 in both 2018 and 2023. In Gyeongbuk, Pohang had an LQ above 1 in both 2018 and 2023, and Yeongdeok had an LQ below 1 in 2018 but increased to above 1 in 2023. Therefore, the East Coast can be considered a region with a high degree of specialization in the yellowtail aquaculture industry.

In the South Coast area, within Gyeongnam, Geoje had an LQ above 1 in 2018 but fell below 1 in 2023, while Tongyeong had LQs below 1 in both 2018 and 2023. In Jeonnam, Yeosu had LQs below 1 in both 2018 and 2023. Therefore, the South Coast can be considered a region with a low degree of specialization in the yellowtail aquaculture industry.

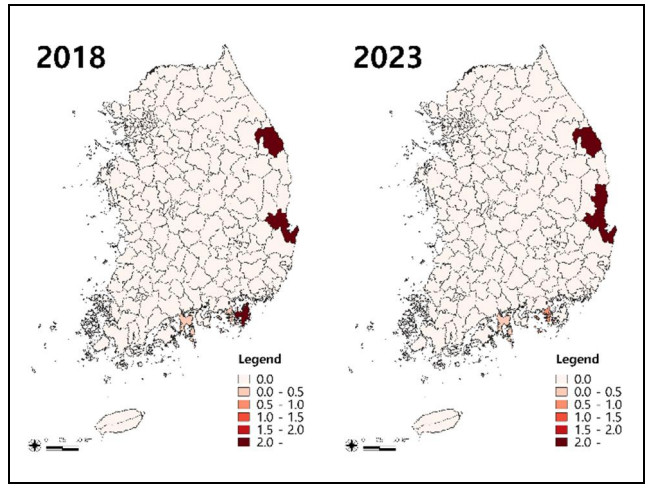

Figure 4: LQ for Yellowtail Aquaculture (Production Value)

The analysis of regional specialization in aquaculture using the LQ indicates that in the metropolitan cities of Busan and Ulsan, the specialization in aquaculture is low regardless of the species. On the East Coast, the specialization in yellowtail aquaculture is high, while the specialization in flounder, rockfish, and sea bream aquaculture is low. In the South Coast, the specialized species vary by region. In Gyeongnam, Goseong shows a high degree of specialization in flounder aquaculture, while Sacheon and Changwon have a high specialization in sea bream aquaculture. Tongyeong, Geoje, and Namhae show high specialization in both rockfish and sea bream aquaculture but low specialization in flounder aquaculture. In Jeonnam, Yeosu has a low specialization in flounder aquaculture but high specialization in rockfish and sea bream aquaculture. In Wando and other areas, the specialization in flounder aquaculture is high, while the specialization in rockfish and sea bream aquaculture is low. On Jeju Island, there is high specialization in flounder aquaculture, but low specialization in rockfish and sea bream aquaculture. On the West Coast, the specialization in

rockfish aquaculture is high, while the specialization in sea bream aquaculture is low.

4.2. Shift Share Analysis

Using the production values from 2018 and 2023, a Shift-Share Analysis was performed by species and region. The total production value of the fish aquaculture industry in South Korea increased from 929,167 million KRW in 2018 to 1,119,367 million KRW in 2023, resulting in a positive NGE_{ij}.

In the TCE_{ij}, the share of NGE_{ij} is consistently 20.47% across all species and regions. In Flounder aquaculture, the region with the highest NGE_{ij} is Seogwipo, with 39,090 million KRW, while the region with the lowest NGE_{ij} is Uljin, with 29 million KRW. In Rockfish aquaculture, the highest NGE_{ij} is found in Tongyeong, with 12,470 million KRW, and the lowest is in Jeju, with 11 million KRW. For Sea Bream aquaculture, Tongyeong has the highest NGE_{ij} at 9,892 million KRW, while Hadong has the lowest at 30 million KRW. In Yellowtail aquaculture, Pohang has the highest NGE_{ij} at 835 million KRW, and Yeosu and Tongyeong have the lowest at 20 million KRW.

The production value of flounder aquaculture increased from 495,391 million KRW in 2018 to 646,430 million KRW in 2023, giving a positive IME_{ij}, with a growth rate of 10.0% (see Table 2). By region, in the East Coast area, while the total production value in Ulju, Ulsan, increased, the RSE_{ij} is negative (see Figure 5), indicating that the region lacks competitiveness, and the increase in production value is due to national and industry growth rather than regional factors. Additionally, both the RSE_{ij} and TCE_{ij} for Gangwon and Gyeongbuk are negative, indicating that despite national and industry growth, the production value of flounder aquaculture in these regions declined due to low competitiveness. Therefore, it can be concluded that the East Coast region has low competitiveness in flounder aquaculture.

The South Coast region exhibits high competitiveness in flounder aquaculture. In Gyeongnam, both Geoje and Namhae have positive values for RSE_{ij} and TCE_{ij}, indicating that high regional competitiveness, coupled with overall national growth, contributes to the increase in production value. Conversely, Goseong shows negative values for both RSE_{ij} and TCE_{ij}, suggesting that low regional competitiveness has resulted in a decline in production value. In Tongyeong, although RSE_{ij} is negative, TCE_{ij} is positive, implying that despite low regional competitiveness, the combined effects of the NGE and IME have led to an overall increase in production value.

Table 2: The Shift Share Analysis Results for Flounder

Region	IME	RSE	TCE
Gijang	184 (10.0%)	-1,329 (-72.5%)	-770 (-42.0%)
Ulju	209 (10.0%)	-277 (-13.3%)	359 (17.2%)
Gangneung	94 (10.0%)	-1,223 (-130.5%)	-937 (-100.0%)
Yeosu	59 (10.0%)	358 (61.3%)	536 (91.8%)
Goheung	69 (10.0%)	984 (142.6%)	1,194 (173.0%)
Jangheung	585 (10.0%)	5,320 (91.1%)	7,101 (121.6%)
Gangjin	166 (10.0%)	-256 (-15.4%)	250 (15.1%)
Haenam	857 (10.0%)	832 (9.7%)	3,439 (40.2%)
Wando	16,652 (10.0%)	27,189 (16.4%)	77,862 (46.8%)
Jindo	483 (10.0%)	3,479 (72.2%)	4,948 (102.7%)
Pohang	1,163 (10.0%)	-9,375 (-80.7%)	-5,835 (-50.3%)
Gyeongju	27 (10.0%)	-351 (-130.5%)	-269 (-100.0%)
Uljin	14 (10.0%)	-49 (-34.8%)	-6 (-4.3%)
Tongyeong	131 (10.0%)	-104 (-8.0%)	294 (22.5%)
Geoje	496 (10.0%)	6,014 (121.6%)	7,523 (152.0%)
Goseong	324 (10.0%)	-1,720 (-53.1%)	-733 (-22.7%)
Namhae	258 (10.0%)	5,009 (194.2%)	5,795 (224.7%)
Jeju	8,730 (10.0%)	-18,034 (-20.7%)	8,533 (9.8%)
Seogwipo	19,133 (10.0%)	-16,910 (-8.9%)	41,313 (21.6%)

Note: The unit of measurement is million KRW. The values in parentheses indicate the increase in production value in 2023 compared to the production value in 2018.

For Gyeongnam, the sum of RSE_{ij} values for Tongyeong, Geoje, Goseong, and Namhae is 6,199.60 million KRW, and the sum of TCE_{ij} values is 12,879.00 million KRW. This indicates that Gyeongnam maintains a competitive edge in flounder aquaculture.

In Jeonnam, Yeosu, Goheung, Jangheung, Haenam, Wando, and Jindo have positive values for both RSE_{ij} and TCE_{ij}, demonstrating that high regional competitiveness, in conjunction with national growth, drives the increase in production value. Gangjin, while exhibiting a negative RSE_{ij}, has a positive TCE_{ij}, suggesting that although regional competitiveness is low, the combined impact of the NGE and IME has resulted in an overall increase in production value. For Jeonnam, the total sum of RSE_{ij} values for Yeosu, Goheung, Jangheung, Gangjin, Haenam, Wando, and Jindo is 37,904.88 million KRW, while the total sum of TCE_{ij} values is 95,330.00 million KRW. This indicates that Jeonnam demonstrates significant competitiveness in flounder aquaculture.

In Gijang, Busan, both RSE_{ij} and TCE_{ij} have negative values, indicating that despite national and industry growth during the period, the low regional competitiveness has led to a decrease in flounder aquaculture production value. For Jeju Island, while the production value of flounder aquaculture in both Jeju and Seogwipo has increased, the negative RSE_{ij} suggest that regional competitiveness is lacking. Nevertheless, the overall growth

of the national and industry sectors has driven the increase in production value, indicating low competitiveness in flounder aquaculture.

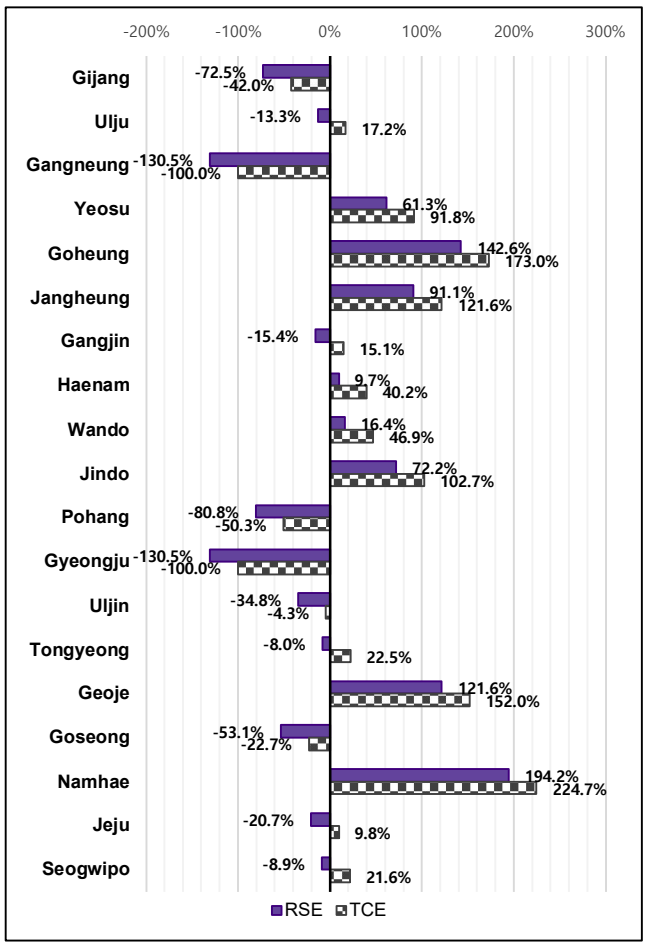

Figure 5: Regional RSE and TCE for Flounder Aquaculture

In 2023, the production value of fish aquaculture increased compared to 2018. However, the production value of rockfish aquaculture decreased from 192,448 million KRW to 146,240 million KRW over the same period. This results in a negative IME_{ij}, which stands at -44.5% (see Table 3). Regionally, on the East Coast, Pohang in Gyeongbuk saw a decrease in total production value. Despite this, the positive RSE_{ij} indicates that Pohang remains a competitive region (see Figure 6). The decrease in rockfish aquaculture production is greater than the gains from national growth and regional competitiveness, leading to a reduction in overall production value. Conversely, Gyeongju in Gyeongbuk displays negative values for both RSE_{ij} and TCE_{ij}, suggesting that both industry decline and low regional competitiveness are responsible for the decrease in production value.

Table 3: The Shift Share Analysis Results for Rockfish

Region	IME	RSE	TCE
Boryeong	-1,354 (-44.5%)	1,895 (62.2%)	1,164 (38.2%)
Seosan	-709 (-44.5%)	1,809 (113.4%)	1,426 (89.4%)
Taean	-11,115 (-44.5%)	742 (3.0%)	-5,258 (-21.0%)
Dangjin	-723 (-44.5%)	138 (8.5%)	-252 (-15.5%)
Yeosu	-11,823 (-44.5%)	-5,404 (-20.3%)	-11,786 (-44.3%)
Wando	-3,866 (-44.5%)	-938 (-10.8%)	-3,025 (-34.8%)
Shinan	-13,088 (-44.5%)	5,100 (17.3%)	-1,962 (-6.7%)
Pohang	-2,185 (-44.5%)	556 (11.3%)	-623 (-12.7%)
Gyeongju	-321 (-44.5%)	-549 (-76.0%)	-722 (-100.0%)
Tongyeong	-27,097 (-44.5%)	-3,622 (-5.9%)	-18,249 (-30.0%)
Geoje	-4,617 (-44.5%)	-1,381 (-13.3%)	-3,873 (-37.3%)
Namhae	-8,152 (-44.5%)	2,175 (11.9%)	-2,225 (-12.1%)
Hadong	-40 (-44.5%)	-69 (-76.0%)	-91 (-100.0%)
Jeju	-25 (-44.5%)	41 (74.0%)	28 (50.0%)
Seogwipo	-487 (-44.5%)	-652 (-59.6%)	-915 (-83.6%)

Note: The unit of measurement is million KRW. The values in parentheses indicate the increase in production value in 2023 compared to the production value in 2018.

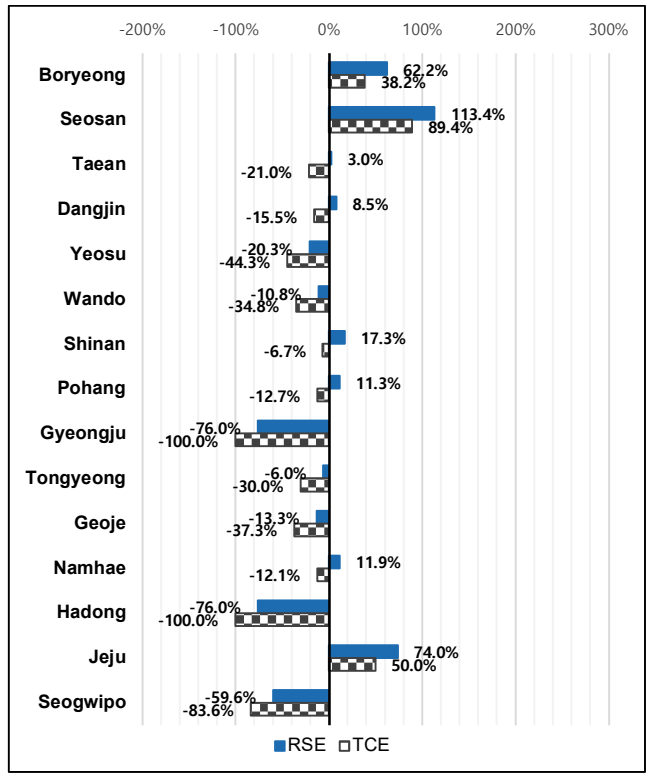

Figure 6: Regional RSE and TCE for Rockfish Aquaculture

On the South Coast, in Gyeongnam, Namhae has a positive RSE but a negative TCE, indicating that while regional competitiveness is present, it is insufficient compared to the National Growth Effect and Industrial Mixed Effect, resulting in decreased production value. In

other areas of Gyeongnam (Tongyeong, Geoje, Hadong), both RSE and TCE are negative, confirming that the decline in the industry and low regional competitiveness contribute to reduced production value. The aggregate RSE_{ij} value for Gyeongnam (Tongyeong, Geoje, Namhae, Hadong) is -2,896.86 million KRW, and the total TCE_{ij} value is -24,438.00 million KRW, suggesting that Gyeongnam lacks competitiveness in rockfish aquaculture. Similarly, in Jeonnam (Yeosu, Wando), negative values for both RSE_{ij} and TCE_{ij} indicate that the decline in the industry and low regional competitiveness are the primary factors behind the reduction in production value, reflecting low competitiveness in rockfish aquaculture.

In Jeju Island, Jeju exhibits positive values for both RSE_{ij} and TCE_{ij}, indicating that high regional competitiveness, coupled with national growth, contributes to the increase in production value. In contrast, Seogwipo has negative values for both RSE_{ij} and TCE_{ij}. The combined RSE_{ij} value for rockfish aquaculture in Jeju Island (Jeju, Seogwipo) is -610.87 million KRW, and the TCE_{ij} value is -887.00 million KRW, suggesting that Jeju Island has low competitiveness in rockfish aquaculture.

On the West Coast, Jeonnam (Shinan) shows a positive RSE_{ij} but a negative TCE_{ij}. In Chungnam, Taean and Dangjin have positive RSE_{ij} values but negative TCE_{ij} values, indicating that although regional competitiveness exists, it is outweighed by the smaller NGE and IME, leading to a decrease in production value. Conversely, Boryeong and Seosan in Chungnam show positive values for both RSE_{ij} and TCE_{ij}, demonstrating that high regional competitiveness, combined with national growth, drives the increase in production value. Therefore, the West Coast is identified as a region with competitiveness in rockfish aquaculture.

Although the production value of the grouper aquaculture increased slightly from 106,789 million KRW in 2018 to 118,351 million KRW in 2023, it did not match the overall growth rate of the aquaculture industry. Consequently, the IME_{ij} is negative, with a rate of -9.6% (see Table 4). Regionally, on the East Coast, in Gyeongbuk (Pohang), both RSE_{ij} and TCE_{ij} are positive (see Figure 7). This indicates that despite the decline in the industry, the growth at the national level and regional competitiveness have led to an increase in production value.

On the South Coast, in Gyeongnam, Sacheon and Geoje exhibit positive values for both RSE_{ij} and TCE_{ij}. This suggests that despite the industry's decline, the overall national growth and high regional competitiveness in these areas have resulted in an increase in production value. In contrast, other areas in Gyeongnam (Tongyeong, Goseong, Namhae, Hadong) show negative values for both RSE_{ij} and TCE_{ij}, indicating that the decline in the industry and low regional competitiveness are the causes of the reduction in production value. Additionally, the sum of RSE_{ij} values for Gyeongnam (Tongyeong, Sacheon, Geoje, Goseong, Namhae, Hadong) is -4,772.74 million KRW, and the sum of TCE_{ij} values is 4,107.00 million KRW, indicating significant variability within Gyeongnam. In Jeonnam (Yeosu, Wando), both RSE_{ij} and TCE_{ij} are negative, showing that the decline in the industry and low regional competitiveness are responsible for the decrease in production value, suggesting low competitiveness in grouper aquaculture. In Jeju Island, Jeju exhibits positive values for both RSE_{ij} and TCE_{ij}, indicating that high regional competitiveness, coupled with national growth, is the reason for the increase in production value. Therefore, Jeju Island is identified as a region with high competitiveness in grouper aquaculture.

On the West Coast, in Jeonnam (Shinan), both RSE_{ij} and TCE_{ij} are positive, indicating that despite the industry's decline, national growth and high regional competitiveness have led to an increase in production value. In Chungnam, Taean shows positive values for both RSE_{ij} and TCE_{ij}, suggesting that despite the industry's decline, national growth and high regional competitiveness have contributed to an increase in production value. Conversely, Seosan, Dangjin, and Buan represent negative values for both RSE_{ij} and TCE_{ij}, indicating that the decline in the industry, along with low regional competitiveness, is responsible for the reduction in production value. Thus, the West Coast is identified as a region with low competitiveness in grouper aquaculture.

Table 4: The Shift Share Analysis Results for Sea Bream

Region	IME	RSE	TCE
Seosan	-24 (-9.6%)	-47 (-18.9%)	-20 (-8.1%)
Taean	-17 (-9.6%)	132 (74.0%)	151 (84.8%)
Dangjin	-36 (-9.6%)	-341 (-90.8%)	-300 (-80.0%)
Buan	-151 (-9.6%)	-1,738 (-110.8%)	-1,568 (-100.0%)
Yeosu	-1,025 (-9.6%)	6,482 (61.0%)	7,633 (71.8%)
Goheung	-290 (-9.6%)	-3,334 (-110.8%)	-3,008 (-100.0%)
Wando	-482 (-9.6%)	389 (7.8%)	930 (18.6%)
Shinan	-35 (-9.6%)	457 (127.0%)	496 (137.8%)
Pohang	-80 (-9.6%)	1,213 (147.0%)	1,302 (157.8%)
Tongyeong	-4,660 (-9.6%)	-5,597 (-11.6%)	-365 (-0.8%)
Sacheon	-140 (-9.6%)	944 (65.1%)	1,101 (75.9%)
Geoje	-1,201 (-9.6%)	5,841 (46.9%)	7,189 (57.7%)
Goseong	-97 (-9.6%)	-898 (-89.1%)	-789 (-78.3%)
Namhae	-1,797 (-9.6%)	-4,901 (-26.3%)	-2,884 (-15.5%)
Hadong	-14 (-9.6%)	-161 (-110.8%)	-145 (-100.0%)
Jeju	-96 (-9.6%)	875 (88.3%)	982 (99.1%)
Seogwipo	-153 (-9.6%)	485 (30.5%)	657 (41.3%)

Note: The unit of measurement is million KRW. The values in parentheses indicate the increase in production value in 2023 compared to the production value in 2018.

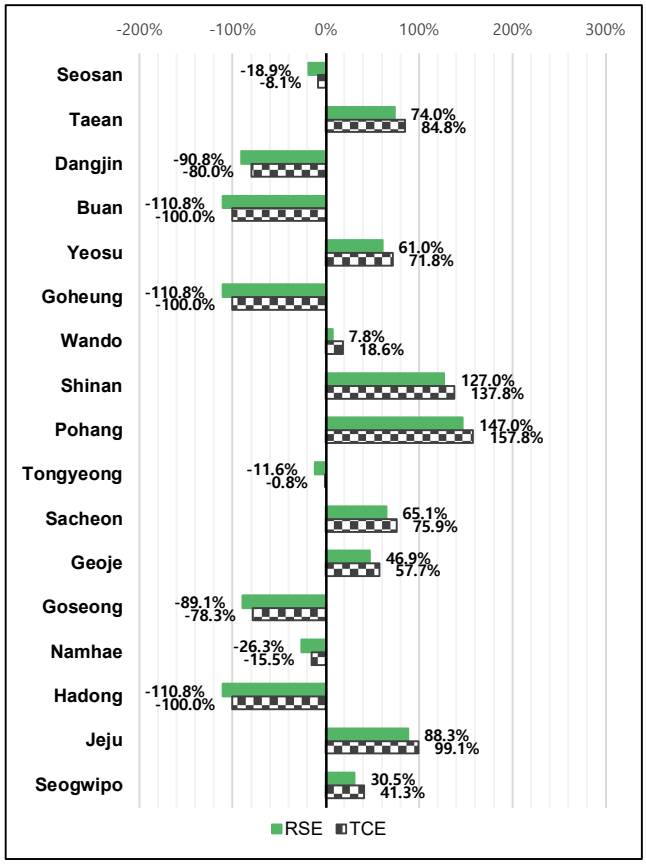

Figure 7: Regional RSE and TCE for Sea Bream Aquaculture

The production value of mackerel aquaculture increased from 5,265 million KRW in 2018 to 10,456 million KRW in 2023, resulting in a positive IME_{ij}, with a rate of 78.1%. (see Table 5). Regionally, on the East Coast, Gangwon (Samcheok) shows positive values for both RSE_{ij} and TCE_{ij} (see Figure 8). This indicates that the increase in production value is due to both industry factors and the high regional competitiveness. In contrast, Gyeongbuk (Pohang) has experienced an increase in total production value; however, with a negative RSE_{ij}, it suggests that regional competitiveness is lacking, and the increase is primarily driven by national and industry growth.

Table 5: The Shift Share Analysis Results for Yellowtail

Region	IME	RSE	TCE
Samcheok	312 (78.1%)	707 (177.1%)	1,100 (275.7%)
Yeosu	77 (78.1%)	-145 (-146.1%)	-47 (-47.5%)
Pohang	3,187 (78.1%)	-383 (-9.4%)	3,639 (89.2%)
Tongyeong	77 (78.1%)	530 (541.2%)	627 (639.8%)
Geoje	461 (78.1%)	-1,172 (-198.6%)	-590 (-100.0%)

Note: The unit of measurement is million KRW. The values in parentheses indicate the increase in production value in 2023 compared to the production value in 2018.

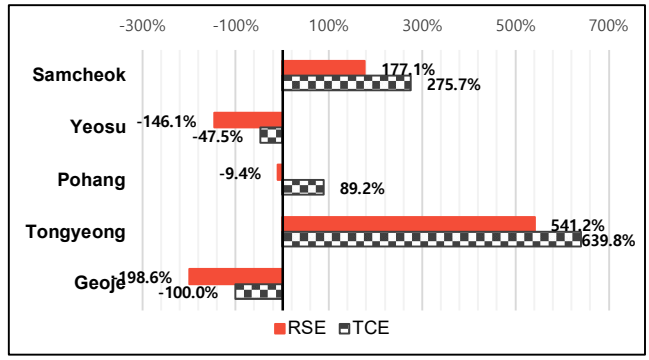

Figure 8: Regional RSE and TCE for Yellowtail Aquaculture

On the South Coast, in Gyeongnam, Tongyeong shows positive values for both RSE_{ij} and TCE_{ij}, indicating that the rise in production value is due to both industry factors and high regional competitiveness. Conversely, Geoje has negative values for both RSE_{ij} and TCE_{ij}, suggesting that despite national and industry growth, low regional competitiveness has led to a decline in production value. Similarly, Jeonnam (Yeosu) also has negative values for both RSE_{ij} and TCE_{ij}, showing that despite national and industry growth, low regional competitiveness has resulted in a decrease in production value.

The results from the Shift Share Analysis, conducted to evaluate regional competitiveness for major aquaculture species, can be summarized as follows. In the East Coast region, it was found that regional competitiveness for flounder farming is low, while the competitiveness for sea bream and yellowtail farming is high. The regional competitiveness for rockfish farming varies by area. Similarly, the South Coast region shows varying regional competitiveness by area, consistent with the results of the LQ calculation. On Jeju Island, regional competitiveness is low for both flounder and rockfish farming, but high for sea bream farming. On the West Coast, regional competitiveness is high for rockfish farming, but low for sea bream and yellowtail farming.

4.3. The Combined Analysis of LQ and Shift Share

Considering the results from both LQ and Shift Share Analysis, the major aquaculture species production regions can be categorized into six distinct types. This categorization facilitates the identification of regional trends and simplifies comparisons between different regions. As a result, specific patterns or differences can be clearly identified. Table 6 provides an explanation of the regional classification based on the integration of LQ and Shift Share Analysis.

Table 6: Regional Types from LQ and Shift Share Analysis

Type	Explanation
I	Regions specialized in both 2018 and 2023 with high regional competitiveness
II	Regions not specialized in 2018 but specialized by 2023, with regional competitiveness
III	Regions with low specialization in both 2018 and 2023 but showing regional competitiveness
IV	Regions specialized in both 2018 and 2023 but with low regional competitiveness
V	Regions specialized in both 2018 and 2023 but with low regional competitiveness
VI	Regions not specialized in either 2018 or 2023, with low regional competitivenes

According to the combined results of LQ and Shift Share Analysis for classifying flounder aquaculture regions (see Table 7), the regions are categorized as follows: Haenam, Wando, and Jindo correspond to Type I; Goheung corresponds to Type II; Yeosu, Geoje, and Namhae fall under Type III; Gangjin, Goseong, Jeju, and Seogwipo correspond to Type IV; Gijang and Ulju fall under Type V; and finally, Gangneung, Pohang, Gyeongju, Uljin, and Tongyeong correspond to Type VI.

Table 7: Classification of Flounder Aquaculture Regions Based on the Integration of LQ and Shift Share Analysis

	Location Quotient			
	2018 ≥ 1, 2023 ≥ 1	**2018 ≥ 1, 2023 < 1**	**2018 < 1, 2023 ≥ 1**	**2018 < 1, 2023 < 1**
RSE +	< Type I> Jangheung Haenam Wando Jindo	-	< Type II > Goheung	< Type III > Yeosu Geoje Namhae
RSE -	< Type IV> Gangjin Goseong Jeju Seogwipo	< Type V > Gijang Ulju	-	< Type VI > Gangneung Pohang Gyeongju Uljin Tongyeong

Note: The unit for production value is million KRW.

Based on the combined results of LQ and Shift Share Analysis as detailed in Table 8, the categorization of rockfish aquaculture regions can be described as follows: Regions that fall into Type I include Boryeong, Seosan, Taean, Dangjin, Shinan, and Namhae. Pohang and Jeju are classified under Type III. The regions designated as Type IV consist of Yeosu, Tongyeong, and Geoje. Finally, Wando, Gyeongju, Hadong, and Seogwipo are identified as Type VI.

Table 8: Classification of Rockfish Aquaculture Regions Based on the Integration of LQ and Shift Share Analysis

	Location Quotient			
	2018 ≥ 1, 2023 ≥ 1	**2018 ≥ 1, 2023 < 1**	**2018 < 1, 2023 ≥ 1**	**2018 < 1, 2023 < 1**
RSE +	< Type I> Boryeong Seosan Taean Dangjin Shinan Namhae	-	-	< Type III > Pohang Jeju
RSE -	< Type IV> Yeosu Tongyeong Geoje	-	-	< Type VI > Wando Gyeongju Hadong Seogwipo

Note: The unit for production value is million KRW.

Based on the integration of LQ and Shift Share Analysis to classify sea bream aquaculture regions (see Table 9), the following designations apply: Yeosu, Sacheon, and Geoje correspond to Type I; Taean, Wando, Shinan, Pohang, Jeju, and Seogwipo fall under Type III; Tongyeong and Namhae correspond to Type IV; Dangjin, Buan, Goheung, and Goseong fall under Type V; and Seosan and Hadong correspond to Type VI.

Table 9: Classification of Sea Bream Aquaculture Regions Based on the Integration of LQ and Shift Share Analysis

	Location Quotient			
	2018 ≥ 1, 2023 ≥ 1	**2018 ≥ 1, 2023 < 1**	**2018 < 1, 2023 ≥ 1**	**2018 < 1, 2023 < 1**
RSE +	< Type I> Yeosu Sacheon Geoje	-	-	< Type III > Taean Wando Shinan Pohang Jeju Seogwipo
RSE -	< Type IV> Tongyeong Namhae	< Type V > Dangjin Buan Goheung Goseong	-	< Type VI > Seosan Hadong

Note: The unit for production value is million KRW.

When categorizing yellowtail aquaculture regions based on the integration of LQ and Shift Share Analysis (see Table 10), the following designations apply: Samcheok is classified as Type I; Tongyeong as Type III; Pohang as Type IV; Geoje as Type V; and Yeosu as Type VI.

Table 10: Classification of Yellowtail Aquaculture Regions Based on the Integration of LQ and Shift Share Analysis

	Location Quotient			
	2018 ≥ 1, 2023 ≥ 1	**2018 ≥ 1, 2023 < 1**	**2018 < 1, 2023 ≥ 1**	**2018 < 1, 2023 < 1**
RSE +	< Type I > Samcheok	-	-	< Type III > Tongyeong
RSE -	< Type IV > Pohang	<Type V> Geoje	-	< Type VI > Yeosu

Note: The unit for production value is million KRW.

Cross-referencing the results of the LQ and Shift Share Analysis, it is observed that in Flounder aquaculture, Goheung falls into Type II, indicating a competitive region where the LQ has grown. Conversely, Gijang and Ulju are classified as Type V regions, showing declining competitiveness in Flounder aquaculture. In Rockfish aquaculture, there has been no change in specialized regions between 2018 and 2023. For Sea Bream aquaculture, Dangjin, Buan, Goheung, and Goseong are identified as Type V regions, indicating declining industry competitiveness. In Yellowtail aquaculture, Geoje is classified as Type V, reflecting declining industry competitiveness.

5. Conclusions

As aquaculture gains increased attention as a crucial industry responsible for food security and sustainable production, the demand for research in this area continues to grow. In this study, the regional characteristics of aquaculture in South Korea, with a focus on major aquaculture species, were examined using LQ and Shift Share Analysis. The findings revealed that in metropolitan areas, both specialization and regional competitiveness of aquaculture were generally low, regardless of the species. Conversely, outside metropolitan areas, specialization and regional competitiveness varied by species and region.

In flounder aquaculture, Jangheung, Haenam, Wando, and Jindo are identified as regions with both high specialization and regional competitiveness, indicating a strong presence in the Jeolla province area. On the other hand, Gijang, Ulju, Gangneung, Pohang, Gyeongju, Uljin, and Tongyeong are identified as regions with low specialization and regional competitiveness, indicating a weaker performance in the Gyeongsang province area.

In rockfish aquaculture, Boryeong, Seosan, Taean, Dangjin, Shinan, and Namhae are identified as regions with both high specialization and regional competitiveness, indicating that the South Chungcheong Province area has a strong presence in rockfish aquaculture. Conversely, Wando, Gyeongju, Hadong, and Seogwipo are characterized by low specialization and regional competitiveness, suggesting that the weaker regions are relatively evenly distributed.

In sea bream aquaculture, the regions of Yeosu, Sacheon, and Geoje are identified as having high levels of both specialization and regional competitiveness, indicating that the South Coast area, encompassing parts of South Jeolla Province and South Gyeongsang Province, demonstrates a strong presence. The regions of Seosan, Dangjin, Buan, Goheung, Goseong, and Hadong are identified as having both low specialization and regional competitiveness, suggesting that weaker regions are relatively evenly distributed.

In yellowtail aquaculture, Samcheok is identified as having both high specialization and regional competitiveness, indicating that Gangwon Province is dominant in this sector. Yeosu and Geoje exhibit both low specialization and regional competitiveness, suggesting that the South Coast area, which includes parts of South Jeolla Province and South Gyeongsang Province, shows a relatively weak presence.

Based on the regional types identified in this study, distinct strategies for regional policies can be formulated. Type I and Type II regions, which demonstrate high specialization and strong regional competitiveness, would benefit from production concentration strategies. These could include the establishment of aquaculture clusters aimed at advancing technology and facilitating large-scale demonstration projects, as well as the development of extensive processing facilities. Type III regions, while possessing regional competitiveness, have yet to fully harness their potential. In these areas, policies should focus on attracting new personnel through incentives like housing and settlement support, as well as fostering networks among industry stakeholders. For Type IV regions, where regional competitiveness is currently limited, the creation of a stable supply chain through volume contracts could be an effective approach to enhance their position. Finally, Type V and Type VI regions, which are characterized by both low specialization and low competitiveness, should seek to create additional value through initiatives like experiential and leisure tourism. These strategies would not only diversify income sources but also bolster the regions' overall economic viability.

This study provides information on regional specialization and competitiveness within the aquaculture sector, contributing to the identification of major aquaculture regions and offering a foundation for the development of targeted aquaculture policies. The analysis utilized LQ, Shift Share Analysis and combined analysis of the two methods, focusing on production value. The methods used in this study reflect relative specialization, making it effective for identifying a region's comparative advantage in relation to other regions. However, it has the

limitation of not providing absolute numerical data on the specialization of a specific industry within a single region. Nonetheless, the methodology remains valuable, as it intuitively illustrates the degree of industrial specialization within a region and offers important insights for regional policy-making by showing how this specialization compares to that of other regions. While a thorough examination of regional specialization typically requires calculating LQ and Shift Share values based on employment figures or the number of enterprises in the industry, this study faced limitations due to insufficient data in these areas, and focused on data from 2018 and 2023. To rigorously and continuously monitor regional trends in aquaculture, it is important to conduct periodic assessments of regional specialization and competitiveness at shorter intervals.

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