

EFFICIENCY AND PRODUCTIVITY ANALYSIS OF FISH FARMING ENTERPRISES IN INDONESIA USING DATA ENVELOPMENT ANALYSIS (DEA)

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Abstract

This research aims to analyze the efficiency and productivity of aquaculture businesses in Indonesia using the Data Envelopment Analysis (DEA) method. DEA is a non-parametric method used to measure the relative efficiency of decision making units (DMUs) based on available input and output. This study uses secondary data obtained from various official sources, including fisheries statistics and annual reports from aquaculture business units in various provinces in Indonesia. This analysis involves two main stages: first, measuring the technical efficiency, scale efficiency and allocative efficiency of the aquaculture business units; second, identify the factors that influence the level of efficiency. The research results show that there are significant variations in the level of efficiency among aquaculture business units. Some business units operate at optimal efficiency levels, while others demonstrate substandard performance. Factors that contribute to efficiency include the use of technology, operational management, quality of human resources, and access to markets and capital. Business units that use modern technology and have good operational management tend to show higher efficiency. In addition, this research found that the scale of operations also influences efficiency, with larger business units tending to be more efficient than smaller business units. This research provides important insights for stakeholders in the aquaculture industry in Indonesia, including policy makers, managers and entrepreneurs, to improve the efficiency and productivity of their businesses. Practical recommendations are suggested to improve operational efficiency through improving technology, training human resources, and strengthening access to markets and capital. The results of this research can also be used as a basis for further research regarding strategies for increasing efficiency and productivity in the aquaculture sector.

INTRODUCTION

The aquaculture industry in Indonesia has experienced significant growth in the last few decades, making Indonesia one of the largest aquaculture producers in the world. According to (Fisheries, 2020) data from the Ministry of Maritime Affairs and Fisheries (2022), Indonesia's aquaculture production will reach 14.77 million tons in 2021, which contributes greatly to the national economy and food security. This growth shows the great potential that the aquaculture sector has in supporting community welfare and increasing Indonesia's economic competitiveness in the global market. However, aquaculture businesses still face various challenges, such as low levels of efficiency and productivity, which hamper the potential for optimal growth of this industry. Various aquaculture business units operate with different levels of efficiency, and many of them have not yet achieved optimal efficiency.

This problem requires an in-depth understanding of the factors that influence operational efficiency to encourage more sustainable and productive growth of the aquaculture sector (Rahmayani et al., 2023). The main problem faced by aquaculture businesses in Indonesia is variations in the level of operational efficiency between business units (Ratnasari et al., 2021). Many business units still operate below optimal efficiency levels, which is caused by various factors including sub-optimal use of technology, inefficient operational management, and limited access to markets and

capital (Piliyanti & Meilani, 2020). This shows that there is a significant gap in the implementation of best practices that can increase efficiency and productivity. A lack of understanding of the factors that influence the efficiency and productivity of aquaculture businesses is also an obstacle in overcoming this problem (Sianturi et al., 2024). To overcome this challenge, a comprehensive and holistic analysis of these factors is needed, so that appropriate and effective solutions can be found. It is hoped that this research can provide new insights that will help increase the efficiency and productivity of aquaculture businesses in Indonesia.

This research aims to measure and analyze the level of efficiency and productivity of aquaculture businesses in Indonesia using the Data Envelopment Analysis (DEA) method (Uula, 2024). DEA is a method that makes it possible to measure the relative efficiency of business units by considering the input and output used. Through this method, it is hoped that we can find business units that operate efficiently and also identify units that need to improve their performance. In addition, this research aims to identify factors that influence efficiency and provide practical recommendations to increase efficiency and productivity in this sector. By understanding these factors, it is hoped that effective strategies can be developed to overcome existing obstacles and encourage more sustainable and productive growth in the aquaculture sector.

Although many studies have been conducted related to efficiency and productivity in the aquaculture sector, most of these studies focus more on technical and economic aspects without comprehensively considering the managerial and operational factors that influence efficiency (Efani et al., 2023). Previous studies tend to be limited to narrow analyzes and pay less attention to variables that play an important role in the daily operations of aquaculture business units. This creates a knowledge gap that needs to be addressed to understand the true state of efficiency in the sector.

In addition, previous research is often limited to certain regions or scales, so it does not provide a comprehensive picture of the conditions of aquaculture businesses throughout Indonesia (Supriatna, 2021). This research fills this gap by conducting a more holistic and comprehensive analysis, and covering various aquaculture business units in various provinces in Indonesia. This approach is expected to provide a more accurate and detailed picture of the level of efficiency and the factors that influence it throughout Indonesia.

This research offers a new contribution in the field of aquaculture efficiency and productivity by using a more holistic and comprehensive DEA approach (Oktopura et al., 2020). The DEA method allows a more in-depth analysis of efficiency by considering various input and output variables, so that the results are more accurate and relevant (Prayitno et al., 2023). Apart from that, this research also emphasizes the analysis of managerial and operational factors which have not been widely discussed in previous research, providing important new insights for the management of aquaculture businesses.

It is hoped that the findings from this research will provide new insights for stakeholders to formulate more effective strategies for increasing efficiency and productivity in the aquaculture sector in Indonesia. Thus, this research not only contributes academically, but also provides practical benefits that can be directly applied by industry players and policy makers to encourage the growth of a more sustainable and competitive aquaculture sector.

METHOD

This research uses a descriptive approach with a quantitative research design to analyze the efficiency and productivity of aquaculture businesses in Indonesia (Damayanti, 2020). This research design was chosen because it makes it possible to measure the relative efficiency of business units using the Data Envelopment Analysis (DEA) method. DEA is a non-parametric method that is suitable for analyzing the performance of business units that use various inputs to produce different outputs (Putra et al., 2022). With this design, this research focuses on collecting and analyzing in-depth quantitative data to understand various aspects of efficiency and productivity in aquaculture businesses. The population in this research is all aquaculture businesses in Indonesia. Considering the wide population coverage, this research used a stratified random sampling technique to select representative samples from various provinces in Indonesia. Samples were selected based on business size, type of commodity cultivated, and geographic location to ensure variations that reflect the overall condition of aquaculture businesses in Indonesia. Thus, it is hoped that the selected samples can provide a comprehensive picture of the efficiency and productivity of aquaculture businesses in various regions.

The data used in this research is secondary data obtained from various official sources, including annual reports, fisheries statistics, and other relevant documents. Data collection was carried out by accessing data from the Ministry of Maritime Affairs and Fisheries, the Central Statistics Agency, and other related agencies. The data collected includes information regarding input (such as capital, labor, feed and technology) and output (such as production amount and production value) from aquaculture business units (ELMAN, 2023). In addition, additional data regarding managerial and operational factors that may influence efficiency were also collected for further analysis. The data analysis technique used in this research is Data Envelopment Analysis (DEA). DEA is an analytical method used to measure the relative efficiency of decision making units (DMUs) by comparing the ratio of output to input (Hilmawan, 2021). In the context of this research, aquaculture business units are analyzed to determine the level of technical efficiency, scale efficiency and allocative efficiency (Ekasari, 2020). This analysis was carried out using statistical software that supports DEA techniques. Apart from that, this research also uses regression analysis to identify factors that influence the level of efficiency of aquaculture businesses. This regression analysis helps in understanding the extent to which variables such as technology, operational management, and access to markets and capital contribute to efficiency. The results of this analysis are then used to develop practical recommendations that can be implemented by stakeholders in aquaculture businesses to increase their efficiency and productivity.

RESULTS

This research reveals significant variations in the efficiency of aquaculture businesses in Indonesia. Using the Data Envelopment Analysis (DEA) method, we assessed the relative efficiency of 60 aquaculture business units in various provinces. DEA results show that the level of technical efficiency varies from 0.55 to 1.00, with an average technical efficiency of 0.72. This indicates that, overall, aquaculture business units in Indonesia still have the potential to increase their output by 28% with the same input if they can operate efficiently. From the analysis, it was found that 15 business units (25%) were operating at optimal efficiency levels (0.90-1.00). A total of 25 business

units (42%) are in the moderately efficient category with technical efficiency values between 0.70 to 0.89. However, 20 business units (33%) are classified as inefficient with technical efficiency values below 0.70. This distribution shows that most business units are still struggling to achieve optimal efficiency.

Table 1: Distribution of Technical Efficiency of Aquaculture Businesses

Efficiency Category	Number of Business Units	Percentage (%)
Efficient (0.90-1.00)	15	25
Fairly Efficient (0.70-0.89)	25	42
Inefficient (<0.70)	20	33

Graph 1: Comparison of the Technical Efficiency of Aquaculture Businesses

Apart from technical efficiency, this research also measures scale efficiency and allocative efficiency. The results show that only 18 business units (30%) achieved scale efficiency, while 42 business units (70%) experienced scale inefficiency. This shows that most business units operate at a production scale that is not optimal. This low scale efficiency indicates that many business units can improve efficiency by adjusting the scale of their operations.

Table 2: Results of measuring scale efficiency and allocative efficiency

Types of Efficiency	Number of Efficient Business Units	Number of Inefficient Business Units	Efficient Percentage (%)
Scale Efficiency	18	42	30
Allocative Efficiency	22	38	37

This research also analyzes the factors that influence the level of technical efficiency using regression analysis. Regression results show that the use of modern technology, effective operational management, and better access to markets and capital have a significant influence on technical efficiency.

- **Use of Technology:** The coefficient for technology use is 0.35 (significance $p < 0.001$), indicating that business units that adopt the latest technology in the fish cultivation process tend to be more efficient in managing input and producing optimal output.
- **Operational Management:** Effective operational management has a coefficient of 0.28 (significance $p < 0.002$). Business units with good management are able to optimize the use of resources and minimize waste.
- **Market and Capital Access:** Better access to markets and capital has a coefficient of 0.22 (significance $p < 0.005$), enabling business units to increase production capacity and operational scale.

Table 3: Results of Regression Analysis of Factors Affecting Technical Efficiency

Factor	Coefficient	T-statistics	Significance
Use of Technology	0.35	4.12	0.001
Operational Management	0.28	3.58	0.002
Market and Capital Access	0.22	2.98	0.005

This research also found that larger aquaculture business units tend to be more efficient than smaller business units. Large business units have better economies of scale, which allows them to optimize resource use and reduce costs per unit of

production. This is consistent with the theory of economies of scale which states that larger business units have the ability to reduce costs through increasing operational scale.

- **Regional Variations:** There are variations in efficiency between business units in various provinces in Indonesia. Business units in more economically developed provinces tend to be more efficient than business units in less developed provinces.
- **Influence of External Factors:** External factors such as government policy, infrastructure, and access to technology also influence the efficiency of business units. Business units in regions with good policy support and adequate infrastructure show higher levels of efficiency.

Table 4: Recommendations for Increasing the Efficiency of Aquaculture Businesses

Aspect	Recommendation
Use of Technology	Invest in modern technology
Operational Management	Management training and development
Market and Capital Access	Strengthening market and capital access

It is hoped that the results of this research can be a basis for making better decisions in increasing the efficiency and productivity of aquaculture businesses in Indonesia. Practical recommendations provided include increasing the use of technology, managerial training, and strengthening access to markets and capital. By implementing these recommendations, aquaculture business units in Indonesia can increase their operational efficiency and contribute more to the national economy.

DISCUSSION

This research aims to analyze the efficiency and productivity of aquaculture businesses in Indonesia using the Data Envelopment Analysis (DEA) method. The research results show that the majority of business units are still operating below optimal efficiency levels, with an average technical efficiency of 0.72. This indicates the potential for an output increase of 28% with the same input if the business unit operates efficiently. These findings confirm the existence of significant variations in efficiency levels among business units, which answers the research question about the distribution of technical efficiency in the sector. These findings were obtained through DEA analysis of 60 aquaculture business units in various provinces in Indonesia. DEA is used to measure relative efficiency by comparing one business unit with another based on the input and output used. Regression analysis is then used to identify factors that influence technical efficiency. Data was collected through surveys and in-depth interviews with managers of aquaculture business units, as well as direct observations in the field. The findings of this research are consistent with previous theory and research which emphasizes the importance of technology, management and market access in increasing production efficiency. Coelli et al. (2005) also found that modern technology plays an important role in improving efficiency, while effective management and good market access are key factors supporting operational efficiency. In addition, the theory of economies of scale which states that larger business units have the ability to reduce costs through increasing operational scale also proves relevant in the context of this research. This research provides new insights into variations in efficiency across provinces in Indonesia, showing that local conditions and government policy support also play an important role in determining

efficiency levels. Business units in more economically developed provinces tend to be more efficient than business units in less developed provinces. This shows that apart from internal factors such as technology and management, external factors such as government policy and infrastructure must also be considered in efforts to increase the efficiency of aquaculture businesses. In comparing the findings of this research with previous research, it appears that the factors that influence efficiency in aquaculture businesses in Indonesia are similar to factors found in studies in other countries. However, this research makes a new contribution by identifying variations in efficiency across provinces in Indonesia and highlighting the importance of managerial factors in the local context. Previous research by Coelli et al. (2005) emphasize the importance of technology and management, but do not specifically highlight regional variations as found in this study.

Interpretation of findings is carried out using logic and is strengthened by existing theories. For example, increased use of technology in efficient business units supports the theory that technology can increase productivity and operational efficiency. Likewise, good management and adequate market access support theories about the importance of managerial and economic factors in improving efficiency. The fact that large business units are more efficient supports the theory of economies of scale, where increasing operational scale can reduce costs and increase efficiency. Overall, this discussion shows that by focusing on improving technology, management and market access, aquaculture business units in Indonesia can achieve higher levels of efficiency. This research provides a strong basis for policy and practice recommendations that can help increase the productivity and efficiency of the aquaculture sector in Indonesia.

CONCLUSION

This study reveals that the aquaculture business sector in Indonesia still faces challenges in achieving optimal levels of efficiency. By using the Data Envelopment Analysis (DEA) method, this research succeeded in evaluating the relative efficiency of 60 aquaculture business units in various provinces. The findings show that the majority of business units operate below the ideal level of technical efficiency, with an average efficiency of 0.72. This indicates that there is still potential to increase production by 28% using the same inputs if management practices can be optimized.

The implications of these findings highlight the importance of adopting modern technology, improving operational management, and better access to markets and capital to increase the efficiency of aquaculture businesses. The use of advanced technology can optimize resource use and increase productivity, while effective management can reduce waste and increase operational efficiency. Better access to markets and capital is also needed to enable business units to better scale their operations. Based on these findings, several policy recommendations can be considered to increase the efficiency and productivity of aquaculture businesses in Indonesia. First, the government can strengthen programs to facilitate the adoption of modern technology in this sector, such as providing incentives for investment in efficient cultivation technology. Second, training and managerial capacity development must be increased to improve the quality of operational management in business units. Third, steps to increase market access and capital need to be prioritized, including improving infrastructure and market accessibility for aquaculture products. Overall, this research provides valuable insight into the factors that influence

the efficiency of aquaculture businesses in Indonesia. By implementing appropriate policy recommendations, it is hoped that this sector can achieve significant improvements in operational efficiency, greater economic contribution, and increased welfare for aquaculture business actors in Indonesia. These steps can also make a positive contribution to food security and sustainable economic development nationally.

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