Aquaculture performance in Indonesia: economics and social perspectives

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Abstract. Aquaculture is one of the fisheries sub-sectors that play a strategic role in national development. Currently, the aquaculture sector contributes significantly to both food security and national economic growth. This study aims to analyze the performance of aquaculture in 6 major islands located in Indonesia at the period of 2010 to 2018. The research was carried out with quantitative and qualitative approaches using descriptive analysis, taking into account economic and social aspects. Economic aspects were measured by five variable indicators, namely Gross Domestic Product (GDP), and aquaculture production volume, budget value, aquaculture land area and the number of fish farmer households. Social aspects were measured based on five variables of fish cultivator exchange rate (NTPi), budget value, price index received by fish cultivation, household consumption index, production cost index. The results showed that the contribution of aquaculture was fairly significant toward the achievement of national development goals, although not all indicators were able to achieve the set targets.

1. Introduction
Indonesia, with a coastline of 99,093 km² and sea area 6,315,222 km², is one of the countries that have enormous economic potential in the field of marine and fisheries. The fisheries sector is one of the sectors that are expected to be the driving force of national development. During this time, the development of the national fisheries sector has been more focused on the fishing sector, but the volume of capture fisheries production has decreased in the past decade due to IUU fishing and not environmentally friendly fishing activities.

This condition is inversely proportional to the need for fish consumption which increases every year in line with the increase in population. Therefore, an alternative strategy is needed in the fisheries sector to ensure the availability of fish supply for consumption. Aquaculture is a strategic sector that can become an alternative in marine and fisheries economic development policies in Indonesia. In addition to the contribution of sustaining national food security and independence through increased
fish production, the aquaculture sector also contributes to increasing the country's foreign exchange by increasing the volume. Besides, aquaculture also has an essential role in improving the welfare of the community, creating jobs, and sustainable management of natural resources.

The role of aquaculture in food security is strengthened by the existence of law no. 18 2012 concerning Food which sets fishery commodities as one of the commodities to meet national food security in Indonesia in addition to the agricultural sector. Aquaculture is defined as the farming of aquatic organisms, including fish, mollusks, crustaceans and aquatic plants. Farming entails some form of intervention in the rearing process to enhance production such as regular stocking, feeding, protection from predators, etc. and also implies individuals or corporate ownership [1,2,3].

Based on business location, aquaculture is categorized into three, namely freshwater fish, brackish water and seawater. The total potential area for aquaculture in Indonesia is 17.9 million hectares; consisting of 2.8 million hectares of freshwater aquaculture with a utilization rate of 11.18%, brackish water aquaculture land of 2.9 million hectares with a utilization rate of 20.44 %, and seawater aquaculture land 12.12 million Ha with a utilization rate of 2.3%. From these data, it can be seen that the average utilization of aquaculture land in Indonesia is still very small at 6.7% [4].

To encourage an increase in the role of aquaculture as a driving force for the national economy and to support national food security, the Indonesian government has allocated budgets and implemented several policies and programs that are national and regional, including the development of ‘minapolitan’ areas, innovation and application of environmentally friendly technologies, institutional strengthening and human resource capacity, strengthening competitiveness and product quality, integration of programs with cross-sectors, industrialization of fisheries, developing independent feeds to provide quality low-cost feed, implementing disease and environmental management and biosecurity, protecting business for small-scale fish farmers and providing access to capital for aquaculture businesses.

Based on data from the Central Statistics Agency in 2017, in the last five years, aquaculture production in Indonesia has increased by 15.24%, from originally 9,675,553 tons in 2012 to 16,675,031 tons in 2016. From 2015 through 2017, data from the Central Statistics Agency showed that there was an increase in the contribution of aquaculture commodities to the value of fishery exports by 1.64% and the value of Fisheries GDP was always above the value of national GDP. The contribution of the aquaculture sector to the GDP of fisheries has increased from year to year where in 2017, the aquaculture sector contributed 52.6% to the value of fisheries GDP.

Aquaculture is one of the prospective and substantial fisheries sub-sectors to be developed to guarantee national food security and become the driving force of the national economy in the future. Furthermore, the utilization of aquaculture economic potential resources has not been optimally carried out so that an appropriate strategy is needed to be able to optimize the contribution of aquaculture.

In developing a comprehensive strategy for aquaculture development, it is necessary to evaluate and measure performance against the level of efficiency and the impact of aquaculture development on established performance indicators. The results of evaluations and performance measurements are significant as benchmarking for the planning process in the future. This study aims to analyze and measure the performance of aquaculture development in 6 major islands in Indonesia and analyze the competitiveness of superior commodities of aquaculture in the global market.

2. Data and method

2.1. Efficiency analysis of aquaculture development performance

To measure the efficiency of aquaculture development performance in Indonesia, this study was conducted quantitatively using secondary data and analyzed descriptively. The type of data used to measure the performance of aquaculture development was panel data in the time period from 2013 to 2017. Panel data is a combination of time series data and cross-section data. There are two aspects of
the approach considered in this study referring to the performance targets that have been set in the medium to long term development plan (RPJMN), namely the economic and social aspects.

Efficiency and productivity are concepts that show the ratio of the results of a comparison between input and output. Both ratios indicate that efficiency and productivity can be controlled by manipulating input and output management, or even both at the same time. Efficiency and productivity can be used to measure the performance of a unit of economic activity. An activity can be called efficient if the effort that has been done provides maximum output, both in quantity and quality. Measurement of efficiency is divided into several parts, namely: technical efficiency, scale efficiency, cost efficiency and allocative efficiency. Technical efficiency is the process of converting inputs into maximum output, both in quantity and quality.

The analytical method used in this study was the Data Envelopment Analysis (DEA). Data Envelopment Analysis is a non-parametric mathematical model program used for the frontier approach. Efficiency measurement methods, currently widely known as the Data Envelopment Analysis (DEA) approach. DEA is based on the production frontier curve in the form of Cobb Douglas. DEA is a tool that can be used to measure and compare the performance of a number of service units or business units such as banks, the non-bank financial industry, hospitals, and even educational institutions. The DEA can also show the specification of the inefficiency of the service unit.

In this study, DEA was used as a tool to measure and compare the performance of aquaculture development in Indonesia in the 2013-2017 period. Furthermore, to measure the observed productivity of Islamic banks, this study uses an analysis of the Malmquist Productivity Index (MPI). The Malmquist Index is part of the DEA method that looks explicitly at the level of productivity of each business unit so that changes in the level of efficiency and technology will be seen based on predetermined inputs and outputs. The Malmquist Index is also used to analyze changes in performance over time.

**Table 1.** Output and input data on economic performance of aquaculture development in Indonesia 2013 – 2017.

| Year | DMU        | Output  | Input  |
|------|------------|---------|--------|
|      |            | Y1      | Y2     | X1     | X2     | X3     |
| 2013 | Sumatera   | 42.95   | 1,262.870 | 97.24 | 231.832 | 353.643 |
|      | Java       | 69.85   | 2,527.853 | 140.24 | 418.592 | 850.898 |
|      | Bali –NT   | 73.06   | 2,730.396 | 32.01 | 41.066  | 84.617  |
|      | Kalimantan | 44.1    | 570.047  | 30.3  | 225.454 | 119.168 |
|      | Sulawesi   | 61.39   | 5,431.890 | 79.04 | 302.954 | 228.480 |
|      | Maluku Papua | 21.16   | 777.850  | 31.1  | 58.567  | 30.622  |
|      | Sumatera   | 47.19   | 1,396.839 | 94.19 | 234.631 | 354.848 |
|      | Java       | 72.24   | 2,732.301 | 138.54 | 430.629 | 831.509 |
|      | Bali –NT   | 77.94   | 2,959.973 | 27.91 | 43.205  | 84.637  |
| 2014 | Kalimantan | 48.77   | 677.640  | 58.59 | 223.542 | 120.917 |
|      | Sulawesi   | 59.13   | 5,913.751 | 32.58 | 307.276 | 232.672 |
|      | Maluku Papua | 28.97   | 678.625  | 31.47 | 14.491  | 24.588  |
|      | Sumatera   | 46.1    | 1,392.244 | 154.05 | 241.749 | 364.306 |
| 2015 | Java       | 61.79   | 2,773.390 | 203.09 | 413.011 | 807.874 |
|      | Bali –NT   | 67.39   | 3,479.149 | 45.94 | 39.432  | 82.959  |
|      | Kalimantan | 41.62   | 672.026  | 39.85 | 249.344 | 134.453 |
### Table 2. Data on outputs and inputs on social performance evaluation of aquaculture development in Indonesia 2013-2017.

| Year | DMU             | Output | Input |
|------|-----------------|--------|-------|
|      |                 | Y1     | X1    | X2    | X3    | X4    |
| 2013 | Sumatera        | 101.32 | 97.24 | 108.96| 109.33| 104.36|
|      | Java            | 101.23 | 140.24| 109.38| 110.26| 104.65|
|      | Bali –NT        | 98.7   | 32.01 | 105.20| 109.24| 103.01|
|      | Kalimantan      | 98.04  | 30.3  | 105.30| 109.87| 103.81|
|      | Sulawesi        | 100.71 | 79.04 | 108.86| 109.66| 103.45|
|      | Maluku Papua    | 104.14 | 31.1  | 111.96| 109.50| 103.37|
|      | Sumatera        | 102.06 | 94.19 | 108.96| 118.08| 109.42|
|      | Java            | 100.58 | 138.54| 109.38| 120.18| 108.64|
|      | Bali –NT        | 97.37  | 27.91 | 105.20| 118.46| 110.05|
|      | Kalimantan      | 97.96  | 58.59 | 105.30| 120.02| 109.08|
|      | Sulawesi        | 99.88  | 32.58 | 108.86| 119.74| 108.82|
|      | Maluku Papua    | 100.16 | 31.47 | 111.96| 117.36| 107.77|
| 2014 | Sumatera        | 99.62  | 154.05| 117.96| 122.49| 111.85|
|      | Java            | 99.87  | 203.09| 120.54| 125.79| 110.66|
|      | Bali –NT        | 94.93  | 45.94 | 111.10| 122.52| 110.33|
|      | Kalimantan      | 97.19  | 39.85 | 115.84| 124.83| 110.64|
|      | Sulawesi        | 96.52  | 83.05 | 116.95| 125.71| 109.76|
|      | Maluku Papua    | 100.16 | 38.51 | 118.34| 124.12| 107.73|
| 2015 | Sumatera        | 98.44  | 143.38| 120.54| 128.02| 113.30|
|      | Java            | 99.26  | 193.05| 122.81| 131.88| 111.62|

Source: Central Statistics Agency (2017) and annual report of the directorate general of aquaculture, 2013-2017.
2.2. Performance Analysis of Aquaculture Commodity Competitiveness

To measure the competitiveness of aquaculture in Indonesia, the research was conducted quantitatively using secondary data and analyzed descriptively. The type of data used to measure the competitiveness of aquaculture commodities developed in Indonesia was a combination of panel data and time-series data with a time period from 2013 to 2017. The method of analysis carried out using the revealed comparative advantage (RCA) approach and the Trade Specialization Index (ISP).

The identification of superior aquaculture commodities in Indonesia becomes very important because the selected excellent commodity will be expected to become the main driving commodity of the economy in Indonesia, both traded in fresh commodities and the form of various processed products. One way to determine the superior commodity is to examine the comparative and competitive advantages of the commodity in the international market.

The comparative advantage here is defined as the ability of an area to produce commodities or products that are relatively superior to other regions or can be said to have an abundance of resources owned by an area so that it can distribute these resources to other regions [5], while competitive advantage can be interpreted as an advantage possessed by a country or nation to be able to compete in international markets [6]. Revealed Comparative Advantage (RCA) was used to measure the comparative advantage of Indonesian shrimp in the global market compared to China and Vietnam. The formula for calculating RCA is as follows:

\[
RCA = \frac{X_{ij}/X_j}{X_{iw}/X_w}
\]

RCA  : Revealed Comparative Advantage  
\(X_{ij}\) : Value of commodity exports \(i\) from country \(j\)  
\(X_j\) : Total value of country exports \(j\)  
\(j\) : Country of exporter (Indonesia)  
\(X_{iw}\) : The value of commodity exports \(i\) from the world  
\(X_w\) : Total value of world exports

If the RCA value <1, it can be concluded that the comparative advantage of the country’s shrimp commodity is low or below the world average. Conversely, if the value of RCA> 1, it can be concluded that the shrimp commodity has a tremendous comparative advantage or above the world average. Revealed Comparative Advantage (RCA) is defined that if the share of Indonesian aquaculture commodity exports in a country’s total commodity exports is higher than the market share of aquaculture commodity exports in total world commodity exports. It is also expected that the country has a comparative advantage in the production and export of commodities shrimp. If the RCA
value is more significant than one, it means that the country has a comparative advantage (above the world average) for the commodity in this study, meaning that the commodity (Indonesian aquaculture commodity) is highly competitive. Conversely, if the RCA value is smaller than one, it means that the comparative advantage for commodities is low (below the world average) or weakly competitive [7].

The Trade Specialization Index (ISP) was used to calculate the competitive advantage of Indonesian shrimp commodities and the position of Indonesian shrimp commodity exports in the international market compared to China and Vietnam. The formula for calculating the ISP is as follows:

\[
\text{ISP} = \frac{X_a - M_a}{X_a + M_a}
\]

where:
- ISP : Trade Specialization Index
- Xa : The value of exports of one country's fish commodity a
- Ma : The value of imports of one country's commodity a

The value of the trade specialization index (ISP) is between -1 and +1. If the value of the trade specialization index is positive (0 < ISP < 1), then the country has strong competitiveness or the country is likely to be an exporter of shrimp commodities. Conversely, these countries have low competitiveness or tend to be importing shrimp commodities if the value of the trade specialization index is negative (-1 < ISP < 0).

In addition, the ISP value also has another meaning, namely ISP value between -1 to -0.5, then the country's shrimp exports are in the introduction phase. If the ISP value is between -0.5 to 0, the country's shrimp exports are in the import substitution stage. If the ISP value is between 0 and 0.8, the country's shrimp exports are in the growth stage, then if the ISP's value is between 0.8 and +1, the country's shrimp exports are in the maturation stage.

3. Result and analysis

3.1. Efficiency analysis of aquaculture development performance

The performance of aquaculture development in Indonesia can be seen from 2 (two) aspects, namely economic and social. Economic indicators to measure the performance of aquaculture development are an increase in Gross Domestic Product (GDP) or Gross Regional Domestic Product (GRDP) and an increase in the volume of aquaculture production. In this study, there were 2 (two) output variables, namely the ratio of the contribution of Aquaculture to the GDP of the fisheries sector and the volume of production and 3 (three) input variables, namely the budget, land area, and the number of cultivator households (RTP) used to measure the performance of fisheries development cultivation in terms of economic aspects. Furthermore, the output indicator to measure the performance of national aquaculture development in terms of social issues is the exchange rate of fish farmers (NTPi). In this study, using one output variable, namely the exchange rate of fish farmers (NTPi) and 4 (four) input variables, namely budget, income index for aquaculture business income (Ii), household consumption index (Ik), and production cost index (Ib).

Table 3 and Table 4 show the results of the calculation of the Malmquist index using the data envelopment analysis (DEA) method and the WinDeap analysis tool and based on the assumption of output optimization and constant cost ratio (CCR). Furthermore, it is illustrated the performance of the aquaculture development sector, measured based on the index of technical efficiency change (Eff Ch.), Technological change (Tech Ch.), Pure technical efficiency change (PE Ch.), Scale efficiency change (SE Ch.) and total factor productivity change (TPF Ch.) [8].

Table 3 shows that the achievement of an increase in NTPi occurred in almost all of Indonesia area except on Sulawesi Island with technical efficiency change (Eff Ch.) below 1 (0.991). Furthermore, Table 3 shows that the technological efficiency in 6 island regions in Indonesia displayed a shift away from the production frontier. This was indicated by the index value of tech < 1. This suggested that changes in technological efficiency have not contributed positively to the achievement of efficiency in
aquaculture development performance to achieve community welfare improvement in all study areas in the five periods.

Table 4 shows that based on economic aspects, there are two regions, Kalimantan and Papua Maluku with technical efficiency changes (Eff Ch.) value below 1 (0.990 and 0.91). It was suggested that the performance of aquaculture development has not been efficient in both locations. Furthermore, the performance of aquaculture development had contributed to a 1% increase in the volume of national fish production and GDP of the fisheries sector, but when viewed in each region there were three regions with a total factor productivity change index value <1 namely Sumatra, Java and Kalimantan. It is indicated that the performance of aquaculture development in the three regions was not optimal and efficient during the 2013-2017 period, but based on the national average was quite efficient.

| DMU             | Effch | techch | pech | sech | Tfpch |
|-----------------|-------|--------|------|------|-------|
| Sumatera        | 1.001 | 0.962  | 1.001| 1.001| 0.963 |
| Java            | 1.002 | 0.957  | 1.000| 1.000| 0.959 |
| Bali Nusa Tenggara | 1.000 | 0.953  | 1.000| 1.000| 0.953 |
| Kalimantan      | 1.001 | 0.914  | 1.000| 1.001| 0.914 |
| Sulawesi        | 0.991 | 0.959  | 0.991| 1.000| 0.950 |
| Papua Maluku    | 1.000 | 0.931  | 1.000| 1.000| 0.931 |
| Mean            | 0.999 | 0.946  | 0.999| 1.000| 0.945 |

| DMU             | Effch | techch | pech | sech  | tfpch  |
|-----------------|-------|--------|------|-------|--------|
| Sumatera        | 1.134 | 0.853  | 1.084| 1.046 | 0.967  |
| Java            | 1.065 | 0.855  | 1.011| 1.054 | 0.911  |
| Bali Nusa Tenggara | 1.000 | 1.102  | 1.000| 1.000 | 1.010  |
| Kalimantan      | 0.990 | 0.909  | 0.953| 1.039 | 0.899  |
| Sulawesi        | 1.056 | 0.968  | 1.000| 1.056 | 1.022  |
| Papua Maluku    | 0.910 | 1.236  | 1.000| 0.910 | 1.126  |
| Mean            | 1.023 | 0.978  | 1.007| 1.016 | 1.001  |

3.2. Performance Analysis of Aquaculture Commodity Competitiveness
Commodity selection is one of the factors that determine the efficiency of aquaculture development performance. The selection of superior commodities in this study was done by taking into consideration the competitiveness in the global market of each of the leading commodities of aquaculture that have been set in Indonesia.

Table 5 shows the results of calculating the RCA and ISP values for the 12 primary aquaculture commodities. In the table, it can be seen that there are 4 (four) commodities that have an average value of RCA > 1 in the period 2013 - 2017, namely seaweed (4.21), tilapia (2.47), shrimp (2.45) and grouper (1.66). This shows that the seaweed, tilapia, shrimp and grouper commodities have strong comparative competitiveness in the international market. Commodity selection is one of the factors that determine the efficiency of aquaculture development performance. The selection of superior commodities in this study was done by taking into consideration the competitiveness in the global market of each of the leading commodities of aquaculture that have been set in Indonesia. This study uses two approaches to measure the competitiveness of aquaculture commodities, namely revealed compared advantage (RCA) analysis and the trade specialization index (ISP) while other commodities...
have low comparative competitiveness. Besides, there are three prospective commodities to compete in the international market, namely pangasius and milkfish with an average RCA value of 0.28, 0.28 and 0.14, respectively. Furthermore, it can be concluded that aquaculture commodities have strong competitive competitiveness and are in the maturation stage except for white snapper, catfish and shellfish with an average ISP value of -0.27, 0 and 0.54.

Table 5. RCA and ISP values for aquaculture commodities for the period of 2013 – 2017.

| Komoditas   | Value RCA | Value ISP |
|-------------|-----------|-----------|
|             | 2013  | 2014  | 2015  | 2016  | 2017  | 2013  | 2014  | 2015  | 2016  | 2017  |
| Seaweed     | 4.2   | 4.9   | 4.4   | 3.5   | 4.1   | 0.8   | 0.8   | 0.8   | 0.8   | 0.8   |
| Thilapia    | 2.3   | 2.4   | 2.8   | 2.5   | 2.2   | 1.0   | 1.0   | 1.0   | 1.0   | 1.0   |
| Shrimp      | 2.4   | 2.6   | 2.5   | 2.5   | 2.3   | 0.8   | 0.8   | 0.8   | 0.8   | 0.8   |
| Grouper     | 1.3   | 1.1   | 1.7   | 2.2   | 2.1   | 1.0   | 1.0   | 1.0   | 1.0   | 1.0   |
| Pangasius   | 0.4   | 0.2   | 0.3   | 0.3   | 0.2   | 1.0   | 1.0   | 1.0   | 1.0   | 1.0   |
| Milkfish    | 0.3   | 0.3   | 0.3   | 0.3   | 0.3   | 1.0   | 1.0   | 1.0   | 1.0   | 1.0   |
| Pomfret Star| 0.1   | 0.1   | 0.0   | 0.1   | 0.0   | 1.0   | 1.0   | 1.0   | 1.0   | 0.9   |
| White Snapper| 0.0  | 0.0   | 0.0   | 0.0   | 0.0   | -1.0  | 1.0   | -1.0  | -0.3  | -0.1  |
| Shellfish   | 0.2   | 0.1   | 0.2   | 0.2   | 0.2   | 0.4   | 0.5   | 0.7   | 0.6   | 0.5   |
| Goldfish    | 0.1   | 0.0   | 0.2   | 0.0   | 0.0   | 1.0   | 1.0   | 1.0   | 1.0   | 1.0   |
| Gouramay    | 2.7   | 0.0   | 0.0   | 0.1   | 0.0   | 1.0   | 0.0   | 1.0   | 0.0   | 0.0   |
| Catfish     | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |

4. Conclusions
This study attempted to analyze the CCR model as a basic model in DEA to see the level of efficiency of aquaculture development performance in Indonesia for the period 2013-2017. Performance measurement was carried out by considering economic and social aspects as well as the competitiveness of aquaculture commodities. Based on the results of the study it can be concluded as follows:

1. Based on the results of the economic aspect performance evaluation by considering 2 output variables namely the contribution of GRDP and fish production volume as well as 3 input variables namely budget, land area and number of FHs, the nationally performance of aquaculture development in Indonesia had been efficient it is shown by the average effch and tfpch index > 1 are 1,023 and 1,001. However, the performance of aquaculture development can still be optimized to be more efficient by encouraging policies related to the development of production systems so that the value of the technology index will increase.

2. Based on the results of the evaluation of social aspects of performance by considering 1 output variable, namely NTPi and 4 input variables, namely budget, receive index, household consumption index, production cost index, the performance of aquaculture development in Indonesia had not been efficient, with the achievement of the average value of the effch, techch, pech and tfpch index <1 namely 0.999, 0.946, 0.999 and 0.945.

3. Based on the analysis of competitiveness and trade specialization, from the 12 primary aquaculture commodities developed in Indonesia in the period 2013-2017, only 25% of aquaculture commodities have comparative and competitive competitiveness in the global market, namely shrimp, seaweed, indigo and grouper.
4. This study also proved that the use of DEA with the assumption of optimizing output and constant cost ratio (CCR) was very useful to evaluate performance in the Aquaculture sector in a certain region and period.

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