Efficiency and economic benefits of skipjack pole and line (huhat) in central Moluccas, Indonesia

Stevanus M Siahainenia, Johanis Hiariey, Mulyono S Baskoro, Wellem Waeleruny

1 Graduate Student of Pattimura University, Ambon, Indonesia
2 Faculty of Fisheries and Marine Science, Pattimura University, Ambon, Indonesia
3 Faculty of Fisheries and Marine Science, Bogor Agriculture University, Indonesia

Email: johanishiariey6@gmail.com

Abstract. Excess fishing capacity is a crucial problem in marine capture fisheries. This phenomenon needed to be investigated regarding sustainability and development of the fishery. This research was aimed at analyzing technical efficiency (TE) and computing financial aspects of the skipjack pole and line. Primary data were collected from the owners of the fishing units at the different size of gross boat tonnage (GT), while secondary data were gathered from official publications relating to this research. Data envelopment analysis (DEA) approach was applied to estimate technical efficiency whereas a selected financial analysis was utilized to calculate economic benefits of the skipjack pole and line business. The fishing units with a size of 26-30 GT provided a higher TE value, and also achieved larger economic benefit values than that of the other fishing units. The empirical results indicate that skipjack pole and line in the size of 26-30 GT is a good fishing gear for the business development in central Moluccas.

1. Introduction
The potential of fisheries resources can be used as an economic resource for the development of coastal areas. The sustainable use of fish resources will contribute to the increase of the country's foreign exchange, fishermen's income, and employment and business opportunity. The trends of poor management will lead to a massive pressure on fish resources. For example, the use of very excessive fishing inputs in the territorial waters will influence the reduction of quality and quantity of fish resources.

Fish resources as a natural capital need to be optimally managed for the sustainability of fisheries business [1]. The more fishing gears operating on the regulated open-access fisheries conditions regardless of fishing capacity will cause inefficient fishing activities. Also, low control on the resource will trigger the fishermen to utilize the fish resources in excess, resulting in inefficient resource utilization [2]. This condition will cause the fishermen's inability to maximize profits from fishing business [3,4]. The control of input use is one of the sustainability-based approaches to fisheries management which aims to improve the performance of the fishing industry through the reduction of excessive fishing capacity [5].

In fishery business, boats and other inputs are directly controlled by fishermen except for the production. Due to the amount of production which depends on the level of fishing effort and the size of the fish population. The size of the fish population varies and is determined by fishing intensity [3]. Theoretically, these conditions can be explained by the model of Gordon-Schaefer, to examine the economic aspects with the constraint of the fish resources biology, to what level of fisheries inputs (GT of boats, trip, etc.) should be controlled to generate maximum economic benefits [6].

In open-access fisheries, fishery production function is assumed to be in a state of biological balance, so the value of net income (π) from fishing activities is the difference between total revenue
(TR) and total cost (TC). At the condition where the marine fishery is open-accessin nature, and the fishing industry is competitive, the fishery will expand to point where sustainable resource rent is completely dissipated. And if the TR = TC, a balance production occurs, so that economic rent of fish resources is zero, (π) = 0 [7]. Furthermore, in a certain period of equilibrium, fishing effort will be gradually decreased until zero when TR ≤ TC, which in turn, has an impact on the fishing company.

It is necessary to have fish stocks balance with fishing inputs to achieve fishery business sustainability by a fishing company. If the fisheries, in fact, are well managed, the resource will stabilize at Maximum Economic Yield, where sustainable resource rent is maximized [7]. Umar [8] suggests the ideal principle for the company to take advantage of natural resources is a policy to control expenditure so that the marginal revenue is greater than or at least equal to the marginal cost.

The continuation of exploitation of fish resources needs to be managed effectively to control ‘race to fish’ which leads to overcapacity and overfishing [9]. Excess capacity and overfishing that occur in the exploitation of skipjack tuna resources will cause a massive pressure on the resources. This condition has implications on the social and economic aspects such as the decline in fishery production and income and other socio-economic issues [10,11]. Whether the exploitation of fish resources in a certain waters is efficient regarding economic overfishing, production decreases due to an imbalance of fishing inputs and fish stocks can be determined by data envelopment analysis (DEA) approach. This is a non-parametric method that uses mathematical programming to determine an optimal solution that is subject to existing constraints.

The potential of large-pelagic fish resources, i.e., tunas and skipjack in Moluccas contained in the Republic of Indonesia’s Fisheries Management Area (FMA)-714, FMA-715, and FMA-718 were estimated at 261.5 ton/year, while total production reached 101.2 ton/year [12]. These figures indicate that large-pelagic resources still have a chance for future development. If the potential is not managed optimally, it will lead to over-exploited and pressure on tuna skipjack resources. This research was aimed at analyzing the technical efficiency and financial index of skipjack pole and line in Central Maluku, in the perspective of the sustainable development of pole and line (Huhate) fisheries business.

2. Research Methods

2.1 Methods of data collection
Sampling was conducted randomly with GT size stratification of the pole and line boats at the capture fishery centers. It covered the skipjack pole and line units that were still active in fishing during the research. Primary data were collected from the boat owner which includes the main size of the vessels and machinery, fishing gear, production, the price of fish, the cost of input, duration of the fishing trip and investment value. Secondary data were obtained from the official publications that relate to the research.

2.2 Data Analysis
Measurement of technical efficiency (TE) was conducted by using the technique of DEA (Data Envelopment Analysis). In the context of capture fisheries, the transformation of inputs to outputs could be either variable returns to scale, VRS, where the production function is decreasing returns to scale, so the DEA model was modified according to the model developed by Banker-Charnes-Cooper (BCC) [13]. It could be explained that the use of the BCC model is possible for the analysis of VRS economic activities. The use of the specific model is based on assumptions that (i) there is still budget constraint faced by pole and line units in fishing skipjack at the waters of central Moluccas; (ii) not all pole and line units are operating in optimum scale. Consequently, the BCC model of DEA can be utilized to analyze technical efficiency. Therefore, the analysis of technical efficiency with the VRS and input orientation was used to determine input utilization rates in producing outputs, in addition to describing the technical efficiency of each DMU.

The DEA model of input minimization with VRS assumption is formulated as follows,

\[
TE = \text{Max } \emptyset
\]
Subject to the following restrictions,

\[ \sum_{j=1}^{J} z_j x_{jn} \leq \theta u_j, \quad n \in \alpha \]

\[ \sum_{j=1}^{J} z_j x_{jn} = \gamma_j x_{jn}, \quad n \in \alpha \]

\[ Z_j \geq 0, \quad \gamma_j \geq j = 1,2,\ldots,J, \quad n = 1,2,\ldots,N \]

It was assumed that \( j = 1, 2, \ldots, J \) is the number of observations on 20 skipjack pole and line (huhate) boats or \( J = 20 \) which is also the DMU (Decision Making Unit). Inputs used are the duration of the fishing trip and operating costs so that \( n = 1, 2, N \), input \( (n = 2) \), where:

TE = technical efficiency of fishing gear to-\( j \)th

\( \theta \) = measurement value of each observation \( (\geq 1) \)

\( U_j \) = output for fishing gear to-\( j \)th, which is 1 output (catch fish)

\( x_{jn} \) = used inputs to-\( n \) which are the duration of fishing trip and operating costs

\( Y_j \) = level of the variable input use to-\( n \)

\( z_j \) = utilization rate of variables.

The determination of financial feasibility index of fishery business was conducted by using investment criteria of NPV, IRR, and Net B/C with formula, as follows.

(a) **Net Present Value (NPV)**

\[ \text{NPV} = \sum_{t=1}^{n} \frac{B_t - C_t}{(1 + i)^t} \]  

Where:

\( B_t \) = the benefit of \( i \) year

\( C_t \) = the cost of \( i \) year

\( r \) = interest rate per year

\( i \) = time of calculation

Decision criteria: \( \text{NPV} \geq 0 \) means "go project"; \( \text{NPV} < 0 \) means "no go project."

(b) **Internal Rate of Return (IRR)**

\[ \text{IRR} = P_1 - C_1 \times \frac{P_2 - P_1}{C_2 - C_1} \]  

Where:

\( P_1 \) = the 1st interest rate

\( P_2 \) = the 2nd interest rate

\( C_1 \) = the 1st NPV

\( C_2 \) = the 2nd NPV

Decision criteria: if \( \text{IRR} \geq \text{social discount rate} \) means "go" project; \( \text{IRR} < \text{social discount rate} \) means "no go" project.

(c) **Net Benefit Cost Ratio (Net BCR)**
Decision criteria: Net BCR ≥ 1 then investment activity is feasible to be implemented and if Net BCR <1, investment activity is not feasible to be implemented.

3. Results and Discussion

3.1 Technical description of skipjack pole and line (huhate)

Pole and line as a fishing gear consist of fishing rods, fishing lines, unrelated fishing rods and baits operated by fishers together on board. The fishing rods are made of quite an old bamboo or synthetic materials such as plastics or fibers having a good level of elasticity. The length of the rod is 2 -2.5 m with diameter 3-4 cm at the base and the tip 1-1.5 cm. The line is made from monofilament materials such as a white fishing line or wire leader with a length of 20 cm. The hook size used is 2.5 - 2.8.

The dimension of skipjack pole and line (huhate) boat size ranged from 13.6 to 32 GT, powered by the main engine of 105 to 250 HP and equipped with GPS to find out the fishing ground of skipjack. The duration of fishing time ranged from 1 to 6 days/trip, and 17 to 27 fishermen employed in one boat for the fishing operation.

3.2 Technical efficiency

The measurement of the technical efficiency of the skipjack pole and line boat in size of 20-32 GT utilized the technique of DEA with a variable return to scale (VRS). This scale was applied to assess changes in production levels due to the changes of input use. The results of the analysis are shown in Figure 1.

![Figure 1](image_url)

**Figure 1.** Technical efficiency scores of the skipjack pole and line units

The technical efficiency of skipjack pole and line boat tended to be fluctuated by its size. This result indicated that the use of inputs per vessel was not proportional to the outputs, except for DMU with efficiency score equal to 1 that is an optimal input use which is a base value in determining
relative efficiency. Empirical results indicate that 5 out of 20 DMUs had the most efficient scores. And 10 DMUs had scores above 0.9, while the remaining 5 DMUs had efficiency scores above 0.8. Assumed that the efficiency score equals to 0.8 as a basis value, the entire DMUs find to be efficient. Based on this assumption, the skipjack fishing activities in the Maluku Sea indicated excess capacity. Pascoe et al. [14] state that the excess capacity is more in short-term and can be gradually changed to optimum input use. According to Cooper et al. [15], DEA application is used for calculating the efficiency by reducing input or output of vessels individually or in total. The highest input use was found in the DMU-17 which is indicated by the lowest score of technical efficiency compared with other DMUs. To achieve input utilization optimally, each input of the duration of the fishing trip and the operation cost should be decreased by 35.5% and 18.8% respectively. To improve the efficiency score of all the DMUs or the 20 units of skipjack pole and line it could be conducted by reducing 58% of the duration of the fishing trip and 42% of the operating cost. However, the input of operating cost is difficult to control except for the length of the fishing trip. Hence, the duration of the fishing trip can be used as an instrument for capacity control in skipjack fishery.

3.3 Financial analysis
3.3.1 Investment. Investment is a permanent working cost to purchase capital goods that are expected to have long-term benefits. The types of capital goods of skipjack pole and line business by boat size are presented in Table 1.

| Boat size (GT) | Type of equipment and investment value (in rupiah) |
|---------------|--------------------------------------------------|
|               | Boats    | Main Engine | Auxiliary Engine | Navigation Equipment | Fishing Gear and Other | Amount        |
| ≤ 20          | 507,410,000 | 225,000,000 | 32,000,000     | 23,000,000         | 3,400,000              | 903,431,500 |
| 21-25         | 652,385,000 | 250,000,000 | 32,000,000     | 23,000,000         | 3,400,500              | 1,104,902,750 |
| 26-30         | 690,000,000 | 300,000,000 | 32,000,000     | 23,000,000         | 5,000,000              | 1,207,500,000 |
| ≥ 31          | 858,280,000 | 350,500,000 | 32,000,000     | 23,000,000         | 5,000,000              | 1,458,522,000 |

Source: Fiber vessel industry

The highest investment was on the skipjack pole and line boats in size ≥ 31 GT, and the lowest one was in size ≤ 20 GT. The average use of capital goods for skipjack pole and line company were 66.54% for boats, 27.64% for main engines, 3.15% for auxiliary engines, 2.26% for navigation equipment and the remaining 0.41% for fishing gear.

3.3.2 Variable costs. Variable costs are the costs incurred due to the use of variable inputs in which the changes are linear to the changes in production levels [16]. The variable costs of skipjack pole and line fishery consisted of the wage of fishermen 30.57%, fuel 27.12%, ice 17.41%, baits 13.87, and ration 11.08% (Figure 2). Also, the expenditure of operation costs by boat size per year is the following. The annual operation cost spent to the boat size of less than or equal 20 GT amounted to Rp202,850,000; the boat size of 21-25 GT Rp 330,509,074; boat size of 26-30 GT Rp 461,808,642; and boat size ≥ 31 GT Rp 532,420,560.
3.3.3 Fixed cost. Fixed cost is the cost that companies or producers have to pay at any rate of output. The fixed costs of the skipjack pole and line company identified consisted of the costs of depreciation, repair and maintenance cost, and the cost of company license for fishing (Table 2).

| Boat size (GT) | Depreciation | Repair and Maintenance | Fishing business license | Amount  |
|----------------|--------------|------------------------|--------------------------|---------|
| ≤ 20           | 30,188,266   | 13,886,483             | 5,100,000                | 49,174,749 |
| 21-25          | 51,813,142   | 19,048,949             | 5,100,000                | 75,962,092 |
| 26-30          | 60,030,000   | 21,750,000             | 5,100,000                | 86,880,000 |
| ≥ 31           | 69,830,824   | 22,307,068             | 5,100,000                | 97,237,892 |

The calculation of depreciation cost was based on the straight-line method, in which the economic life of the boat was estimated 30 years, the main engine 15 years, the auxiliary machinery five years, the navigation equipment four years, and the fishing gear four months. Of the total fixed costs, expenditure for the depreciation component amounted to 68.51%, repair and maintenance 24.90%, fishing business license 6.60%. The highest fixed cost was in the depreciation component. In the period of economic life of fishing capital goods, the internal sources of funds should be well allocated to generate the opportunities for business development.

3.3.4 Analysis of revenue and earnings. Revenue is the product of multiplication of the fish production and its price. The revenue of the fishing business has a linear relationship to the production. It means that the higher production leads to greater revenue, and vice versa. The average price of skipjack was Rp 7,500/kg. Earning is the difference between total revenue and total cost. The earnings before tax are earning value minus taxes (10%), while earnings after tax or net revenue represent the difference between earnings before tax and with tax value (Table 3).

| Boat size (GT) | Revenue (Rp/Year) | Expenditure (Rp/Year) | Earning (Rp/Year) |
|----------------|-------------------|-----------------------|-------------------|
|                |                   | Variable cost | Fixed cost | Total cost | Before tax | After tax  |
| ≤ 20           | 576,330,000       | 202,850,000    | 49,174,749 | 252,024,749 | 324,305,250 | 291,874,725 |
| 21-25          | 864,075,000       | 330,509,074    | 75,962,091 | 406,471,165 | 457,603,835 | 411,843,451 |
| 26-30          | 1,233,994,710     | 461,808,462    | 86,880,000 | 548,688,642 | 685,306,247 | 611,775,623 |
| ≥ 31           | 1,316,752,500     | 532,420,560    | 97,237,892 | 629,658,452 | 687,094,047 | 618,384,643 |

The empirical results of the research indicated that business of the skipjack fishing of all boat size (GT) observed was found to be profitable. Value of the net income varied due to the differences in
revenues and expenditures among the vessel sizes. The total cost per kilogram of skipjack was found to be Rp. 3,451, variable cost Rp. 2,871, and net income reached Rp 3,643.

3.4 Business feasibility
Business feasibility aims to provide information about the feasibility of a business project, which is usually an investment project [8]. Business feasibility analysis was conducted by using investment criteria approach. According to Umar [17], the investment criteria are categorized as a criterion based on (1) income, and (2) cash flow which does not consider the time value of money (discounting factor) and considers the time value of money.

The business feasibility was analyzed using the investment criteria of NPV, IRR, and Net B/C for the skipjack fishing business. Results of the feasibility analysis are presented in Table 4.

| Table 4. Index of investment criteria of skipjack pole and line by boat size

| Boat size (GT) | NPV (Rp)     | IRR (%) | BC Ratio |
|---------------|--------------|---------|----------|
| ≤ 20          | 297,111,637  | 8.34    | 1.35     |
| 21-25         | 471,734,375  | 9.07    | 1.76     |
| 26-30         | 1,284,091,063| 13.61   | 1.91     |
| ≥ 31          | 855,990,866  | 8.81    | 1.67     |

Based on the empirical analysis of investment criteria, the skipjack pole and line fishery were financially feasible to be developed due to the higher financial index of B/C ratio as well as the NPV and IRR figures. Among the skipjack fishing boats, the boat in size of 26 to 30 GT was the priority to be developed. The priority is determined by using the decision-making method by Gray et al. [18]. Results of the empirical analysis for development priority are shown in Table 5. In the business perspective, the choice of investment for fishing business development should utilize the capital efficiently so it could provide a higher level of economic benefits.

| Table 5. Development priority of skipjack pole and line boat

| No. | Boat size (GT) | Net B/C Index | Ranking |
|-----|----------------|---------------|---------|
| 1   | ≤ 20           | 1.35          | 4       |
| 2   | 21-25          | 1.76          | 2       |
| 3   | 26-30          | 1.91          | 1       |
| 4   | ≥ 31           | 1.67          | 3       |

The Net B/C equaled to 1.97 implied that the expenditure of Rp. 1.00 could generate a profit of Rp. 1.97. The IRR value of 13.85% indicated that discount rate was greater than the social discount rate of 8%, that is feasible. The NPV figure indicated that the profit to be gained is Rp. 1,236,422,956 for the next five years based on the present value of money, if the skipjack fishing business is managed effectively in term of capital input.

4. Conclusions
Skipjack pole and line (H uhate) fishery indicated excess capacity except for the boat in size of 26-30 GT which has already used input optimally. The highest excess capacity was found at the boat in size of 20 GT and below 20 GT. To achieve optimal inputs used, the duration of fishing trip needed to be reduced by 35.5% and the operation cost by 18.8% as well. The skipjack fishing boat in size of 26 to 30 GT had the highest values of the NPV, the IRR, and the BC ratio. The findings suggest that the development of skipjack pole and line business in Central Maluku should be focussed on the fishing boat in size of 26 to 30 GT because of the use of inputs efficient in fishing and having the highest scores in financial analysis.
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