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Productivity Analysis Using the Cobb-Douglas Function Based on Effective Working Hours

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ABSTRACT

Objective: *This research aims to compare the productivity of the amount of effective working time in the production department in 2021 and 2022.* ***Method:*** *The productivity measurement method is based on the Cobb-Douglas production function approach, so that we can know the extent of the company's efficiency and effectiveness. Productivity measurement is carried out using the Cobb-Douglas function approach.* ***Results:*** *This research shows that the level of productivity in 2022 is higher than in 2021 with the efficiency index values in 2021 and 2022 being 0.9499104 and 1.0599527. This means that the use of working hours increased by 11.58%.* ***Novelty:*** *These results can be used as consideration in maintaining and increasing productivity.*

INTRODUCTION

The current industrial sector is developing rapidly, resulting in increasingly competitive levels of competition. This level of competition forces companies to evaluate their business processes to remain competitive with their rivals. This evaluation can be carried out by monitoring productivity achievements to ensure that the activities conducted align with the company's plans and targets [1]. Productivity is one of the indicators of a company's success in utilizing its resources to produce the targeted output. Productivity is related to production efficiency, expressed as the ratio between the products produced and the resources used [2]. This ratio indicates a company's level of productivity and can be used by management to evaluate operational processes, aiming to create more effective and efficient company activities [3].

A shoe company in the Sidoarjo area has been attempting to improve its productivity, which has so far been considered less effective. Unstable production productivity occurred in one of its shoe production lines. The company experienced a production decline in 2021, with an output of 24,100 units against a target of 23,400 units, and in 2022, an output of 21,300 units against a target of 26,100 units. This decline impacted the company's ability to meet its set targets. Productivity is a critical factor in supporting the survival of any company, which involves analyzing and evaluating products based on performance levels during a specific period [5].

Productivity is the ratio between total output and total input used by the company [6]. An increase in productivity over each period indicates that the company is performing well [4]. This shows the importance of measurement so that the company can

determine whether productivity has increased or decreased. The Cobb-Douglas production function is chosen because it can describe the returns to scale—whether increasing, constant, or decreasing—using quantitative data [7]. Consequently, productivity relates to how efficiently inputs are used to generate outputs, namely products and services.

Several methods are commonly used for measuring productivity. The Marvin E. Mundel method uses a measured period with a base period, comparing productivity during the measurement period to the base period [8]. The Objective Matrix (OMAX) measures partial performance by monitoring criteria aligned with the function of each department [9]. The American Productivity Center (APC) method measures productivity, profitability, and price improvement [10]. The Craig Harris method measures overall productivity, representing overall efficiency and growth, assuming the company aims to maximize profit [11]. Craig Harris defines input elements in four groups: labor, capital, materials, and other inputs. The Multi Factor Productivity Measurement Model (MFPMM) measures productivity changes based on labor, materials, energy, and others, providing optimal analysis by showing profitability and which factors need future improvement [12]. The POSPAC method (Production, Organization, Sales, Product, Arbeiter, and Capital) is a partial productivity measurement tool evaluating production, sales, organization, labor, product, and capital [13]. Productivity aspects measured in POSPAC include Production, Organization, Sales, Product, Labor, and Capital productivity [14].

The Cobb-Douglas production function is more suitable for industry-level analysis than individual company analysis [15]. It shows the output-to-input ratio, where inputs may include production costs and equipment, and outputs may include sales, revenue, market share, and defects. The Cobb-Douglas function involves two or more variables, with independent variables denoted as X and dependent variables as Y [16].

This study uses the Cobb-Douglas method to measure productivity, aiming to determine how productive the company is based on this method. Independent variables are inputs from the production process, such as working hours, while dependent variables are the outputs produced. The Cobb-Douglas method is relatively simple and easy to understand because the exponent coefficients directly indicate elasticity, and the sum of these coefficients shows returns to scale [17].

Operators inevitably experience fatigue, which reduces work ethic over both short and long periods. Any decline in operator performance affects subsequent work processes, materials, and costs. Productivity serves as an indicator of how well a company utilizes resources to produce the desired output, emphasizing the need for improvement and productivity enhancement. Productivity measurement is vital for maintaining business competitiveness annually [18]. The results can serve as a guide to evaluate performance individually, in groups, by industry, or even internationally [19].

Labor productivity variation calculates output per unit of labor, while total factor productivity measures output per unit of total input, including labor and capital [20]. This can be used to calculate profit or loss in business activities using the productivity

formula: output divided by input [21]. A unique characteristic of this study is that shoe production output fluctuates throughout the year, while effective working hours remain constant. Data required include monthly production and effective working hours per month. This study can determine whether effective working hours in production are productive enough to produce the final shoe products according to consumer specifications.

This study aims to measure the productivity of the finishing department in a shoe company in Sidoarjo and identify alternatives to improve productivity. The results can help management enhance productivity using the Cobb-Douglas production function method.

RESEARCH METHOD

The research method used in this study is quantitative. The quantitative method is employed to solve problems using the Cobb-Douglas production function method. Productivity measurement using the Cobb-Douglas function approach can be carried out with the following steps:

A. Research Variables

Several variables that influence the productivity index are described as follows [22]:

1. Dependent variable (fixed variable) is the variable whose value can be influenced by the independent variable. This refers to the output produced, in this case, shoes (Y = shoes).
2. Independent variable (free variable) is the variable that affects or causes an influence on the dependent variable. This refers to the input used, which is the number of effective working hours (X1).

B. Efficiency Index

The efficiency index can be calculated using the previously mentioned equations. The data used to determine the efficiency index include the average natural logarithm value of the output, the average natural logarithm value of the input, and the production elasticity coefficient. The efficiency index can be calculated using equation (1), and the value of δ can be determined by performing calculations using equation (2).

$$\tau = \overline{ln\, Q} - \overline{\beta ln\, L} \quad \text{.....(1)}$$

$$\delta = anti \ln \tau \quad \text{.....(2)}$$

Source: [23]

C. Cobb-Douglas Production Function

The Cobb-Douglas function is a power function that has at least two variables, one of which explains Y (the dependent variable), and the others explain X (the independent variables). Regression is usually used to analyze the relationship between Y and X because it accounts for how changes in Y affect changes in X [24].

The relationship between Y and X represents the Cobb-Douglas function. The equation shows this relationship:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3\, e^u \quad \text{.....(3)}$$

Source: [25], [26], [27]

Explanation:
Y = level of production
A = constant value
X1 = value of variable X1
X2 = value of variable X2
X3 = value of variable X3
b1, b2, b3 = regression coefficients for variables X1, X2, X3
u = error term
e = natural logarithm base (e = 2.718)

The equation above represents the original formula of the Cobb-Douglas production function. After transforming all variables into natural logarithms (Ln), the function is expressed in Ln form, resulting in the following equation:

$$\text{Ln } Y = \text{Ln } a + b_1 \text{ Ln } X_1 + b_2 \text{ Ln } X_2 + b_3 \text{ Ln } X_3 \text{ .....(4)}$$

Sumber: [25], [20]

D. Production Elasticity

When all other production factors remain constant, the partial elasticity of a production factor is a measure of the proportional change in output caused by a proportional change in that production component. Production elasticity for each production factor, or parameter β1 in the Cobb-Douglas function, can be represented as the elasticity of T, L, K, denoted by β1, β2, β3. The interpretation of production elasticity is that if ε = 0.8, it means that if the input (production factor) increases by 10%, output will increase by 8% [28].

E. Calculating the Productivity Index

The purpose of calculating the productivity index is to determine the development of factory productivity—whether it increases, remains constant, or decreases. Productivity index calculation can be done in two ways:

1. By comparing the total value of achievement indicators with the standard indicator value.
2. By comparing it with the total value of indicators from the previous period [7].

The following are the data on production quantity and total working hours from this study:

Table 1. Data on Production Quantity and Working Hours for the Year 2021.

Research Variables	Year	
	2021	2022
Production Quantity (Q) (units)	275,212	7,216
Working Hours (L) (hours)	278,680	7,029

The following is the flowchart of this research:

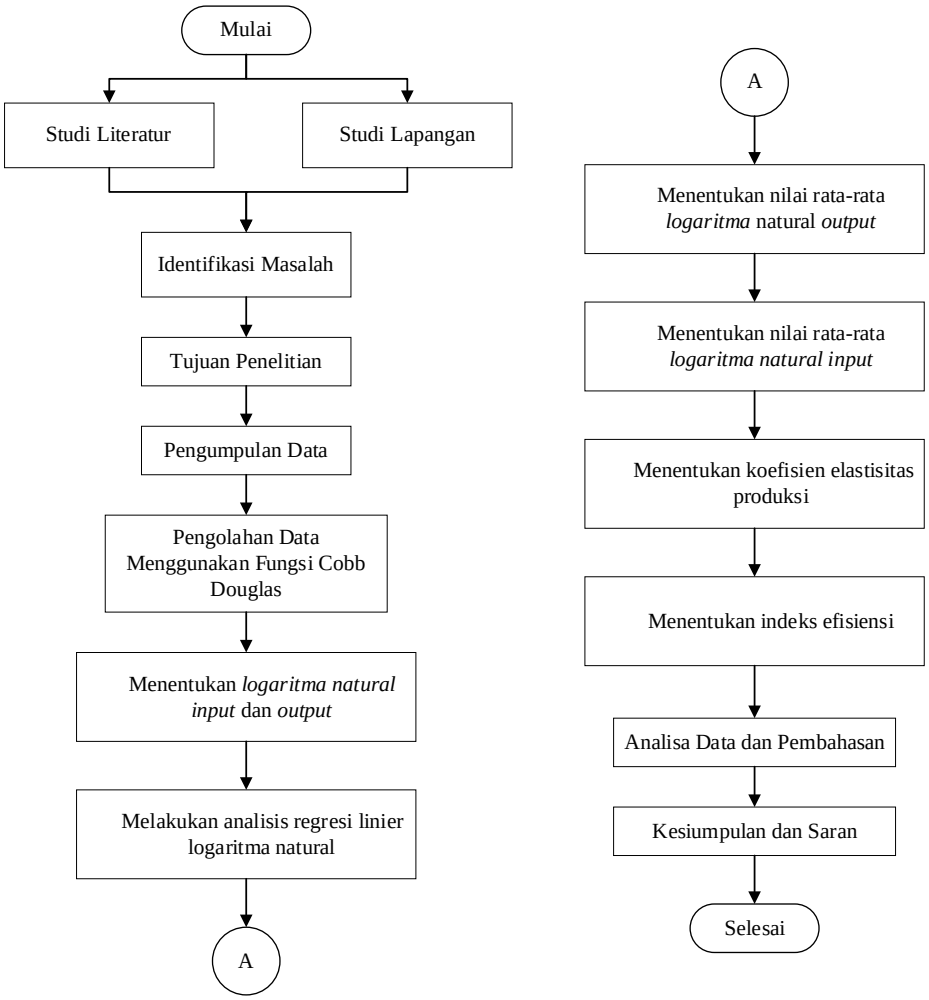

Figure 1. Research Flowchart.

RESULTS AND DISCUSSION

Measuring Productivity Using the Cobb-Douglas Function Approach Can Be Done Using The Following Steps.

1. Determining the Natural Logarithm of Input and Output

The data on the total output and input in the data processing are transformed into natural logarithms (ln) as shown in Table 4 and Table 5.

Table 2. Data on Total Production and Total Working Hours for the Year 2021.

Month	Production Quantity (Q) (units)	Working Hours (L) (hours)	In Q	In L
January	21,715	618	9.98576	6.42649
February	24,885	575	10.12202	6.35437
March	22,157	536	10.00591	6.28413
April	25,226	636	10.13563	6.45520
May	23,453	622	10.06275	6.43294
June	20,563	644	9.93125	6.46770
July	20,533	552	9.92979	6.31355
August	21,401	609	9.97119	6.41182

September	25,225	638	10.13559	6.45834
October	25,871	590	10.16088	6.38012
November	22,759	621	10.03272	6.43133
December	21,424	575	9.97227	6.35437

Table 3. Data on Total Production and Total Working Hours for the Year 2022.

Month	Production Quantity (Q) (units)	Working Hours (L) (hours)	In Q	In L
January	24,550	546	10.10847	6.30262
February	25,527	621	10.14749	6.43133
March	24,416	614	10.10299	6.41999
April	20,920	556	9.94846	6.32077
May	22,424	586	10.01789	6.37332
June	22,377	644	10.01579	6.46770
July	20,563	557	9.93125	6.32257
August	24,355	610	10.10049	6.41346
September	21,938	578	9.99598	6.35957
October	24,456	609	10.10463	6.41182
November	25,486	536	10.14588	6.28413
December	21,668	572	9.98359	6.34914

2. Conducting Natural Logarithm Linear Regression Analysis

The data that has been transformed into natural logarithms (ln) is then used to calculate the coefficients of the Cobb-Douglas production function using natural logarithm linear regression analysis. The calculation of the natural logarithm linear regression analysis can be seen in Table 3 below:

Table 4. Natural Logarithm Data of Shoe Production in 2021.

Month	In Q	In L	(ln Q)(ln L)	$\ln L)^2$
January	9.98576	6.42649	64.17336	41.29975
February	10.12202	6.35437	64.31906	40.37802
March	10.00591	6.28413	62.87847	39.49034
April	10.13563	6.45520	65.42751	41.66959
May	10.06275	6.43294	64.73309	41.38272
June	9.93125	6.46770	64.23232	41.83113
July	9.92979	6.31355	62.69220	39.86089
August	9.97119	6.41182	63.93348	41.11141
September	10.13559	6.45834	65.45907	41.71013
October	10.16088	6.38012	64.82765	40.70596
November	10.03272	6.43133	64.52372	41.36202
December	9.97227	6.35437	63.36748	40.37802

The data transformed into natural logarithms (ln) is then used to calculate the coefficients of the Cobb-Douglas production function using natural logarithm linear

regression analysis. In the linear regression analysis for January 2021, the resulting value is 41.29975.

Table 5. Natural Logarithm Data of Shoe Production in 2022.

Month	In Q	In L	(ln Q)(ln L)	ln L)²
January	10.10847	6.30262	63.70982	39.72301
February	10.14749	6.43133	65.26188	41.36202
March	10.10299	6.41999	64.86117	41.21633
April	9.94846	6.32077	62.88192	39.95211
May	10.01789	6.37332	63.84720	40.61921
June	10.01579	6.46770	64.77911	41.83113
July	9.93125	6.32257	62.79097	39.97483
August	10.10049	6.41346	64.77909	41.13246
September	9.99598	6.35957	63.57015	40.44418
October	10.10463	6.41182	64.78906	41.11141
November	10.14588	6.28413	63.75810	39.49034
December	9.98359	6.34914	63.38721	40.31157

The data transformed into natural logarithms (ln) is then used to calculate the coefficients of the Cobb-Douglas production function using natural logarithm linear regression analysis. In the linear regression analysis for January 2022, the resulting value is 39.72301.

3. Determining the Average Natural Logarithm of Output $\overline{ln\ Q}$

The data in Table 2 and Table 3 can be used to calculate the average natural logarithm of output for 2021 and 2022. The average natural logarithm of output can be calculated using Equation 5.

$$\overline{ln\ Q} = \frac{\sum ln\ Q}{n} \quad \text{.....(5)}$$

The average natural logarithm of output for 2021 is calculated using the following equation:

$$\overline{ln\ Q} = \frac{120.4458}{12}$$

$$\frac{120.4458^{n}}{12} = 10.037$$

The average natural logarithm of output for 2022 is calculated using the following equation:

$$\overline{ln\ Q} = \frac{120.6029}{12}$$

$$\frac{120.6029^{n}}{12} = 10.050$$

4. Determining the Average Natural Logarithm of Input $\overline{ln\ L}$

The data in Table 2 and Table 3 can be used to calculate the average natural logarithm of input for 2021 and 2022. The average natural logarithm of input can be calculated using Equation 6.

$$\overline{ln\ Q} = \frac{\sum ln\ L}{n} \quad \text{.....(6)}$$

The average natural logarithm of input for 2021 is calculated using the following equation:

$$\overline{ln\ Q} = \frac{76.7704}{12}$$

$$\frac{76.7704^{n}}{12} = 6.398$$

The average natural logarithm of input for 2022 is calculated using the following equation:

$$\overline{ln\ Q} = \frac{76.4564}{12}$$

$$\frac{76.4564^{n}}{12} = 6.371$$

5. Determining the Production Elasticity Coefficients

The data in Table 4 and Table 5 can be used to calculate the production elasticity coefficients for 2021 and 2022. The production elasticity coefficients can be calculated using Equation (16) as follows:

$$\beta = \frac{(n\ \Sigma(lnQ \times \ln L)) - (\Sigma\ lnQ)(\Sigma \ln L)}{(n\ \Sigma\ (\ln\ L)^2 - (\Sigma\ \ln\ L)^2} \quad \text{.....(7)}$$

The production elasticity coefficients for 2021 are as follows:

$$\beta = \frac{(n\ \Sigma(lnQ \times \ln L)) - (\Sigma\ lnQ)(\Sigma \ln L)}{(n\ \Sigma\ (\ln\ L)^2 - (\Sigma\ \ln\ L)^2}$$

$$\beta = \frac{(12x9246.66369) - (120.4458x76.7704)}{(12x\ (120.4458)^2) - 5893.6879}$$

$$\beta = \frac{101713.301}{64830.5670} = 1.5689096$$

The production elasticity coefficients for 2022 are as follows:

$$\beta = \frac{(n\ \Sigma(lnQ \times \ln L)) - (\Sigma\ lnQ)(\Sigma \ln L)}{(n\ \Sigma\ (\ln\ L)^2 - (\Sigma\ \ln\ L)^2}$$

$$\beta = \frac{(12x9220.86719) - (120.6029x76.4564)}{(12x\ (120.6029)^2) - 5845.5844}$$

$$\beta = \frac{101429.539}{64301.4279} = 1.5774073$$

6. Determining the Efficiency Index

The efficiency index can be calculated using the previous equations. The data used to determine the efficiency index are the average natural logarithm of output, the average natural logarithm of input, and the production elasticity coefficients. The efficiency index can be calculated using Equation (8), and to determine the value of δ, calculations can be carried out using Equation (9).

$$\tau = \overline{ln\ Q} - \overline{\beta ln\ L} \quad \text{.....(8)}$$

$$\delta = anti \ln \tau \quad \text{.....(9)}$$

The efficiency index for 2021 is as follows:

$$\tau = \overline{ln\ Q} - \overline{\beta ln\ L}$$

$$= 9.98576 - (1.5689096 \times 6.398)$$

$$= -0.05139$$

$$\delta = \text{anti ln } \tau = e^{-0.05139} = 0.9499104$$

The Cobb-Douglas production function for 2021 is:

$$Q = (\delta)(L^{\beta}) = (0.9499104\ )\ (L^{1.5689096}\ )$$

The efficiency index for 2022 is as follows:

$$\tau = \overline{ln\, Q} - \overline{\beta ln\, L}$$

= 10.10847 - (1.5774073 x 6.371)

= 0.05822

δ = anti ln τ = $e^{0.05822}$ = 1.0599527

The Cobb-Douglas production function for 2022 is:

Q = (δ)(L^{β})= (1.0599527) ($L^{1.5774073}$)

The summarized results of the data processing can be presented in Table 6.

Table 6. SPSS Output F-Test on Regression Model.

Year	Cobb-Douglas Function
2021	Q = (δ)(L^{β})= (0.9499104) ($L^{1.5689096}$)
2022	Q = (δ)(L^{β})= (1.0599527) ($L^{1.5774073}$)

From the Cobb-Douglas production function output in Table 6, several pieces of information related to total productivity measurement can be obtained, namely: 1. The input efficiency index to produce output (δ) in 2021 was 0.9499104 hours, while the efficiency index in 2022 was 1.0599527 hours. This means that input usage in 2022 was more efficient than in 2021. 2. The production efficiency index in 2022 (δ=1.0599527 hours) compared to the efficiency index in 2021 (δ=0.9499104 hours) is 1.116. The percentage comparison of production efficiency is (1.116-1) × 100% = 11.58%. Based on the above efficiency index values, it can be concluded that in 2022, the company used working hours more efficiently than in 2021. Therefore, total productivity performance in 2022 increased by 11.58% over the previous year.

CONCLUSION

Fundamental Finding : From the analysis of the results obtained, the author concludes that the productivity level in 2022 was higher than in 2021. This aligns with the author's objective, which was to compare the productivity based on the number of effective working hours in the production section in 2021 and 2022. The increase in productivity level was influenced by the efficient use of input (working hours). The production efficiency index in 2021 was 0.9499104 hours, while in 2022 it was 1.0599527 hours. This means that the use of working hours in 2022 increased by 11.58% compared to 2021. The efficiency improvement, observed from June to December 2022, was not significant but showed a consistent upward trend. **Implication :** Therefore, the company should strive to maintain this trend or even further increase its productivity level. To determine whether a company's condition is improving or declining, the concept of returns to scale can be applied to identify the situation within the company. Some alternatives to maintain and increase the company's productivity level include conducting a review of productivity development in relation to other work elements directly involved in the production process, and expanding marketing areas and enhancing promotion to increase the number of orders, thereby raising productivity levels. **Limitation :** This research has not yet fully provided an exclusive depiction of the

company's productivity, as it mainly focuses on effective working hours and productivity levels over 2021 and 2022, and the efficiency improvement observed was not significant over the period from June to December 2022. **Future Research :** Based on the review of the research results, the author intends to provide suggestions that may be useful for future researchers. Future researchers can further develop this study by examining other variables that could more deeply affect company productivity performance.

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