Comperative Efficiency using Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) in the Banking Industry

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Abstract: - This study's objective is to employ data envelopment analysis (DEA) and stochastic frontier analysis (SFA) to investigate the efficiency accomplishments of Indonesian commercial banking from 2018 to 2019. The first method of measuring efficiency employing a non-parametric data envelopment analysis (DEA) technique reveals that the average efficiency of 71 banks fell from 2018 (0.82) to 2019 (0.81). According to DEA findings, major banks outperform small banks on average. According to the approximated SFA Cobb-Douglas (CD) function, interest expenditure and labor expense have a positive and considerable influence on interest income. This occurs when deposit interest rates rise, banks gain interest revenue by raising lending rates, and banks increase non-interest income. According to the SFA of the Cobb-Douglas function, many banks are inefficient, particularly the first to 49th banks that arise from small banks. The Gamma value is near one (0.999), while the LR test yields a significant result of 36.14. The Cobb-Douglas SFA model is therefore applicable. The efficiency performance findings from the two models above reveal the same thing: large banks are more efficient than small banks.

Key-Words: - Data Envelopment Analysis (DEA), Stochastic Frontier Analysis (SFA), Banking Performance, Efficiency, Indonesia.

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1 Introduction

The banking industry's efficiency performance is often measured using basic ratios based on financial statements, balance sheets, and profit and loss statements. However, there are various approaches for assessing efficiency performance. SFA (Stochastic Frontier Analysis) and DEA (Data Envelopment Analysis) are two extensively utilized efficiency measuring methodologies. SFA is a parametric model approach pioneered that includes two forms of normally distributed random errors as well as one type of random error with multiple distributions, [1]. This one-sided random error is unique to each business and gauges the difference between actual production and prospective output created by high-efficiency technology, allowing technical efficiency to be evaluated.

Since DEA uses linear programming techniques to estimate a firm's technical efficiency while taking a range of inputs and outputs into account, [2]. The DEA, on the other hand, is unable to differentiate between technological inefficiencies and random mistakes. Furthermore, the DEA does not generate standard mistakes. As a result, when analyzing banking efficiency performance, SFA and DEA analytic tools work better together.

When reading the financial performance of banks from 2018 to 2020, the average NPL Ratio of Indonesian banks was 2.7% at the end of 2018, 2.6% at the end of 2019, and 3.1% at the end of 2020. This also applies to the financial performance of the Cost cost-efficiency ratio (CIR). Using the financial ratio approach, this ratio calculates the percentage of a bank's operating expenditures to operational income or efficiency performance. The Covid-19 epidemic was responsible for the decreasing financial performance, [3].

Up to this point, there hasn't been much discussion of how well two methods—Data Envelopment Analysis (DEA) and Stochastics Frontier Analysis (SFA)—perform in terms of banking efficiency in developing countries.

In addition, previous discussions about the efficacy of DEA and SFA on banking efficiency in developing countries have been restricted. This emphasizes the relevance of my research within the context of an economy that faces significant challenges from more developed nations.

This paper's objective is to assess and compare the performance of banking efficiency for the years 2018 and 2019 using DEA and SFA.

2 Literature Review

There are two empirical methods for measuring efficiency: parametric and non-parametric. The most common parametric is stochastic frontier analysis (SFA), [1]. Data envelopment analysis (DEA), is the most widely used nonparametric method, [4]. Empirical studies have utilized these two distinct methodologies, stressing the advantages and disadvantages of each methodology. The stochastic econometric (SFA) technique aims to differentiate the effects of noise from the impacts of inefficiency. Because the programming technique (DEA) is not stochastic, it combines noise with inefficiency and refers to this combination as inefficiency.

Parametric and nonparametric methodologies have been utilized in bank efficiency research, however, there is no consensus on the consistency of efficiency performance, [5]. Due to the inconsistency, various efficient bank ratings were produced.

To conduct a banking study in India, parametric and nonparametric analyses were used. Researchers discovered that SFA and DEA models with different return scales generated the best results, [6].

In the banking industry, inefficiency is caused by a lack of revenue interest, optimal lending, excessive human resource expenses, and high-interest charges when using DEA, [7]. The main reasons for operational inefficiency are high interest costs and the high cost of human resources.

Organizations that effectively implement digital business transformation are more efficient in their use of resources than companies that do not, [8]. Furthermore, government assistance and proper digital infrastructure have a significant influence on firm efficiency.

Conclusions on the relevance of digital business transformation in enhancing firm efficiency and how DEA analytical methodologies may be utilized to assess the effectiveness of digital business transformation in emerging nations like Serbia, [9].

A banking study in Bangladesh utilizing SFA and DEA methodologies claimed that GCG has an impact on efficiency performance, [10].

Organizations that have been in operation for a long time will be more productive and efficient than organizations that have not been in operation for a long time, [11], [12].

State-owned and foreign-owned enterprises outperform private domestic companies in terms of efficiency, [12], [13].

According to the findings of the preceding study, researchers used the SFA approach to conduct research on 26 banks in Ghana from 2003 to 2011 and discovered that large banks are more efficient than small banks since large banks earn money other than interest, [14].

A study on pandemic situations revealed that larger companies are more efficient, [15]. They used the Cobb-Douglas SFA approach to evaluate the data. The findings also reveal that the Covid-19 epidemic has had a significant impact on the technical efficiency of Russian firms, but that this negative effect is expected to fade in the long run.

3 Research Method

3.1 Research Sample

With 88 banks, the research population included all conventional commercial banks but excluded Islamic banks. The secondary data utilized originates from the Financial Services Authority's publishing report period for 2018 and 2019, [16]. Banks with incomplete financial statements throughout the observation period are excluded from the study object.

Thus, the overall sample is 71 banks, with banks 1 to 49 classified as small because their capital is less than Rp. 5 trillion, and banks 50 to 71 classified as large because their capital is greater than Rp. 5 trillion. Because of the COVID pandemic in 2020, the author utilizes data from 2018 and 2019. The company's financial performance dropped throughout the epidemic, [15]. The bank sample is as follows (Table 1, Appendix):

3.2 Analysis Tool

DEA and SFA models reflect the financial intermediation role of a bank and use variables used in similar research to analyze the efficiency performance of bank variables [7], [17]. Interest income and non-interest revenue were chosen as outputs. Interest and labor costs are used as inputs. In this study, we use the Variable Returns to Scale (VRS) model in conjunction with the intermediation technique for DEA, which is based on the input-output relationship between bank functions. Use exogenous variables for SFA, such as size (total asset).

The initial phase in this research is to apply the DEA approach with the Banxia Frontier Analysis (BFA) software to estimate the level of efficiency of small and large banks in the 2018-2019 period. The DEA approach employs a linear model in a non-parametric frontier model.

The selection of outputs and inputs is critical in DEA. Interest income and non-interest revenue are often chosen as outputs since they reflect a bank's primary revenue-generating activities. Interest and labor costs are utilized as inputs since they have a significant impact on a bank's operating efficiency.

The DEA technique contains two approach models: the Charnes-Cooper-Rhodes (CCR) model and the CRS (Constant Return to Scale) model. The second approach model is the Banker, Charnes, Cooper (BCC) model, which assumes that the unit operates at an optimal scale or not.

Since it considers the likelihood that banks might not operate at their ideal scale due to numerous challenges and competition, the BCC model is frequently chosen for studying banks. The VRS model is used along with DEA to account for the possibility that banks could operate at various scales of production. This model makes it possible to analyze efficiency in situations where factors like competition and real-world constraints affect the appropriate operational scale for a bank. The BCC or VRS model is used in this study because the sample is a bank where various obstacles and financial competition can cause the company not to operate optimally, and the BCC model is more appropriate for analyzing the efficiency of service companies, [7].

The DEA degree of efficiency is suppressed data with a restricted value ranging from 0-100. The statistical definition of the model is as follows:

Y*0= ßxi + e0,
y0 = y*0 if y*0 > 0
y0 = 0, otherwise

Where:

-e0 : $\sim N(0, s^2)^3$
-x0 dan ß : variable vectors and unknown parameters
y0 : score DEA
-y* : latent variable

The following study uses the Stochastic frontier analysis (SFA) formula, [18].

$$y_{it} = \left(\beta_o + \sum_{j\leq}^{3} \sum_{k=1}^{3} \beta \, jk^x jit^x kit - u_{it} \right) + v_{it}$$

Information:
In Y_{it} = represents the natural logarithm of output (interest income and non-interest income)
X1 = represents the natural logarithm of interest expenses
X2 = represents the natural logarithm of labor cost

X3 = represents the natural logarithm of size (total asset)

V_{it} denotes the random variables, which are believed to be uniformly distributed normal random errors with a zero mean and an unknown variance.

The U_{it} is a non-negative random variable that is assumed to be distributed independently and represents the technical inefficiency term. These random error variables describe the influence of external production elements that are outside the establishment's control. The magnitude denotes the technical inefficiency term.

SFA models calculate the relation between inputs (interest costs, labor costs, and size) and outputs (interest and non-interest income) while taking random variables (V_{it}) and technical inefficiency (U_{it}) into account. With this strategy, it is recognized that not all inefficiencies ought to be simply explained by chance.

The computer software Frontier 4.1 is used to calculate the greatest probability of a subset of the stochastic frontier production function, [19]. This software determines the most likely functional form that explains the link between inputs and outputs by calculating the likelihood of various subsets of the model.

4 Result and Discussion

4.1 DEA Efficiency Measurement.

According to the findings in Table 2 Appendix, the average efficiency of 71 banks fell from 0.82 in 2018 to 0.81 in 2019. Simultaneously, the categories of major banks and small banks declined somewhat, with small banks falling from 0.78 to 0.77 and large banks falling from 0.82 to 0.81. This demonstrates that all banks' efficiency performance decreased over the previous year.

The results show that the best practice efficiency, with a value of 1, was attained by more than 23% (16 of 71 banks) at the end of 2018, whereas only 13 of 71 banks got the best practice performance in 2019. It implies that, compared to 2018, fewer banks were able to maintain or achieve the greatest degree of efficiency in 2019. More than half of the sample companies (55 of 71 banks) never made it to the border throughout the test period. It demonstrates that the bulk of the banks' operating efficiency may use some work. Certain financial institutions, including Bank Bisnis International, Bank Amar, Bank Jogja, Bank Victoria, Bank Woori Saudara, Bank Tabungan Negara, Bank UOB Indonesia, Bank Mandiri, Bank Nasional Indonesia, Bank Panin, and Bank Rakyat Indonesia, regularly received perfect efficiency rankings of 1 over the two years. Other banks experienced changes in their efficiency ratings, some rising and some falling.

4.2 SFA Efficiency Measurement

The findings of the calculated Cobb-Douglas production function are shown in Table 3. According to these functions, interest expenditure and labor expense have a positive and substantial influence on interest income. Increases in these inputs result in higher interest income since both the interest expense and labor expense coefficients are positive. Interest income increases by 0.264% for every 1% rise in interest expenditures, while interest income increases by 0.355% for every 1% increase in labor expenses. This occurs when deposit interest rises and banks boost their interest revenue by raising lending rates at the same time, they grow their non-interest income. This may occur because of different financial practices used by banks.

Every 1% increase in the size of the bank reduces inefficiencies by 0.425%. The gamma value was close to one, and the LR test was significant. This suggests that technological inefficiency is the product of interest and labor costs, rather than random mistakes. In other words, the Cobb-Douglas SFA model is suitable. When examined further, the efficiency performance findings of SFA and DEA are nearly identical. Table 4 shows the technical efficiency of the Cobb-Douglas function. The banks in the study have a technical efficiency level of 24.2% on average, suggesting moderate efficiency; however, several banks have very high efficiency scores, causing the mean to be higher than the median. This implies that a few banks are much more efficient than the rest of the banks in the sample. On the other hand, there are banks with lower efficiency rankings, which contributes to the vast variation observed. In other words, they are only using 24.2% of their resources to create interest income.

Following that, the study has efficiency scores ranging from 0.026 to 0.999, indicating significant differences in their efficiency levels. The median technical efficiency score of 0.163 separates the banks into two halves: nearly half have scores less than 0.163, while the other half have scores greater than it. The wide range and a median score lower than the mean indicate the presence of outliers - certain banks generate extraordinarily high interest income relative to their inputs, positively skewing the mean efficiency number.

Table 3. Estimation Results from SFA CD Function

Frontier Function	Coef.$^{\text{sig level}}$	Std. error
β_0	8,178***	1,486
β_1 (ln x_1)	0,264***	0,059
β_2 (ln x_2)	0,355***	0,050
β_3 ([ln x_1]^2)		
β_4 ([ln x_2]^2)		
β_5 (ln x_1 ln x_2)		
Inefficiency term		
δ_0	8,888***	1,705
δ_1	-0,425***	0,087
Stochastic term		
σ_s^2	0,034***	0,004
γ	0,999***	0,091
LR		36,14***

Source: Data processing by Frontier 4.1
y: sum interest income and noninterest income
x_1 : interest expense
x_2 : labour cost
****significance at level <0.1%*

Table 4. Technical Efficiency (TE)

Function	Mean	Median	Std. deviate	Min	Max
Cobb-Douglas	0,242	0,163	0,210	0,026	0,999

Source: Data processing by Frontier 4.1

According to Table 4, the average TE is solely 0.242, and the distribution of TE is as follows:

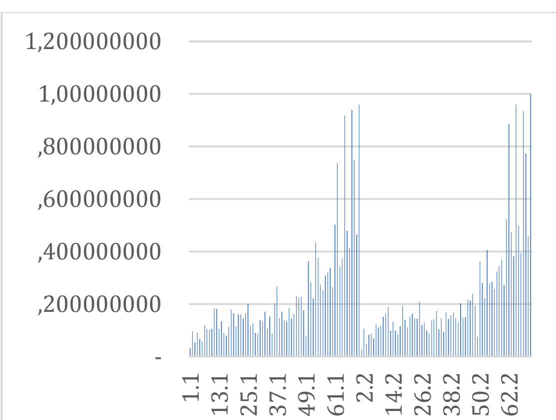

Fig. 1: TE Cobb-Douglas function

Figure 1 is the TE of the Cobb-Douglas function, many banks tend to be inefficient, especially the 1st to 49th banks that come from small banks, the results of the CD function are consistent with the DEA results above, and only a few specific banks show efficiency. The variation in TE is quite large, from a minimum of 0.026 to a maximum of 0.999.

Figure 1 depicts the TE of the Cobb-Douglas function; many banks are inefficient, particularly the first to 49th banks from small banks; the SFA CD function results are consistent with the DEA results above; and only a few unique banks demonstrate efficiency. The range of TE values is wide, ranging from 0.026 to 0.999, and underlines the large variability in efficiency levels between the banks under examination. This disparity in TE ratings implies that some banks have significantly streamlined their resource utilization, while others are still dealing with inefficiencies.

4.3 Discussion

By using DEA large banks outperform small banks on average, which is consistent with previous research, [14], [15]. Large banks, on the other hand, are simpler to obtain non-interest revenue, [14]. This could be related to their larger scale and resources, which allow companies to diversify their income sources more efficiently. Most Indonesian banks are owned by state banks or banks with most of the foreign ownership, [12], [13]. These banks are typically bigger and more visible in the market.

By using SFA, the size of the bank has a negative and considerable influence on inefficiencies, which means that the larger the bank, the fewer inefficiencies there are. To put it another way, the larger the bank, the more efficient it will be. This is supported by a study [14], [15].

Large banks are more efficient than small banks, with state banks owning most large banks and foreign banks owning the remainder. According to a study [12], [13], [20]. Government-owned and foreign-owned banks are more likely to be majority-owned than small, domestically-owned banks because both types of banks are more trusted by the public and can obtain funding at a lower cost than small domestically-owned banks.

The analysis conducted using both the DEA and SFA approaches reveals that large banks perform better in terms of efficiency, especially when they are owned by the government or foreign organizations. These findings highlight the importance of bank size and ownership structure in affecting efficiency outcomes in Indonesia's banking sector.

5 Conclusion

To examine efficiency performance from 2018 to 2019, this study used a non-parametric Data Envelopment Analysis (DEA) and a parametric Stochastic Frontier Analysis (SFA) Cobb-Douglas (CD) Production Function.

According to DEA, the average efficiency of 71 banks fell from 0.82 in 2018 to 0.81 in 2019. Simultaneously, the categories of major banks and small banks declined somewhat, with small banks falling from 0.78 to 0.77 and large banks falling from 0.82 to 0.81. According to the DEA findings, major banks outperform small banks on average.

Cobb-Douglas (CD) Production Function based on the value of Stochastic Frontier Analysis (SFA). The performance of larger banks is more efficient than that of small banks, as evidenced by Gamma and LR test findings that were near to one and significant, respectively. This suggests that technological inefficiency is the product of interest and labor costs, rather than random mistakes. In other words, the Cobb-Douglas frontier model may be applied.

As an outcome of the Cobb-Douglas TE function, many banks are inefficient, notably the first to 49th banks, which are small, and only a few specific banks are efficient. The range of TE is wide, ranging from 0.026 to 0.999.

According to the Cobb-Douglas SFA, interest and labor expenses have a positive and considerable impact on interest and non-interest revenue. This occurs when interest rates rise, and the bank's interest revenue (lending rate) rises at the same time as its non-interest income rises. The outcomes of SFA and DEA are similar in that the larger the bank, the more efficient the bank; this occurs because most major banks are government-owned, and others are foreign-owned.

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APPENDIX

Table 1. Bank Sample

1	Bank Artos
2	Bank Bengkulu
3	Bank Bisnis Internasional
4	Bank BKE
5	Bank FAMA International
6	Bank Harda Internasional
7	Bank Lampung
8	Bank Sulteng
9	Bank Yudha Bakti
10	Bank Amar
11	Bank Artha Graha Internasional
12	Bank Bali
13	Bank Bumi Arta
14	Bank CCB Indonesia
15	Bank Ganesha
16	Bank INA
17	Bank Index
18	Bank J Trust Indonesia
19	Bank Jambi
20	Bank Jasa Jakarta
21	Bank Jogja
22	Bank Kalbar
23	Bank Kalsel
24	Bank Kalteng
25	Bank Kaltim Kaltara
26	Bank MalukuMalut
27	Bank MAS
28	Bank Maspion
29	Bank Mayora
30	Bank Mestika
31	Bank MNC
32	Bank Nagari
33	Bank NOBU
34	Bank NTT
35	Bank Of India Indonesia
36	Bank Papua
37	Bank QNB
38	Bank Resona Perdania
39	Bank Riau Kepri
40	Bank Sahabat Sampoerna

41	Bank Shinhan Indonesia
42	Bank Sulselbar
43	Bank Sultra
44	Bank SulutGo
45	Bank Sumut
46	Bank Victoria
47	Bank Woori Saudara
48	BRI Agro
49	OK Bank
50	Bank BJB
51	Bank Bukopin
52	Bank DKI
53	Bank HSBC
54	Bank ICBC
55	Bank Jateng
56	Bank KEB Hana
57	Bank Mayapada
58	Bank Mega
59	Bank Permata
60	Bank Sinarmas
61	Bank Tabungan Negara
62	Bank UOB Indonesia
63	BTPN
64	Maybank
65	Bank Central Asia
66	Bank CIMB NIAGA
67	Bank Danamon
68	Bank Mandiri
69	Bank Nasional Indonesia
70	Bank Panin
71	Bank Rakyat Indonesia

Source: Otoritas Jasa Keuangan (OJK) 2019

Table 2. DEA Efficiency Summary of bank

No	Bank	2019	2018
1	Bank Artos	0,41	0,47
2	Bank Bengkulu	0,65	0,63
3	Bank Bisnis Internasional	1	1
4	Bank BKE	0,66	0,68
5	Bank FAMA International	1	1
6	Bank Harda Internasional	0,53	0,54
7	Bank Lampung	0,76	0,77
8	Bank Sulteng	0,73	0,69
9	Bank Yudha Bakti	0,70	0,73
10	Bank Amar	1	1
11	Bank Artha Graha Internasional	0,78	0,78
12	Bank Bali	0,85	0,82
13	Bank Bumi Arta	0,68	0,72
14	Bank CCB Indonesia	0,67	0,67
15	Bank Ganesha	0,69	0,65
16	Bank INA	0,77	0,79
17	Bank Index	0,70	0,71
18	Bank J Trust Indonesia	0,62	0,63
19	Bank Jambi	0,81	0,97
20	Bank Jasa Jakarta	0,94	0,98
21	Bank Jogja	1	1
22	Bank Kalbar	0,80	0,79
23	Bank Kalsel	0,74	0,78
24	Bank Kalteng	0,77	0,97
25	Bank Kaltim Kaltara	0,89	0,74
26	Bank MalukuMalut	0,76	0,73
27	Bank MAS	0,79	0,77
28	Bank Maspion	0,68	0,63
29	Bank Mayora	0,62	0,64
30	Bank Mestika	0,79	0,79
31	Bank MNC	0,69	0,62
32	Bank Nagari	0,73	0,72
33	Bank NOBU	0,56	0,62
34	Bank NTT	0,79	0,76
35	Bank Of India Indonesia	0,84	0,80
36	Bank Papua	0,98	1
37	Bank QNB	0,68	0,75
38	Bank Resona Perdania	0,89	0,88
39	Bank Riau Kepri	0,71	0,71
40	Bank Sahabat Sampoerna	0,82	0,79

No	**Bank**	**2019**	**2018**
41	Bank Shinhan Indonesia	0,84	0,90
42	Bank Sulselbar	0,83	0,77
43	Bank Sultra	0,79	0,82
44	Bank SulutGo	0,67	0,68
45	Bank Sumut	0,75	0,77
46	Bank Victoria	1	1
47	Bank Woori Saudara	1	1
48	BRI Agro	0,99	0,97
49	OK Bank	0,59	0,65
	Avarage Small Bank	0,77	0,78
NO	Bank	2019	2018
50	Bank BJB	0,82	0,83
51	Bank Bukopin	0,72	0,74
52	Bank DKI	0,72	0,72
53	Bank HSBC	0,79	1
54	Bank ICBC	1	1
55	Bank Jateng	0,81	0,82
56	Bank KEB Hana	0,93	0,97
57	Bank Mayapada	0,95	0,97
58	Bank Mega	0,81	0,79
59	Bank Permata	0,73	0,72
60	Bank Sinarmas	0,86	0,90
61	Bank Tabungan Negara	1	1
62	Bank UOB Indonesia	1	1
63	BTPN	0,88	0,89
64	Maybank	0,81	0,83
65	Bank Central Asia	1	1
66	Bank CIMB NIAGA	0,79	0,84
67	Bank Danamon	0,69	0,74
68	Bank Mandiri	1	1
69	Bank Nasional Indonesia	0,96	1
70	Bank Panin	1	1
71	Bank Rakyat Indonesia	1	1
	Average Bigger Bank	0,88	0,90
	Average ALL BANK	0,81	0,82

Source: Data processed using MaxDEA 8.0

Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The authors equally contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

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Conflict of Interest

The authors have no conflict of interest to declare.