EFFICIENCY MEASUREMENT OF BUILDING CONSTRUCTION SECTOR COMPANIES LISTED ON INDONESIA STOCK EXCHANGE: STOCHASTIC FRONTIER ANALYSIS APPROACH

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ABSTRACT

The purpose of this study is to estimate the technical efficiency of the building construction sector companies listed on the IDX market over the period 2013-2017 using the Stochastic Frontier Analysis. From the result, shows that variables cost of revenue, capital expenditure, personal expenses, and the inflation rates were found to have a positive and significant effect on the technical efficiency value of companies. Meanwhile, variables net fixed assets and total equity was found to have a positive and insignificant effect on the technical efficiency value of companies. The company with the highest value of technical efficiency was SSIA and the lowest value was DGIK, as compared with other building construction companies listed on the IDX market for both distributional assumptions in time-variant and time-invariant inefficiency effects. Meanwhile, technical efficiency increased gradually over the reference period for time-variant, half-normal distribution is more preferred than truncated normal distribution, and time-invariant is more preferred than time-variant for technical inefficiency effects.

Keywords: Building Construction Sector, Construction Industry, Efficiency, Indonesia Stock Exchange, Stochastic Frontier Analysis

INTRODUCTION

The intensive development of infrastructure in Indonesia has become one of the factors increasing the role of the construction sector in the Indonesian economy. The role of the construction sector can be seen from the absorption of labors, investment, the number of infrastructure and building projects, reciprocal relations with supporting sectors. The construction sector is even a facilitator in the movement and growth of goods and services. The construction sector also plays a role in supporting equitable development in other sectors, such as adequate road access for the transportation of goods and services, food security in each region, improvement of education and health facilities, fulfillment of national electricity and energy needs, and increased tourism attractiveness. On the other hand, economic progress and decline have direct implications for the performance of this sector. Building construction sector companies, which are the main components of the construction industry, have to be efficient; otherwise, they may create an obstacle in the process of development in any economy.

Several studies were conducted using both parametric and non-parametric approaches for efficiency measurement of construction industries : see Wang & Chau (2001), Chau & Wang (2003), Park, Kim, Choi, Kim & Kim (2011), de Araújo Junior, Nogueira, & Shikida (2012), Park, Yoo, Lee, Kim, & Kim (2015), Nazarko and Chodakowska (2015), Hoe, Jinn, Siew, & Hai (2018), and Córdova and Alberto (2018). These studies employed Data Envelopment Analysis (DEA) as a non-parametric approach. Dzeng & Wu (2012), Sahudin, Wan Mahmood, Isa, & Shari (2015), Fernández-López & Coto-Millán (2015) employed Stochastic

Leena and Luna International, Chikusei, Japan.
(株) リナアンドルナインターナショナル, 筑西市,日本
ISSN: 2186-845X ISSN: 2186-8441 Print
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Frontier Analysis (SFA) as a parametric approach, while Nguyen & Giang (2005) (2005) used both Data Envelopment Analysis (DEA) and Stochastic Frontier Production Function. These two approaches are considered as the most appropriate models for estimating frontier functions of various worldwide construction industries.

Several studies were also conducted for efficiency measurement of other industries. Prabowo & Cabanda (2011) attempt to model performance measurement for the firms listed on the IDX market using Stochastic Frontier Analysis (SFA). There are 121 firms analyzed over the period 2000-2005 with 726 pooled observations. The study also examined whether a firm's age, size, market share, manufacturing classifications and time period have effects on the technical inefficiency of the manufacturing sector. Hendrawan & Nugroho (2018) measured and analyzed the efficiency of 14 telecommunication operators in Southeast Asia from 2008 to 2017 by using Data Envelopment Analysis (DEA). By using Stochastic Frontier Analysis (SFA) method, Hendrawan, Nugroho, & Permana (2019) measured the efficiency of 14 telecommunications companies in Southeast Asia over the period of 2008-2017 and measured the impact of efficiency on stock value, as well as the significance level.

The objective of this study is to estimate the technical efficiency of the building construction sector companies listed on the IDX market over the period 2013-2017 using the Stochastic Frontier Analysis (SFA). According to Coelli, Rao, O'Donnell, & Battese (2005), this method has more advantages than others. First, it involves disturbance terms that represent noise, measurement errors, and exogenous variable shock that are out of control. Second, environmental variables are easier to treat. Third, it allows hypothesis testing to use statistics. Fourth, it is easier to identify outliers. Fifth, Cost frontier and distance function can be used to estimate business efficiency that has a lot of output. This study considered the Cobb-Douglas stochastic frontier in which the technical inefficiency effects are defined by a model with two distributional assumptions. Truncated normal and half-normal distributions were used in the model, and both time-variant and time-invariant inefficiency effects were estimated.

LITERATURE REVIEW

Modern efficiency measurements were first proposed by Farrel (1957), who used the work of Debreu (1951) and Koopmans (1951) to define the measurement of company efficiency using several inputs. Farrel (1957) suggests the efficiency of a company consists of two components: technical efficiency, which reflects the ability of a company to obtain maximum output from a series of inputs provided and allocative efficiency, which reflects the company's ability to use inputs in optimal proportions, taking into account the price structure and production technology. These two measures are then combined to provide a measure of total economic efficiency. Kumbhakar & Lovell (2000) argue that technical efficiency is only one component of overall economic efficiency. However, in order to achieve economic efficiency, a company must be technically efficient.

The stochastic frontier production function was first proposed by Aigner, Lovell, & Schmidt (1977) and Meeusen & van den Broeck (1977) separately. The initial specification involves a production function that is used for cross-sectional data that has two-component error terms, one for calculating random error and one for calculating technical inefficiency. The stochastic frontier model for cross-sectional data can be written as follows:

$$Y_i = \exp(x_i\beta + V_i - U_i)\; i = 1,2,\ldots,N \quad \ldots\ldots\ldots\ldots \quad (1)$$

where Y_i represents the production (or logarithmic of production) from the i^{th} company; x_i represents the $(k \times 1)$ vector form (transformation from) input quantity from the i^{th}

company; β represents the vector of unknown parameters to be estimated; V_i are random variable that assumed independent and identically distributed $N(0, \sigma_v^2)$ and independent from U_i; U_i are random non-negative variables that are assumed to estimate technical inefficiency of production and often assumed independent and identically distributed $|N(0, \sigma_u^2)|$ (Coelli T. , 1996).

Battese & Coelli (1992) proposed stochastic frontier production function for (unbalanced) panel data that have firm effects which are assumed to be distributed as a normal truncated random variable, which also allows time-varying. The stochastic frontier model for panel data can be written as follows:

$$Y_{it} = \exp(x_{it}\beta + V_{it} - U_{it})\; i = 1,2,\dots,N;\; t = 1,2,\dots,T \quad \text{..........} \quad (2)$$

where Y_{it} represents the output for the ith company in the tth time period; x_{it} represents the $(1 \times k)$ vector which values are functions of inputs for the ith company in the tth time period; βis $(1 \times k)$ vector of unknown parameters to be estimated; and V_{it} are the error components of random disturbances, independent and identically distributed $N(0, \sigma_v^2)$ and independent from U_{it}. $U_{it}$are non-negative random variables associated with the technical inefficiency of production and can be expressed as :

$$U_{it} = \{exp[-\eta(t - T)]\}U_i \quad \text{..........} \quad (3)$$

where η is an unknown scalar parameter to be estimated, which decides whether inefficiencies are time-varying or time-invariant, and U_i are assumed to be independent and identically distributed and truncated at zero of the $N(\mu, \sigma_u^2)$ distribution. If η is positive, then $-\eta(t - T) = \eta(T - t)$ is positive for $t < T$ and so $\exp\{[-\eta\,(t - T)]\} > 1$, which implies that technical inefficiencies of companies decline over time. If η is zero, technical inefficiencies of industries remain constant, if η is negative, they increase over time.

The maximum likelihood estimation (MLE) method was used to estimate the parameters of the stochastic frontier model. Using the composed error terms of the stochastic frontier model (1), the total variation in output from the frontier level of output, attributed to technical efficiency, is defined by $\boldsymbol{\gamma = \sigma_u^2/(\sigma_u^2 + \sigma_v^2)}$. In truncated and half-normal distributions, the ratio of industry-specific variability to total variability, $\boldsymbol{\gamma}$, is positive and significant, implying that company-specific technical efficiency is important for examining the total variability of output produced. The estimates of the maximum likelihood estimates for the parameters of the stochastic frontier model are obtained by using the FRONTIER 4.1 program (Coelli T. , 1996).

RESEARCH METHODOLOGY

In this study, the data collected from the financial statements of the building construction sector companies listed on the IDX market over the period 2013-2017. The study involved 10 building construction sector companies listed on the IDX market. The total population of building construction sector listed on the IDX market is 17 companies (the year 2018). Purposive sampling technique was used to determine selected samples, with the following criteria: (1) The building construction sector companies listed on the IDX market (2) Have published the financial report over the period 2013-2017. These companies are ADHI, PTPP, WIKA and WSKT which are state-owned companies and ACST, DGIK, JKON, NRCA, SSIA and TOTL which are private companies.

For the determination of the efficiency measurement variables of the building construction sector companies, the authors refer to previous studies. These variables are as follows: Cost of revenue which refers to variable Operating Expenditure (OPEX) from Hendrawan,

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ISSN: 2186-845X ISSN: 2186-8441 Print
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Nugroho, & Permana (2019), Capital Expenditure (CAPEX) refers to Hendrawan & Nugroho (2018) and Hendrawan, Nugroho, & Permana (2019), personal expenses refers to Sahudin, Wan Mahmood, Isa, & Shari (2015), Hendrawan & Nugroho (2018) and Hendrawan, Nugroho, & Permana (2019), net fixed assets refer to Prabowo & Cabanda (2011), Córdova and Alberto (2018) and total equity refer to Park, Yoo, Lee, Kim, & Kim (2015) as an input variable. Meanwhile, revenue refers to Park, Kim, Choi, Kim, & Kim (2011), Park, Yoo, Lee, Kim, & Kim (2015), Hendrawan & Nugroho (2018), and Hendrawan, Nugroho, & Permana (2019) as the output variable. The inflation rate is used as an environment variable. Environmental variables describe variables that cannot be controlled by the company but also influence company profits. Previous studies using the inflation rate as an environmental variable was the study of Al-Farisi & Hendrawan (2011) which measured the profit efficiency of conventional and sharia banking companies in Indonesia over the period 2002-2008 using Distribution Free Approach (DFA) and the study of Hendrawan & Nasution (2018) which assessed the efficiency of 21 banks in the IDX market over the period 2008-2017 using Stochastic Frontier Analysis (SFA).

In order to estimate the technical efficiency of the building construction sector companies, the study considered the stochastic frontier model for technical inefficiency effects in stochastic frontier production function proposed by Battese & Coelli (1992). This model was preferred because in this study no explanatory variables were associated with technical inefficiency effects. The Cobb-Douglas stochastic frontier production with distributional assumption was selected in this study to assess the technical efficiency of the building construction sector companies in the IDX market because panel data was used in this study and the sample number was not very high. Besides, in its generalized form, it is a simple tool that can be handled easily even for multiple inputs (Murthy, 2004). The empirical version of the stochastic frontier model (2) with the specification of Cobb-Douglas functional form can be expressed thus with the decomposed errors:

$$\ln Y_{it} = \beta_0 + \beta_1 lnX_{1it} + \beta_2 lnX_{2it} + \beta_3 lnX_{3it} + \beta_4 lnX_{4it} + \beta_5 lnX_{5it} + \beta_6 lnX_{6it} + V_{it} - U_{it} \text{ .... } (4)$$

where, the subscripts i and t represent the ith company and the tth year of observation, respectively, and i= 1,2,…,50 and t =1,2,….,5; Y_{it} represents the revenue, X_{1it} represents the cost of revenue, X_{2it} represents CAPEX, X_{3it} represents personal expenses, X_{4it} represents net fixed assets, X_{5it} represents total equity and X_{6it} represents inflation rate. ‘‘ln’’ refers to the natural logarithm; the β_i’s are unknown parameters to be estimated; V_{it} follows $N(0, \sigma_v^2)$ and U_{it} follows half-normal or truncated normal distribution at zero and guarantees inefficiency to be positive only. The technical efficiency for the ith company in the tth year can be defined in the context of the stochastic frontier model (2) as follows Battese & Coelli (1988):

$$TE_{it} = \exp(-U_{it}) \text{ .... } (5)$$

U_{it} represents the specifications of the inefficiency model in equation (2).

In this study, a series of formal hypothesis tests were conducted to determine the distribution of the random variables associated with the existence of technical inefficiency and the residual error term. If the null hypothesis involves $\gamma = 0$, it expresses that technical inefficiency effects are not present in the model. The half-normal distribution is a special case of the truncated normal distribution and implicitly involves the restriction $H_0: \mu = 0$. The hypothesis shows that efficiency, invariant over time (i.e. $\eta = 0$), will be tested. These are tested by imposing restrictions on the model and using the generalized likelihood-ratio statistic (λ) to determine the significance of the restriction. The generalized likelihood ratio statistic is defined by:

$$\lambda = -2\{ln[L(H_0)] - L(H_1)\} \quad .... \quad (6)$$

where $\lambda = \{ln[L(H_0)]\}$ and $\lambda = \{ln[L(H_1)]\}$ are the values of the log-likelihood function for the frontier model under the null and alternative hypotheses.

DATA ANALYSIS AND RESULTS

Ordinary Least Square Estimation

Building construction sector companies efficiency estimates were measured using a Cobb Douglas stochastic frontier production model proposed by Battese & Coelli (1992). A two-step process was employed to find out the technical efficiency using the maximum-likelihood method. The ordinary least square (OLS) estimates of the parameters of Cobb-Douglas production function were obtained first by grid search. These estimates were used to estimate the maximum likelihood estimates of the parameters of the Cobb-Douglas stochastic frontier production model. The OLS estimates show the average performance of the sample companies that were presented in Table 1. It is observed that the coefficients of cost of revenue, CAPEX, personal expenses and inflation rate were at 1% level of significance with the value of 0.8888, 0.0215, 0.0845 and 0.6992 respectively. While the coefficients of net fixed assets and total equity were insignificant with the value of 0.0173 and 0.0072 respectively.

Table 1. OLS Estimates of the Cobb-Douglas Stochastic Frontier Production Function

Variables	*Parameters*	*Coefficients*	*S.E*	*t-ratio*
Constant	β_0	-0.0485@	0.2416	-0.2009
Cost of Revenue	β_1	0.8888*	0.0146	60.8294
CAPEX	β_2	0.0215*	0.0073	2.9394
Personal Expenses	β_3	0.0845*	0.0187	4.5277
Net Fixed Assets	β_4	0.0173@	0.0122	1.4117
Total Equity	β_5	0.0072@	0.0221	0.3230
Inflation Rate	β_6	0.6992**	0.2780	2.5145
sigma-squared	σ^2	0.0015		
log likelihood function		95.6715		

*, **, *** : *Significance level* at 1% (t=2.6951), 5% (t=2.0167) and 10% (t=1.6811), @ : *insignificant*, S.E : *Standard Error*

Estimation of Stochastic Frontier Model

The maximum-likelihood estimates (MLE) for the parameters for the time-variant and time-invariant Cobb-Douglas stochastic frontier production function with the assumptions are presented in Tables 2 and 3 respectively.

The results in Table 2 show that the MLE of CAPEX, personal expenses, net fixed assets, total equity, and inflation rate are found to be higher in half-normal distribution than those in truncated normal distribution, only the MLE of cost of revenue in truncated normal distribution is higher than that in half-normal distribution. The estimates of the parameters with time-varying inefficiency effects for truncated and half-normal distributions are respectively 0.9223 and 0.8926 for cost of revenue, 0.0108 and 0.0122 for CAPEX, 0.0687

ISSN: 2186-845X ISSN: 2186-8441 Print
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and 0.0810 for personal expenses, 0.0094 and 0.0130 for net fixed assets, 0.0136 and 0.0233 for total equity, and 0.6240 and 0.8159 for the inflation rate.

As regards Cobb-Douglas stochastic frontier production function with time-variant, the MLE of the coefficients of cost of revenue and personal expenses are found to be significant at 1% level for both distributions, CAPEX is found to be significant at 10% level for truncated normal distribution but insignificant for half-normal distribution, net fixed assets and total equity are found to be insignificant for both distributions, and the inflation rate is found to be significant at 5% level for truncated distribution and significant at 1% level for half-normal distributions. The results indicate that these input variables have a different significance level that affects the amount of revenue on each building construction sector companies listed on the IDX market for both truncated and half normal distributions.

From Table 2, it was further observed that the estimates of σ^2 are 0.0017 and 0.0025 for truncated and half-normal distribution respectively. They are found to be significant at 10% level for truncated normal distribution but insignificant for half-normal distribution. For truncated normal distribution, γ was estimated to be 0.6594 and for half-normal distribution 0.7088, both the values are positive and significant at 1% level. It can be interpreted that 65.94% of random variation for truncated normal distribution, as also 70.88% for half-normal distribution, in revenue of companies is due to inefficiency. This can also be interpreted that the 65.94% variation in output among the companies is due to the differences in technical efficiency for truncated normal distribution and the 70.88% variation to the differences in technical efficiency for half-normal distribution. The μ parameter is restricted to zero in the model with a half-normal distribution. The estimates for the parameters of the time-varying inefficiency model in Table 2 indicate that because the estimates for η parameter are positive, the technical inefficiency effects tend to decrease over time. The log-likelihood functional values are rather similar for the two distributions, for truncated and half-normal distribution was estimated to be 103.0412 and 101.7051 respectively.

Table 2. Maximum-Likelihood Estimates of the Cobb-Douglas Stochastic Frontier Production Function with Time-variant

		Truncated Normal			*Half Normal*		
Variables	*Parameters*	*Coefficient*	*S.E*	*t-ratio*	*Coefficient*	*S.E*	*t-ratio*
Constant	β_0	-0.2336@	0.3194	-0.7314	-0.1441@	0.2664	-0.5410
Cost of Revenue	β_1	0.9223*	0.0241	38.2393	0.8926*	0.0178	50.1209
CAPEX	β_2	0.0108***	0.0056	1.9324	0.0122@	0.0075	1.6276
Personal Expenses	β_3	0.0687*	0.0188	3.6553	0.0810*	0.0184	4.3921
Net Fixed Assets	β_4	0.0094@	0.0122	0.7685	0.0130@	0.0130	1.0069
Total Equity	β_5	0.0136@	0.0186	0.7288	0.0233@	0.0189	1.2361
Inflation Rate	β_6	0.6240**	0.2949	2.1163	0.8159*	0.2853	2.8604
sigma-squared	σ^2	0.0017***	0.0009	1.7958	0.0025@	0.0019	1.3158
Gamma	Υ	0.6594*	0.1684	3.9167	0.7088*	0.2542	2.7887
Mu	M	0.0667**	0.0312	2.1361	0	0	0
Eta	η	0.0149@	0.0701	0.2126	0.0321@	0.1134	0.2834
log likelihood function		103.0412			101.7051		

*, **, *** :*Significance level* at 1% (t=2.6951), 5% (t=2.0167) and 10% (t=1.6811), @ : *insignificant*, S.E : Standard Error

The results in Table 3 show that the MLE of CAPEX, personal expenses, net fixed assets, total equity, and inflation rate are found to be higher in half-normal distribution than those in truncated normal distribution, while the MLE of cost of revenue in truncated normal distribution is higher than that in half-normal distribution. Nonetheless, the estimated values of the parameters of the Cobb-Douglas frontier production function obtained with the two distributional assumptions are almost similar. The estimates of the parameters with time-invarying inefficiency effects for truncated and half-normal distributions are respectively 0.9211 and 0.8935 for cost of revenue, 0.0098 and 0.0108 for CAPEX, 0.0690 and 0.0805 for personal expenses, 0.0100 and 0.0135 for net fixed assets, 0.0164 and 0.0240 for total equity, and 0.6336 and 0.7626 for the inflation rate.

In the case of Cobb-Douglas stochastic frontier production function with time-invariant, the MLE of the coefficients of cost of revenue, personal expenses, and inflation rate are found to be significant at 1% level for both distributions, CAPEX is found to be significant at 10% level for both distributions, net fixed assets and total equity are found to be insignificant for both distributions. The results indicate that these input variables have a different significance level that effects the value of technical efficiency on each building construction sector companies listed on the IDX market for both distributions.

In the case of both truncated and half-normal distributions, the values of parameter γ are found to be positive and significant at 1% level for both distributions. The result is the same as the case of time-variant in truncated and half-normal distributions, they are found to be positive, yet significant at 1% level. Thus, it demonstrates that over time there could be technical inefficiency in the building construction sector companies listed on the IDX market. The η parameter is restricted to zero in the model with time-invariant inefficiency effects. The log-likelihood functional values are rather similar for the two distributions, the log-likelihood function for truncated and half-normal distribution was estimated to be 103.0412 and 101.7051, respectively.

Table 3. Maximum-Likelihood Estimates of the Cobb-Douglas Stochastic Frontier Production Function with Time-invariant

		Truncated Normal			*Half Normal*		
Variables	*Parameters*	*Coefficient*	*S.E*	*t-ratio*	*Coefficient*	*S.E*	*t-ratio*
Constant	β_0	-0.2787@	0.3210	-0.8683	-0.1476@	0.2788	-0.5294
Cost of Revenue	β_1	0.9211*	0.0237	38.8065	0.8935*	0.0187	47.8503
CAPEX	β_2	0.0098***	0.0057	1.7117	0.0108***	0.0062	1.7422
Personal Expenses	β_3	0.0690*	0.0194	3.5559	0.0805*	0.0183	4.3847
Net Fixed Assets	β_4	0.0100@	0.0123	0.8132	0.0135@	0.0129	1.0465
Total Equity	β_5	0.0164@	0.0183	0.8965	0.0240@	0.0192	1.2501
Inflation Rate	β_6	0.6336*	0.2209	2.8682	0.7626*	0.2239	3.4054
sigma-squared	σ^2	0.0017@	0.0012	1.4583	0.0028@	0.0017	1.6343
Gamma	Υ	0.6406*	0.2214	2.8932	0.7481*	0.1862	4.0173
Mu	M	0.0658**	0.0280	2.3445	0	0	0
Eta	η	0	0	0	0	0	0
log likelihood function		103.0280			101.6606		

*, **, *** : *Significance level* at 1% (t=2.6951), 5% (t=2.0167) and 10% (t=1.6811),
@ : *insignificant*, S.E : Standard Error

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ISSN: 2186-845X ISSN: 2186-8441 Print
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Year-wise Average Efficiency of Companies: Results from Truncated and Half-Normal

The year-wise average efficiency of the building construction sector companies listed on the IDX market in truncated and half-normal distributions with time-variant is presented in Figure 1 and Table 4. From Figure 1, it is observed that for time-variant, the half-normal distribution gave higher technical efficiency estimates than truncated normal distribution and the average technical efficiency increased gradually over the reference period but insignificant.

Table 4 show that the average efficiency is in the range of 0.9282 to 0.9322 for truncated normal distribution and 0.9620 to 0.9665 for half-normal distribution. The average technical efficiency of the companies over the period 2013-2017 is 0.9302 for truncated normal distribution and 0.9643 for half-normal distribution. This implies that 93.02% and 96.43% of potential outputs were realized by the building construction sector companies listed on the IDX market according to truncated and half-normal distribution respectively.

Table 4. Year-wise Average Efficiency of Companies by distribution with Time-variant

Year	*Truncated Normal*	*Half Normal*
2013	0.9282	0.9620
2014	0.9292	0.9632
2015	0.9302	0.9643
2016	0.9312	0.9654
2017	0.9322	0.9665
Average	**0.9302**	**0.9643**

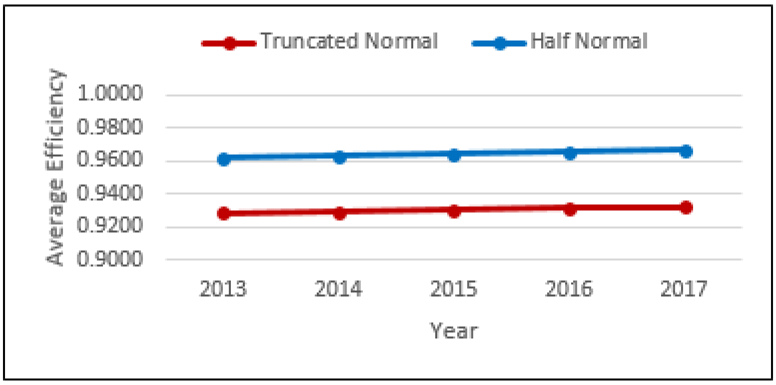

Figure 1. Year-wise Average Efficiency by distribution with Time-variant

Company-wise Technical Efficiency: Results from Truncated and Half-normal with Time-variant

Company-wise technical efficiency of both truncated and half-normal models with time-variant is shown in Figure 2 and Table 5. From Figure 2, it is observed that technical efficiencies for different companies are higher in case of half-normal distribution than those of truncated normal distribution.

Table 5 shows that technical efficiencies vary among different building construction companies in the IDX market. In case of truncated normal distribution, it ranges from a minimum of 0.8936 for DGIK to a maximum of 0.9890 for SSIA, with the actual range is 0.0954. While in case of half-normal distribution, it ranges from a minimum of 0.9169 for DGIK to a maximum of 0.9942 for SSIA with the actual range is 0.0773. Based on these results, it is concluded that for both truncated and half-normal models with time-variant, the value of technical efficiency is high for SSIA and low for DGIK, in comparison to other construction building sector companies listed on the IDX market.

Besides, in time-variant for truncated normal distribution, there are five construction companies that have the technical efficiency values below the average value (< 0.9302), namely: ADHI (0.9155), DGIK (0,8936), NRCA (0.9204), WIKA (0.8969), and WSKT (0.9252). With the highest technical efficiency value of 0.9890, then on average the building construction sector companies still have an improvement area of 0.0588. While for half-normal distribution, there are ADHI (0.9621), DGIK (0.9168), and WIKA (0.9368) that have the technical efficiency values below the average value (< 0.9643). With the highest technical efficiency value of 0.9942, the average building construction company still has room to increase the technical efficiency value by 0.0299.

Table 5. Company-wise Average Efficiency in IDX by distribution with Time-variant

Firm	Truncated Normal	Half Normal
ACST	0.9633	0.9881
ADHI	0.9155@	0.9621@
DGIK	0.8936*@	0.9169*@
JKON	0.9323	0.9660
NRCA	0.9204@	0.9644
PTPP	0.9321	0.9801
SSIA	0.9890**	0.9942**
TOTL	0.9339	0.9651
WIKA	0.8969@	0.9358@
WSKT	0.9252@	0.9698
Average	**0.9302**	**0.9643**

* : The lowest value; ** : The highest value; @ : Below average value

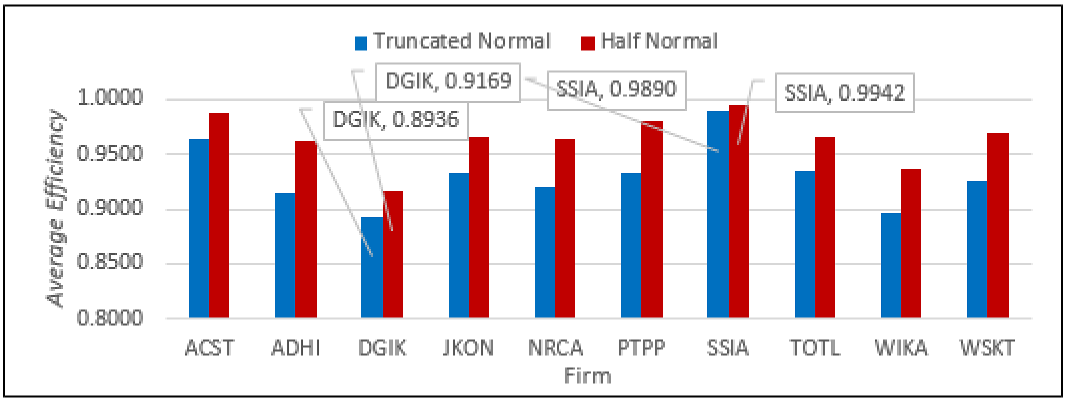

Figure 2. Company-wise Average Efficiency in IDX by distribution with Time-variant

Company-wise Technical Efficiency: Results from Truncated and Half-normal Models with Time-invariant

The results of company-wise technical efficiency of both truncated and half-normal models with time-invariant are presented in Figure 3 and Table 6.

From Figure 3, it is concluded that the values of the efficiency for the building construction sector companies are higher in half-normal distribution than those in truncated normal distribution.

Table 6 shows that the technical efficiencies vary among the different building construction companies listed on the IDX market. For truncated normal distribution, it ranges between a

ISSN: 2186-845X ISSN: 2186-8441 Print
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low of 0.8969 for DGIK and a high of 0.9894 for SSIA, with the actual range is 0.9145. Meanwhile, for half-normal distribution, it ranges from 0.9145 to 0.9940 for the same companies, with the actual range is 0.0775. Based on these results, it is concluded that for both distributional assumptions in time-invariant inefficiency effects, the value of technical efficiency is high for SSIA and low for DGIK, in comparison to other construction building sector companies in the IDX market.

In case of time-invariant for truncated normal distribution, there are ADHI (0.9189), DGIK (0.8969), NRCA (0.9246), WIKA (0.8995) and WSKT (0.9290) that have the technical efficiency values below the average value (< 0.9334). It is the same as time-variant for truncated normal distribution case. With the highest technical efficiency value of 0.9894, the average construction sector company still has improvement area to increase the technical efficiency value by 0.0560. Meanwhile, for half-normal distribution, there are four construction companies that have the technical value efficiency below the average value (< 0.9630), namely: ADHI (0.9603), DGIK (0.9145), NRCA (0.9621) and WIKA (0.9344). With the highest technical efficiency value of 0.9940, on average the building construction sector companies have an improvement area of 0.0310.

Table 6. Company-wise Average Efficiency in IDX by distribution with Time-invariant

Firm	Truncated Normal	Half Normal
ACST	0.9674	0.9875
ADHI	0.9189@	0.9603@
DGIK	0.8969*@	0.9145*@
JKON	0.9359	0.9650
NRCA	0.9246@	0.9621@
PTPP	0.9348	0.9780
SSIA	0.9894**	0.9940**
TOTL	0.9376	0.9633
WIKA	0.8995@	0.9344@
WSKT	0.9290@	0.9705
Average	**0.9334**	**0.9630**

* : The lowest value; ** : The highest value; @ : Below average value

Ownership-wise Technical Efficiency: Res

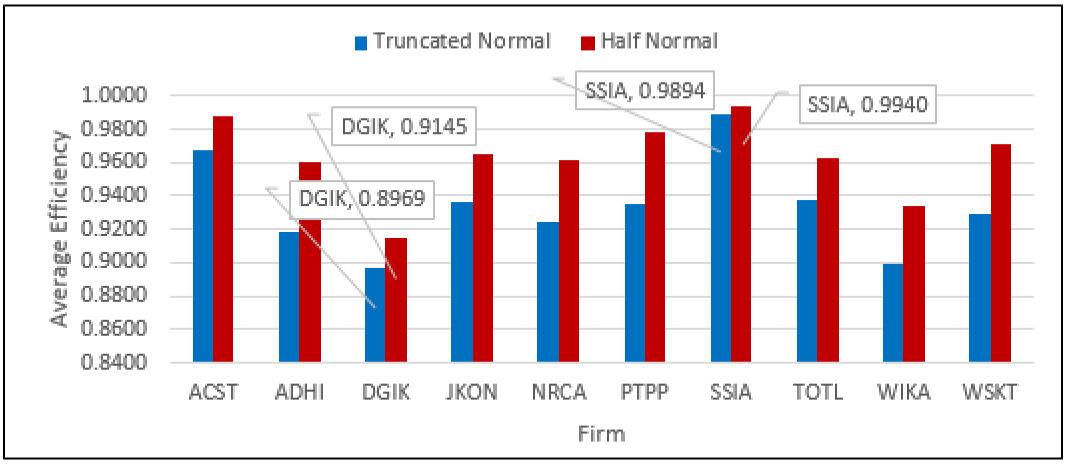

Figure 3. Company-wise Average Efficiency in IDX by distribution with Time-invariant

Results from Truncated and Half-Normal Models

The average technical efficiency of the building construction sector companies based on ownership for truncated and half-normal distribution with time-variant and time-invariant are presented in Table 7 and Table 8 respectively.

The results in Table 7 shows that for truncated normal distribution, the technical efficiency of state-owned companies in the period 2013-2017 is in the range of 0.9151 to 0.9198, with an average of 0.9174, whereas the technical efficiency of private companies is in the range of 0.9370 to 0.9405, with an average of 0.9388. While for half-normal distribution, the technical efficiency of state-owned companies in the period 2013-2017 is in the range of 0.9595 to 0.9643, with an average of 0.9619. Meanwhile, the technical efficiency of the private companies is in the range of 0.9636 to 0.9679, with an average of 0.9658.

Table 8 shows that the average technical efficiency of state-owned companies and private companies with time-varying inefficiency effects for truncated normal distribution are 0.9205 and 0.9420 respectively. Meanwhile, for half-normal distribution, the average technical efficiency of state-owned companies and private companies are 0.9608 and 0.9644 respectively.

From Table 7 and Table 8, it was also observed that the average technical efficiency of the building construction sector companies based on ownership, in case of time-variant and time-invariant, for truncated normal distribution is lower than half-normal distribution.

Table 7. Ownership-wise Average Efficiency by distribution with Time-variant

	Truncated Normal		Half Normal	
Year	**State-Owned Company**	**Private Company**	**State-Owned Company**	**Private Company**
2013	0.9151	0.9370	0.9595	0.9636
2014	0.9163	0.9379	0.9608	0.9647
2015	0.9174	0.9388	0.9620	0.9658
2016	0.9186	0.9396	0.9631	0.9669
2017	0.9198	0.9405	0.9643	0.9679
Average	0.9174	0.9388	0.9619	0.9658

Table 8. Ownership-wise Average Efficiency by distribution with Time-invariant

Ownership	Truncated Normal	Half Normal
State-Owned Company	0.9205	0.9608
Private Company	0.9420	0.9644

Results from Hypothesis Test

Formal tests of various hypotheses were carried out using the Likelihood Ratio statistics (5) presented in Table 9. The first null hypothesis $H_0: \gamma = 0$ specifies that there are no technical inefficiency effects in the model. Having rejected the hypothesis, it is concluded that there are technical inefficiency effects in the model. This implies that the technical inefficiency effects associated with the construction building sector companies listed on the IDX market are found to be significant.

The technical inefficiency effects, with half-normal distribution, were tested by the null hypothesis $H_0: \mu = 0$. In this study, this hypothesis which indicates that the half-normal distribution is preferable to truncate normal distribution for technical inefficiency effects was accepted.

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(株) リナアンドルナインターナショナル, 筑西市,日本
ISSN: 2186-845X ISSN: 2186-8441 Print
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The technical inefficiency effects, having time-invariant, were tested by the null hypothesis $\boldsymbol{H_0 : \eta = 0}$. In this study, this hypothesis which indicates that the technical inefficiency effect with time-invariant is preferable to time-variant for technical inefficiency effects was accepted.

Table 9. Hypothesis Likelihood-Ratio Test from Stochastic Frontier Production Model

Null hypothesis	*Log-likelihood function*	*Test Statistic*	*Critical value**	*Decision*
$H_0 : \Upsilon=0$	95.6715	14.7395	2.706	*Reject* H_0
$H_0 : \mu=0$	101.7051	2.6722	2.706	*Accept* H_0
$H_0 : \eta=0$	103.0280	0.0265	2.706	*Accept* H_0

* All *critical values are significant at* 5% level of significance. The critical value is obtained from the table of Kodde & Palm (1986) work.

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study is to estimate the technical efficiency of the building construction sector companies listed on the IDX market over the period 2013-2017 by using a parametric frontier approach, Stochastic Frontier Analysis (SFA). This study considered the Cobb-Douglas stochastic frontier in which the technical inefficiency effects are defined by a model with two distributional assumptions. Truncated and half-normal distributions were used in the model, and both time-variant and time-invariant inefficiency effects were estimated. The purpose of this study is also to identify the determinants that influence the revenue of the building construction sector companies and the level of influence. Besides, it seeks to find out if factors, such as cost of revenue, CAPEX, personal expenses, net fixed assets, total equity, and the inflation rate are significantly related to revenue. At the same time, it is desirable to checks whether technical efficiency is time-variant or time-invariant.

The results suggest that several variables, such as cost of revenue, CAPEX, personal expenses, and the inflation rate are found to be a positive and have a different significance level that effects on the technical efficiency of the building construction sector companies for both distributional assumptions in time-variant and time-invariant inefficiency effects. Meanwhile, variables such as net fixed assets and total equity are found to be a positive and insignificant effect on the technical efficiency of building construction sector companies. This shows that the relationship between input variables and the technical efficiency or output variable revenue has a positive relationship. If there is an increase in the input variable, the technical efficiency or output variable revenue will increase. In this study, the year-wise average efficiency of the building construction sector companies with time-variant was analyzed. The result shows that the half-normal distribution gave higher technical efficiency estimates than truncated normal distribution and the average technical efficiency increased gradually over the reference period but insignificant. The company-wise technical efficiency of the building construction sector companies was also analyzed. The result shows that for time-variant and time-invariant, the technical efficiencies for different companies are higher in case of half-normal distribution than those of truncated normal distribution. The result also shows that the company with the highest value of technical efficiency was SSIA and the lowest value was DGIK, as compared with other building construction sector companies listed on the IDX market for both distributional assumptions in time-variant and time-invariant inefficiency effects. The result also reveals that the average technical efficiency of state-owned companies is lower than private companies, this shows that private companies are more technically efficient than state-owned companies. The result of hypothesis likelihood-ratio test from stochastic frontier production model shows that there are technical inefficiency effects in the model, half-normal distribution is preferred than truncated normal distribution and that time-invariant is prefer than time-variant for technical inefficiency effects.

The results of this study are very interesting for government or policymakers, local and foreign companies, both listed and unlisted. This study has implications for the government to warn the state-owned companies to increase efficiency while remaining profitable when facing competition. The government needs to improve the bureaucratic process, investment ease, customs processes, tax incentives, and legal certainty in the field of construction, this will reduce costs of revenue of the building construction sector companies.

This study also has implications for the building construction sector companies to improve efficiency, and also encourage immediate action by companies that are below the average to increase efficiency.

This study suggests that in order to achieve a maximum level of revenue, the building construction sector companies must be technically efficient. In order to be technically efficient, the building construction sector companies need to increase their technical efficiency so that they can maximize revenue from their resources. This can be done by optimizing the variables that have a significant effect on the value of technical efficiency of the building construction sector companies, such as cost of revenue, CAPEX and personal expenses.

However, this study has some limitations, there are several possible opportunities for further study. First, this study uses a parametric method, Stochastic Frontier Analysis (SFA), to determine a more complete level of the efficiency value of building construction companies listed on the IDX market, a comparative study can be conducted using a non-parametric method such as Data Envelopment Analysis (DEA) with input or output-oriented. Second, this study uses the stochastic frontier model for technical inefficiency effects in stochastic frontier production function proposed by Battese & Coelli (1992) further study can be considered by using the stochastic frontier model proposed by Battese & Coelli (1995) with explanatory variables were associated with technical inefficiency effects. Third, the object of this study only includes the building construction companies listed on the IDX market, further study can be expanded by adding study objects to the building construction companies listed on stock exchanges in Southeast Asia, such as : Singapore, Malaysia, Thailand, and Philippine as countries that have a project value equivalent to Indonesia. So that in addition to being able to compare the efficiency values of each building construction sector companies, it can also compare the efficiency value of the building construction sector companies based on country.

Leena and Luna International, Chikusei, Japan.
(株) リナアンドルナインターナショナル, 筑西市,日本
ISSN: 2186-845X ISSN: 2186-8441 Print
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