Jurnal Ekonomi Malaysia 53(3) 2019
http://dx.doi.org/10.17576/JEM-2019-5303-05

Determinants of Bank Efficiency: Evidence from Indonesian Regional Development Banks Using Data Envelopment Analysis

(Penentu Kecekapan Bank: Bukti daripada Bank Pembangunan Wilayah Indonesia menggunakan Data Envelopment Analysis)

Lutfi
STIE Perbanas Surabaya

Suyatno
STIE Perbanas Surabaya

ABSTRACT

This study examines the technical efficiency level of regional development banks (RDBs) in Indonesia and then analyzes the influence of bank-specific factors on this efficiency. This study uses data from all 25 conventional RDBs in Indonesia for the period 2012–2017 and a two-stage procedure to examine bank efficiency. Data Envelopment Analysis (DEA) is used to estimate bank technical efficiency and panel data techniques, both fixed effects (FE) and random effects (RE), are used to assess the determinants of bank efficiency. The results of this study indicate that most Indonesian RDBs have yet to become efficient. The most important source of their inefficiency is non-interest income. Furthermore, bank efficiency is positively influenced by capital and the loan-to-deposit ratio, while it is negatively affected by non-performing loans and the proportion of time deposits. There is also evidence that bank size has a U-shaped influence on efficiency. This study recommends that RDBs should increase the capital in improving its fee-based income through the development of innovative technology-based products and services. RDBs also need to optimize their use of depositors' funds for lending coupled with prudential principles to avoid problem loans.

Keywords: Technical efficiency, Data Envelopment Analysis, Regional Development Bank.

ABSTRAK

Kajian ini memeriksa tahap kecekapan teknikal bank pembangunan wilayah (RDBs) di Indonesia dan menganalisis pengaruh faktor khusus bank terhadap kecekapan tersebut. Data kajian ini terdiri daripada semua 25 buah bank pembangunan wilayah konvensional di Indonesia untuk tempoh 2012-2017 dan prosedur dua peringkat telah digunakan untuk memeriksa tahap kecekapan bank tersebut. Kaedah *Data Envelopment Analysis (DEA)* telah digunakan untuk menganggar kecekapan teknikal bank, manakala kaedah data panel iaitu kesan tetap (FE) dan kesan rawak (RE) digunakan untuk menganggar penentu kecekapan bank tersebut. Hasil kajian menunjukkan kebanyakan RDBs di Indonesia belum mencapai kecekapan lagi. Sumber utama kepada ketidakcekapan RDBs adalah pendapatan bukan bunga. Tambahan lagi, kecekapan bank secara positif dipengaruhi oleh modal dan nisbah pinjaman kepada deposit, manakala pinjaman tidak berbayar dan kadar deposit bermasa mempunyai pengaruh negatif kepada kecekapan bank. Selain itu, dapatan kajian juga mendapati saiz bank mempunyai pengaruh yang berbentuk U terhadap kecekapan bank. Kajian ini mengesyorkan bahawa RDBs perlu meningkatkan modal untuk mengukuhkan pendapatan berasaskan yuran melalui pembangunan produk dan perkhidmatan yang berasaskan teknologi inovatif. RDBs juga perlu mengoptimumkan penggunaan dana pendeposit dengan memberikan pinjaman secara berhemat untuk mengelakkan masalah pinjaman.

Kata kunci: Kecekapan teknikal, Data Envelopment Analysis (DEA), Bank Pembangunan Wilayah

INTRODUCTION

In terms of ownership, Indonesian commercial banks are grouped into state-owned banks, private banks, foreign banks, joint venture banks and regional development banks (RDBs). The contribution of RDBs to the Indonesian economy is relatively small, as reflected in the proportion of their assets and third-party deposits compared to the total value of the Indonesian banking industry, namely 8.19 percent and 8.49 percent, respectively. The contribution made by this group of banks to micro, small and medium business loans, which is the main function of RDBs, is even smaller, at only 7.97 percent (Keuangan 2018b).

Another problem faced by RDBs relates to their ownership structure. In general, almost 100 percent of the shares in RDBs are owned by local governments, at both the provincial and district levels (Keuangan 2018a). Ownership by local

government is often considered to lead to bank inefficiency due to intervention from governors and deputy governors, regents, and deputy regents and members of the local parliament. These political interventions can result in RDBs being less efficient, thus making it more difficult for them to compete with other commercial banks (Hadad et al. 2012).

Many RDBs face problems arising from high non-performing loans (NPLs). The average NPL rate of an RDB in 2017 stood at 3.23 percent. This rate exceeds those of both the state-owned and private banks, which stand at 2.50 percent and 2.80 percent respectively (Keuangan 2018b). This is in contrast to RBD credit growth, although this is also below that of the other sectors of the banking industry. RDB credit growth is only 9.09 percent while the rates of state-owned banks and private banks are 11.55 percent and 13.58 percent respectively (Keuangan 2018b). This could indicate that RDBs are experiencing difficulties in channeling productive and profitable loans.

In the 2015 Otoritas Jasa Keuangan (OJK), the Indonesian Financial Authority, Annual Report, it was mentioned that one of OJK's focuses for 2015 was the implementation of the Regional Development Bank Transformation program with the aim of transforming RDBs into competitive banks with strong rates of growth and a role to play in the regional economy. However, no single RDB has been successful in meeting all of the transformation program targets due to a range of fundamental problems, including weak competitiveness and governance (Keuangan 2016). One way of improving competitiveness and governance is to improve efficiency by optimizing internal bank factors. For this reason, RDB efficiency is a very interesting area to study and seek to identify the internal factors that affect the level of RDB efficiency. Increasing the efficiency of these banks will help both the central and local governments to achieve the transformation program targets.

Studies on bank efficiency in Indonesia have so far been dominated by commercial banks in general and have tended to focus more on the level of bank efficiency without further examining the determinants of that level of efficiency (Hadad et al. 2012; Hadad et al. 2003a; Kurnia 2004; Muharam 2007; Ferari & Sudarsono 2011; Omar et al. 2007; Kalis et al. 2012; Pramuka 2011; Sadalia & Kautsar 2018). Using Data Envelopment Analysis (DEA), Omar et al. (2007) stated that in 2004, the level of technical efficiency of commercial banks in Indonesia, for both conventional and Sharia banks, was still low, at 86 percent. Using the same approach, Kalis et al. (2012) showed that the level of efficiency of RDBs was lower than that of state-owned banks. Pramuka (2011) used the DEA approach to assess the efficiency of Islamic banks and found that bank efficiency levels tended to increase from 2003 to 2009, from 88 percent to 99 percent. On the other hand, Sadalia and Kautsar (2018) used the Stochastic Frontier Analysis (SFA) approach to assess the level of technical efficiency of banks in Indonesia and found that conventional and Islamic commercial banks in Indonesia were inefficient, with an efficiency rate of 84 percent for conventional banks and 85 percent for Islamic banks. Wardhani and Mongid (2019) focused on assessing the efficiency of Islamic banks in Indonesia using the SFA approach and found the level of efficiency of Islamic banks to be in the low and medium range.

Two published studies have examined the level of efficiency of RDBs in Indonesia. Sutanto (2015) used DEA and found the RDBs to have a technical efficiency level of 93 percent in 2013. Abidin and Endri (2010) added that the efficiency level of larger-scale RDBs was better than that of smaller banks. Lastly, Defung et al. (2016) stated that RDBs had lower technical efficiency than both state-owned and private banks in Indonesia.

As stated earlier, there is a lack of research examining the level of bank efficiency in Indonesia and then analyzing the determinants of that bank efficiency. No articles have been published that comprehensively review the efficiency level of RDBs at the same time as examining the determinants. Widiarti et al. (2015) was the only study to have examined the level of efficiency of commercial banks in Indonesia using the DEA approach and then analyze its determinants. They studied bank efficiency during the period 2012–2014 and revealed that it was positively affected by bank size and capital, and negatively affected by NPL and the cost/efficiency ratio.

Based on the explanation above, this study aims to examine the level of efficiency of RDBs in Indonesia and then analyze the determinants of that efficiency using the DEA approach. Previous studies have revealed RDBs to have the lowest technical efficiency compared to other bank groups, namely state-owned banks and private banks (Hadad et al. 2003b; Defung et al. 2016). By reviewing the level of efficiency of regional banks and further examining the determinants of that efficiency, this research can provide input policies for regional governments as the owners and management of regional banks in order for them to take the actions needed to improve the efficiency of regional banks, especially in lending. This research also adds a reference to the study of RDB, which has suffered from a relative lack of research attention (Abidin and Endri 2010; Defung et al. 2016; Sutanto 2015). This study uses DEA to analyze bank technical efficiency as this approach does not require any explicit specification of the functional form and requires only a few structures to form its efficiency frontier. This study then uses the estimated technical efficiency generated by DEA as the dependent variable in the panel data regression model. Both fixed effects (FE) and random effects (RE) panel data techniques are used to examine the factors influencing technical efficiency.

LITERATURE REVIEW

BANK EFFICIENCY AND DATA ENVELOPMENT ANALYSIS

Efficiency is one of the performance parameters that theoretically underpins the entire performance of an organization. The ability to produce the maximum amount of output from an existing input is a measure of performance expected by any company. A company is faced with the issue of either trying to obtain an optimal level of output with existing input levels

or using a minimum level of input to generate a certain level of output. By identifying the allocation of inputs and outputs the firm can go further to see the causes of inefficiency.

The methods of efficiency measures can be grouped into two main categories, namely parametric and non-parametric (Jarzebowski 2013; Casu et al. 2004; Resti 1997; Dong et al. 2014). Each type of approach aims to estimate the frontier that represents the best practice of the system. The estimated frontier is used as a benchmark for a company against all other companies. In the parametric approach, measurements are made using stochastic econometrics and seek to eliminate the interference from inefficiency influences. There are three parametric approaches, namely SFA, the Thick Frontier Approach (TFA) and the Distribution-Free Approach (DFA). The non-parametric approach is built on the findings and observations of the population and evaluates the relative efficiency of the observed units. The non-parametric approach consists of DEA and Free Disposal Hull (FDH). This type of approach requires accurate information on the price of inputs and sufficient samples in addition to the recognition of the proper functional form of the frontier and the structure of a one-sided error. While the non-parametric approach does not require as much in the way of information, samples or other assumptions. However, the two approaches generally do not produce remarkably different results in terms of identifying the factors that determine a bank's technical efficiency (Casu et al. 2004).

There are two basic model classifications in DEA analysis, i.e. input-oriented and output-oriented models (Farrell 1957). The purpose of the input-oriented method is to evaluate how much the input quantity can be reduced proportionally without changing the amount of output. While the output-oriented method is used to assess how much the amount of output can be increased proportionally without changing the number of inputs used. Charnes et al. (1978) proposed an input-oriented model using constant returns to scale (CRS) and Banker et al. (1984) proposed an input-oriented model using variable returns to scale (VRS). Both input- and output-oriented models will give the same result for CRS and different results for VRS (Färe & Lovell 1978).

The true value of technical efficiency is not directly observed; rather, it is estimated. Previous studies have examined the appropriate inputs for DEA applications in the banking industry. Some of the outputs that are currently widely used are total loans (Chen & Yeh 1998; Howland & Rowse 2006; Sufian & Noor 2009; Wu et al. 2006; Golany & Storbeck 1999; Resti 1997; Felix et al. 1998), interest income and non-interest income (Felix et al. 1998; Sakar 2006; Mukherjee et al. 2002). Total loans and interest income are very appropriate measures of output to use in determining the technical efficiency of RDBs as their income is dominated by loan disbursement, which carries an income generation capacity. Non-interest income, as one of the outputs in the DEA model, can be used to show the extent to which RDBs are starting to shift their business from traditional lending to more fee-based income activities.

One of the most commonly used inputs in DEA in the banking industry is number of employees or employee costs (Mukherjee et al. 2002; Sufian & Noor 2009; Wu et al. 2006; Golany & Storbeck 1999; Chen & Yeh 1998; Seiford & Zhu 1999; Felix et al. 1998; Favero & Papi 1995; Resti 1997). Employee expenses may be preferable for two reasons. First, data are available more publicly. Second, since the outputs are measured in units of currency, the inputs should be expressed in similar terms. The second type of input is third-party deposits, which cover current accounts, savings accounts and time deposits (Mokhtar et al. 2008; Sakar 2006; Zenios et al. 1999; Felix et al. 1998; Fukuyama 1993). The final commonly used input in DEA is fixed assets, including available space (Golany & Storbeck 1999; Sufian & Noor 2009; Zenios et al. 1999; Al-Faraj et al. 1993; Vassiloglou & Giokas 1990; Hassan et al. 2009). The use of fixed assets as a DEA input is considered very appropriate in the context of measuring RDB efficiency, for two main reasons. First, RDBs generally operate in one province and should cover up to the sub-district level, which means they require a large number of physical branches and cash offices. Second, the customers of RDBs generally comprise rural and suburban communities who prefer to meet directly with bank employees as opposed to using technological devices and channels such as mobile banking.

Many studies have turned to the DEA approach to examine the level of bank efficiency around the world and most have settled on using the intermediation approach (Bonin et al. 2005; Jemric & Vujcic 2002; Staub et al. 2010; Sathye 2003; Karray & Chichti 2013; Gardener et al. 2011; Sathye 2001; Miller & Noulas 1996). Gardener et al. (2011) showed that bank efficiency in South East Asian countries (Indonesia, Malaysia, the Philippines, Thailand, and Vietnam) fell significantly over the period from 1998 to 2004. Miller and Noulas (1996) also identified a reduction in bank efficiency using data from large US banks in the period 1984–1990. Staub et al. (2010) found Brazilian banks to have lower efficiency compared to banks in Europe and the US. Havrylchyk (2006), on the other hand, found no improvement in Polish bank efficiency during the period 1997–2001. In addition, Havrylchyk (2006) and Staub et al. (2010) found that foreign-owned banks had better efficiency than local private banks, while Gardener et al. (2011) reported that state-owned banks had better efficiency than private banks.

Empirical evidence from the Indonesian banking industry has revealed a slight improvement in bank efficiency over time (Novandra 2017; Sufian & Noor 2009). Indonesian banks had the lowest technical efficiency compared to their counterpart country banks in Malaysia, the Philippines, Thailand and Vietnam (Gardener et al. 2011). Efficiency at RDBs was lower in comparison to that at both state-owned and private banks (Defung et al. 2016; Hadad et al. 2003a). In addition, foreign-owned banks have been cited as the most efficient bank group (Hadad et al. 2003a). Islamic banks, meanwhile, were found to be more efficient than conventional banks (Rosyadi 2017; Novandra 2017).

DETERMINANTS OF BANK TECHNICAL EFFICIENCY

Many bank-specific factors influence bank efficiency. The first factor that greatly affects the level of bank efficiency is the size of the bank. This is reflected by total assets and is a very commonly used variable in research on bank efficiency. The basic consideration with regard to the use of bank size is to determine whether the sample banks reflect economies of scale. The concept is that an increase in a bank's assets can generate an increase in the efficiency level (Hughes et al. 2001; Pasiouras 2008; Perera et al. 2007; Altunbas et al. 2000). Economies of scale theory state that when a company grows in size, its operating costs per unit will decrease. This decline in operating costs is based on achieving lower production costs per unit due to the fact that the costs of production can be spread over a higher volume of production (output). Other studies, however, have found that the relationship between bank size and technical efficiency is not always positive; instead, it tends to be U-shaped (Karray & Chichti 2013; Hadad et al. 2013). While an increase in asset size improves bank efficiency initially, after reaching a certain point, the increase may actually lead to lower bank efficiency.

NPLs are another factor that influences a bank's level of technical efficiency. Given that approximately 90 percent of bank assets are embedded in credit, NPLs reflect not only credit quality but also asset quality as a whole. Banks with high NPLs must allocate substantial extra managerial effort and expense to the handling of these problem loans (Karim et al. 2010). The costs related to handing problem loans include the legal costs associated with the settling of NPLs both inside and outside court; employee expenses incurred in handling the administration, monitoring and collection of problem loans, as well as costs associated with the taking over, maintenance and disposal of the loan collateral; and the management cost associated with the additional time and effort expended by management to handle the problem loans. These incremental costs due to problem loans will reduce the bank's operational efficiency (Kwan & Eisenbeis 1996; Rajaraman & Vasishtha 2002; Tan & Floros 2013). High NPLs can also lower bank efficiency as the banks are required to allocate additional capital to cover such risks, thereby limiting their degree of credit expansion and subsequent interest income, which are the outputs in DEA efficiency.

Capital plays an important role in determining bank efficiency. In addition to acting as a buffer against the risk of financial and operational losses, capital is useful for providing resources for the development of new products, services, facilities, and expansion as well as for increasing public confidence and convincing creditors, especially depositors, of the soundness of banks (Rose & Hudgins 2013). The availability of large amounts of capital will enable banks to increase lending without worrying too much about not being able to assume the risk of losses incurred. This credit expansion can further increase interest income. The high trust of depositors can encourage them to entrust their funds in the bank without requiring high returns, thus lowering the cost of bank funds. Thus, the amount of capital can improve the technical efficiency of banks (Altunbas et al. 2000; Karim et al. 2010).

The loan-to-deposit ratio (LDR) can affect bank efficiency from both sides, namely the outputs and inputs. Loan disbursement is the main activity of Indonesian banking, as reflected in the fact that around 92 percent of third-party funds disbursed are in the form of credit (Keuangan 2016). The higher the LDR, the greater the proportion of funds disbursed as credit, thus potentially generating greater levels of interest income and enhancing bank profitability (Gul et al. 2011; Molyneux & Thornton 1992; Dietrich & Wanzenried 2011; Anbar & Alper 2011). On the lending side (outputs), LDR is a source of potential growth (Caprio et al. 2007). Thus, LDR has a positive impact on improving bank efficiency.

Another important factor affecting a bank's efficiency is the Net Interest Margin (NIM). NIM reflects the spread between the interest earned on the loan and the interest paid on the source of the funds. A high NIM may indicate that the bank imposes high borrowing costs on debtors, which can lead to the bank encountering difficulties in lending. The debtors willing to borrow at such rates tend to be those with poor creditworthiness, thereby increasing the number of problem loans (Sinkey & Greenawalt 1991; Salas & Saurina 2002). This ultimately lowers bank efficiency (Kwan & Eisenbeis 1997; Berger & DeYoung 1997).

The composition of deposits (CoD) reflects the proportion of each form of third-party funds, comprising demand deposits, savings deposits, and time deposits. In this study, CoD is the ratio of time deposits to total third-party funds, which is about 45% in Indonesia (Keuangan 2016). Time deposits are the most expensive source of funds among other third-party funds. The greater the level of time deposits, the greater the operational expenses borne by banks. Therefore, CoD can have a negative effect on bank technical efficiency.

Some researchers have examined the determinants of bank technical efficiency in Indonesia. Muazaroh et al. (2012) used the SFA approach and found that bank profit efficiency was positively influenced by bank size, capital, foreign ownership, and market share and negatively influenced by listing on the stock exchange. Widiarti et al. (2015) used the DEA technical efficiency approach and the panel data common effects approach during the period 2012–2014 and found that bank technical efficiency was positively affected by bank size and capital, and negatively affected by NPL and the cost/efficiency ratio.

This research is different from Widiarti et al. (2015) in many ways. First, this study covers a longer period, namely 2012–2017, so it is expected to better describe the condition of banks in Indonesia in various economic conditions. Second, this study specifically examines RDBs that have particularities in terms of ownership and the involvement of local governments in their management. Third, this study adds the variable CoD based on the consideration that the greater the composition of bank funds from time deposits, the higher the cost of funding will be. This will further reduce the ability of banks to extend credit and generate interest income. Finally, this study uses panel data analysis techniques, including both

FE and RE approaches. These approaches consider variations in the bank intercept and therefore are more appropriate when analyzing data consisting of many banks and time series.

RESEARCH METHODOLOGY

This study uses a two-stage DEA procedure. The first step is to estimate regional bank technical efficiency using the DEA approach. The second step is to use the estimated efficiency results of DEA as the dependent variable to determine the factors influencing estimated efficiency using the panel data regression model. The research framework is presented in Figure 1.

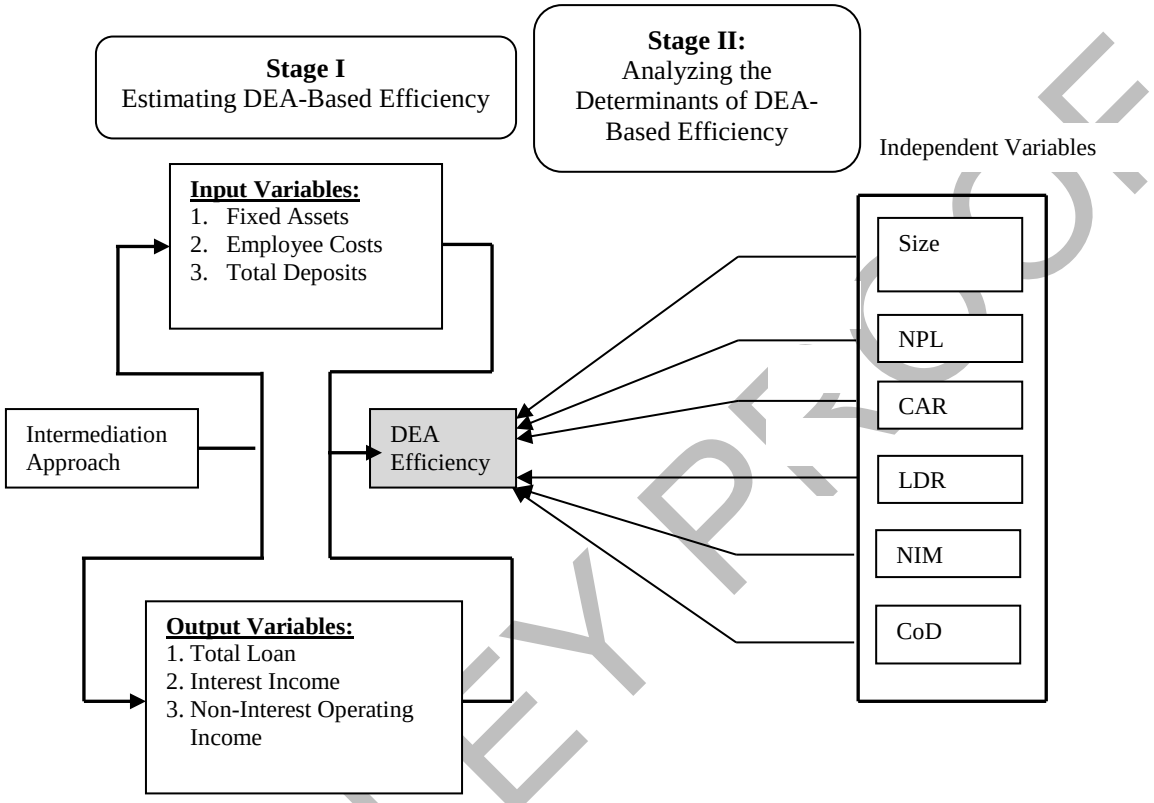

FIGURE 1. Research Framework

DATA ENVELOPMENT ANALYSIS

Basically, DEA attempts to minimize inputs and maximize outputs. It permits the use of multiple inputs and outputs. The DEA model is based on output-oriented VRS and can be expressed in terms of a ratio as follows (Charnes et al. 1978).

$$\text{Max}\,TE_0 = \frac{\sum_{r=1}^{s} U_r Y_{r,0}}{\sum_{i=1}^{m} V_i X_{i,0}} \qquad (1)$$

Subject to:

$$\frac{\sum_{r=1}^{s} U_r Y_{r,j}}{\sum_{i=1}^{m} V_i X_{i,j}} \le 1;\ j = 1, 2, ..., n \qquad (2)$$

$$U_r, V_i \ge 0,\ r = 1, 2, ..., s;\ i = 1, 2, ..., m$$

Measurement of the total efficiency (TE) of a decision-making unit (DMU) is obtained using the weighted maximum ratio output to weighted input for that unit, subject to conditions that are similar for all other ratios. This results in an efficiency score for DMUs of less than or equal to one. $Y_{r,j}$ and $X_{i,j}$ are DEA outputs and inputs that are all positive, and U_r and V_i are unknown variable weights. The outputs of the DEA model are a total loan, interest income, and non-interest operating income. While the inputs of the DEA model are fixed assets, employee costs, and total deposits. All output and input variables are in rupiahs.

Under the DEA approach, a bank is considered efficient if it cannot improve its output or reduce its input without increasing other inputs or decreasing other outputs, and therefore efficient banks have an efficiency score of unity or 100 percent (Chen & Yeh 2000; Vincova 2005). In other words, if the DMU has an efficiency score of 1 then it is considered efficient in DEA, otherwise, it is inefficient (Sathye 2001).

The DEA approach has several advantages, namely that it requires less data, fewer assumptions are required and fewer samples are used (Hadad et al. 2003a; Dong et al. 2014). It does not include random error, therefore the result of inefficiency is only used as a factor of inefficiency by the DMUs. DEA is able to identify the source and magnitude of inefficiencies in each input and output for each unit as well as identify which units can be used as benchmarks by other inefficient units (Hawdon 2003; Cook et al. 2014). DEA is also more appropriate for use in developing countries where regulation and market imperfections can disrupt input and output prices (Mostafa 2011). Thus, this non-parametric approach can be used to measure inefficiencies more generally and is therefore more widely used to measure banks' technical efficiency (Akhtar 2010; Miller & Noulas 1996; Sathye 2001; Haslem et al. 1999; Al-Khasawneh et al. 2012; Mostafa 2011; Sufian & Noor 2009). This study uses *Banxia Software* to calculate bank technical efficiency.

PANEL DATA REGRESSION MODEL

After estimating bank technical efficiency using the DEA model, the next step is to use the estimated DEA-based total efficiency (TE) as the dependent variable. The second step involves analyzing the determinants of the estimated technical efficiency using panel data techniques. Panel data techniques can improve statistical analysis by controlling heterogeneity, reducing collinearity between variables and explaining dynamic changes better than time-series and cross-sectional data analysis (Gujarati and Porter, 2009). This study examines the panel data model that includes the pooled regression (PR), FE and RE models. In the PR model, all coefficients are constant over time and individually. In general, the PR model is:

$$Y_{it} = \alpha + \beta X_{it} + \mu_{it} \quad (i = 1, \dots, N; t = 1, \dots, T) \qquad (3)$$

where *i* represents cross-sections (banks) and *t* represents time periods. α is a scalar, β is K × 1 matrix, and X_{it} is the *it*-th observation on K explanatory variables. *N* is the number of cross-section units and *T* is the number of periods. The error term is μ_{it} and it is identically distributed with zero mean and constant variance. Therefore, the weakness of the PR model is that it ignores the specific nature of each cross section. This weakness can be overcome by using the FE model, in which the specifications include unit-specific components:

$$Y_{it} = (\alpha + \gamma_i) + \beta X_{it} + \mu_{it} \quad (i = 1, \dots, N; t = 1, \dots, T) \qquad (4)$$

where γ_i is an unobserved specific effect in which is a part of constant, and X and γ_i are correlated. To consider the intercepts vary among cross-sections, we can use the dummy variable technique, known as the Least Square Dummy Variable (LSDV) methodology. Equation (4) can then be rewritten as follows:

$$Y_{it} = \alpha_1 + \alpha_2 D_{2i} + \alpha_3 D_{3i} + \cdots + \alpha_N D_{Ni} + \beta X_{it} + \mu_{it} \qquad (5)$$

In the LSV approach, the unobserved time effect is obtained by including a set of N – 1 dummy variables that are homogeneous across cross-sections but vary over time. D_i is the dummy variable for unit *i*; $D_{21} = 1$ for unit 1, 0 otherwise; $D_{31} = 1$ for unit 2, 0 otherwise; and so on.

FE assumes that any differences among the cross-sections can be accommodated from differences in their intercepts. However, the FE model may have weaknesses because the time-invariant effect and its coefficients cannot be identified. Both cross-section and time variables can be included in the intercepts vary over the individuals and time. The RE model incorporates time invariants into the model as follows:

$$Y_{it} = \alpha + \beta X_{it} + \gamma_i + \mu_{it} \quad (i = 1, \dots, N; t = 1, \dots, T) \qquad (6)$$

In the random effect model, there are two residual components. The first, μ_{it}, is the overall residual which is a combination of cross-section and time series. The second residual, γ_i, is an individual residual which is a random characteristic of the *i*-th unit observation and is homogeneous over time. In equation (6), α is represented as the mean value of all cross-sectional intercepts and the error component Z_i indicates the deviation of individual intercepts from the mean

value. Components of individual errors are assumed to be uncorrelated with each other and not correlated across units. Therefore, the random error Z_i is homogeneous over time but differs across sections.

This study uses *EViews Software* to test the hypothesis. The Chow test was conducted to determine the choice between PR and FE as the correct model to use. If Prob. ≥ 0.05, the PR model is more appropriate, otherwise, the FE model is more appropriate. The Hausman test was used to determine whether the FE or RE model is the appropriate option. If Prob. ≥ 0.05, the RE model is more appropriate for use, otherwise, the FE model is more appropriate.

The empirical model of this study can be expressed as follows:

$$TE_{it} = \beta_0 + \beta_{i1}Size_{it} + \beta_2 NPL_{it} + \beta_3 CAR_{it} + \beta_4 LDR_{it} + \beta_5 NIM_{it} + \beta_6 CoD_{it} + \varepsilon_{it} \quad (7)$$

where the subscripts *i* and *t* indicate banks and time in years, respectively, TE is the DEA estimated of total efficiency, Size is the log-normal of total assets, NPL is non-performing loans, CAR is the capital adequacy ratio, LDR is the loan-to-deposit ratio, NIM is the net interest margin and CoD is the composition of deposits, and ε is the error terms. The effect of bank size on bank efficiency is U-shaped. The increase in assets initially leads to an increase in the level of bank efficiency due to economies of scale (Pasiouras, 2008, Perera et al., 2007). However, after reaching a certain point, the increase in assets then actually reduces the efficiency of the bank due to various problems of coordination, monitoring, and delays in decision making caused by the increasing number of branches and employees (Hadad et al., 2013, Karray and Chichti, 2013). NPLs will incur additional costs in the form of legal fees, administrative costs, monitoring costs and the maintenance and disposal of collateral, as well as the management time and effort needed to handle the problem loans. This means that an increase in NPLs will reduce the level of bank efficiency (Rajaraman and Vasishtha, 2002, Tan and Floros, 2013, Kwan and Eisenbeis, 1996). Capital is the main resource that banks use to expand credit and provide banking services that can increase interest income. The availability of capital will also increase depositors' confidence to place their funds in banks without demanding a relatively high interest rate, which will reduce the cost of sources of funds. Thus, the greater the capital, the higher the level of bank efficiency (Altunbas et al., 2000, Karim et al., 2010). LDR reflects the proportion of third-party funds channeled into loans. The greater the LDR, the greater the potential interest income generated, thereby increasing bank efficiency (Anbar and Alper, 2011, Dietrich and Wanzenried, 2011, Gul et al. 2011, Molyneux and Thornton, 1992). A high NIM indicates that banks charge high interest to debtors, which can make it difficult for banks to channel credit and subsequently reduce their interest income. Thus, NIM has a negative effect on efficiency (Berger and DeYoung, 1997, Kwan and Eisenbeis, 1997, Salas and Saurina, 2002, Sinkey and Greenawalt, 1991). Finally, CoD is the proportion of time deposits to total third-party deposits. Time deposits are the most expensive source of funds from third parties, which means that the greater the composition of time deposits, the lower the level of bank efficiency.

SAMPLE AND DATA

The sample of this research comprises 25 conventional RDBs, from 2012 to 2017. There are actually 26 RDBs in Indonesia; however, one has been an Islamic bank since 2016 and was therefore excluded from this study. The bank-related data were obtained from the website of the Financial Services Authority and the Association of Regional Development Banks (ASBANDA). Table 1 lists the sample banks, along with their total assets, core capital, and book category.

Based on Bank Indonesia Regulation No. 14/26/PBI/2012, the banks are categorized into four groups based on their core capital, namely Book 1, Book 2, Book 3 and Book 4. Book 1 banks may only engage in the collection and distribution of funds arising from basic products or activities in rupiahs, trade financing activities, a limited range of activities for agency and cooperation, and payment system and electronic banking activities. Book 1 banks can only engage in restricted foreign exchange activities as a foreign exchange trader. Book 2 banks may engage in a wider range of products or activities than Book 1 banks, in both rupiahs and foreign currency, limited treasury activities covering spot and plain vanilla derivatives, and they may have a participation of 15% in domestic financial institutions. Book 3 banks may conduct all business activities in rupiahs and foreign currency and have up to a 25% participation level in domestic and Asian financial institutions. Book 4 banks may conduct all business activities in rupiahs and foreign currency and have a 35% participation in both domestic and international financial institutions. The table reveals that most RDBs fall into the Book 1 and Book 2 categories. The implication of this is that they have a limited scope of operations.

TABLE 1. Sample Bank, Assets and Capital as of December 2017

No	Bank	Total Assets (million IDR)	Core Capital (million IDR)	Book Category
1	Bank Jabar Banten	108,408,673	8,458,884	3
2	Bank Jatim	51,518,681	6,928,205	3
3	Bank Jateng	61,466,427	5,838,985	3
4	Bank DKI	51,417,045	7,510,678	3
5	Bank Kaltim	22,631,038	4,271,348	2
6	Bank Sumut	28,931,824	2,863,990	2
7	Bank Papua	20,400,813	2,197,544	2
8	Bank Riau Kepri	25,492,550	2,691,816	2
9	Bank Sumbar	21,371,464	2,367,047	2
10	Bank Sumsel Babel	22,145,410	2,633,444	2
11	Bank Bali	22,150,905	2,484,771	2
12	Bank Kalbar	16,575,748	2,035,703	2
13	Bank Sulselbar	17,545,995	2,539,355	2
14	Bank Kalsel	11,907,552	1,564,136	2
15	Bank SulutGo	14,075,393	1,334,806	2
16	Bank NTT	10,379,174	1,562,145	2
17	Bank DIY	10,695,373	1,420,564	2
18	Bank NTB	8,864,391	1,272,085	2
19	Bank Kalteng	6,226,993	1,343,367	2
20	Bank Jambi	9,526,849	1,178,589	1
21	Bank Lampung	5,979,451	618,605	1
22	Bank Maluku Malut	6,369,510	792,941	1
23	Bank Bengkulu	5,865,006	592,207	1
24	Bank Sultra	6,161,553	812,111	1
25	Bank Sulteng	5,259,524	608,522	1
Mean		22,854,694	2,636,874	

Sources: Bank Annual Report

RESULTS AND DISCUSSION

BANK EFFICIENCY

In this study, a bank's technical efficiency is calculated using the DEA method based on output-oriented VRS. A bank is classed as efficient if it has an efficiency score of 100 percent (Vincova, 2005, Chen and Yeh, 2000, Sathye, 2003). Thus, a bank with an efficiency score of less than 100 percent is categorized as inefficient. Table 2 presents the development of Indonesian regional banks' efficiency from 2012 to 2017, with the rankings based on their total technical efficiency.

TABLE 2. Regional Development Bank Efficiency, 2012–2017

No	Bank	Year						Average
		2012	2013	2014	2015	2016	2017	
1	Bank Jambi	100.00%	97.40%	97.60%	100.00%	95.00%	95.00%	97.50%
2	Bank Lampung	90.50%	96.00%	100.00%	99.00%	100.00%	93.30%	96.47%
3	Bank SulutGo	94.20%	99.90%	81.70%	100.00%	100.00%	100.00%	95.97%
4	Bank Sulselbar	94.60%	94.70%	93.70%	100.00%	88.80%	100.00%	95.30%
5	Bank Bengkulu	82.60%	95.60%	87.60%	97.90%	94.30%	98.20%	92.70%
6	Bank Kaltim	81.00%	100.00%	100.00%	100.00%	91.90%	80.70%	92.27%
7	Bank Bali	76.80%	84.30%	94.20%	100.00%	100.00%	96.20%	91.92%
8	Bank Sultra	79.70%	80.30%	95.70%	100.00%	95.70%	100.00%	91.90%
9	Bank Jabar Banten	85.60%	99.80%	96.40%	88.00%	82.00%	85.00%	89.47%
10	Bank Jatim	96.70%	88.10%	82.70%	87.80%	81.90%	74.70%	85.32%
11	Bank Sulteng	86.50%	100.00%	97.20%	70.30%	78.20%	79.40%	85.27%
12	Bank NTB	90.40%	87.90%	82.50%	86.30%	84.10%	72.40%	83.93%
13	Bank NTT	79.70%	81.90%	75.40%	77.30%	89.20%	93.40%	82.82%
14	Bank Maluku Malut	90.60%	91.40%	81.40%	77.60%	77.80%	77.70%	82.75%
15	Bank Jateng	82.50%	75.20%	80.10%	86.10%	82.30%	84.30%	81.75%

16	Bank Kalsel	72.00%	79.10%	82.00%	90.70%	87.80%	77.70%	81.55%
17	Bank DKI	84.60%	97.70%	100.00%	73.20%	67.80%	62.00%	80.88%
18	Bank Riau Kepri	68.50%	74.30%	65.50%	94.70%	100.00%	79.70%	80.45%
19	Bank Sumbar	78.30%	77.50%	79.90%	79.20%	77.90%	79.30%	78.68%
20	Bank Sumut	80.20%	81.80%	80.70%	84.20%	72.10%	71.40%	78.40%
21	Bank Kalteng	65.30%	66.20%	69.40%	85.30%	79.80%	83.90%	74.98%
22	Bank Sumsel Babel	68.40%	78.70%	73.50%	80.90%	75.40%	66.50%	73.90%
23	Bank Papua	63.20%	69.40%	74.00%	71.00%	71.80%	66.50%	69.32%
24	Bank DIY	71.90%	64.00%	70.10%	67.80%	67.80%	68.80%	68.40%
25	Bank Kalbar	66.60%	65.90%	66.10%	63.60%	69.70%	60.80%	65.45%
Mean		81.22%	85.08%	84.30%	86.44%	84.45%	81.88%	83.89%
Minimum		63.20%	64.00%	65.50%	63.60%	67.80%	60.80%	65.45%
Maximum		100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	97.50%
Standard Deviation		10.38%	11.86%	11.26%	11.69%	10.69%	12.42%	9.11%

Sources: Banxia Output

Table 2 shows that no single RDB has consistently operated efficiently. The numbers of banks operating efficiently were one bank in 2012, two banks in 2013, three banks in 2014, six banks in 2015, four banks in 2016 and three banks in 2017. The table reveals Bank Lampung to be the most efficient bank with an average TE score of 97.50 %, while Bank Kalbar, with an average DEA score of 65.45 percent, is the least efficient bank. In general, there was a slight increase in the technical efficiency level of RDBs over the period, increasing from 81.22 percent in 2012 to 81.88 percent in 2017.

In Figure 2 the bank efficiency scores are arranged into five groups. Banks with a score of 100 are categorized as very efficient, banks with a score of 91–99.9 are categorized as efficient, banks with a score of 81–90 are categorized as quite efficient, those with a score of 71–80 are categorized as less efficient, and banks with a score of 61–80 are categorized as inefficient. A majority of the banks fall within the technical efficiency range of 71–80 percent, meaning they are mostly less efficient.

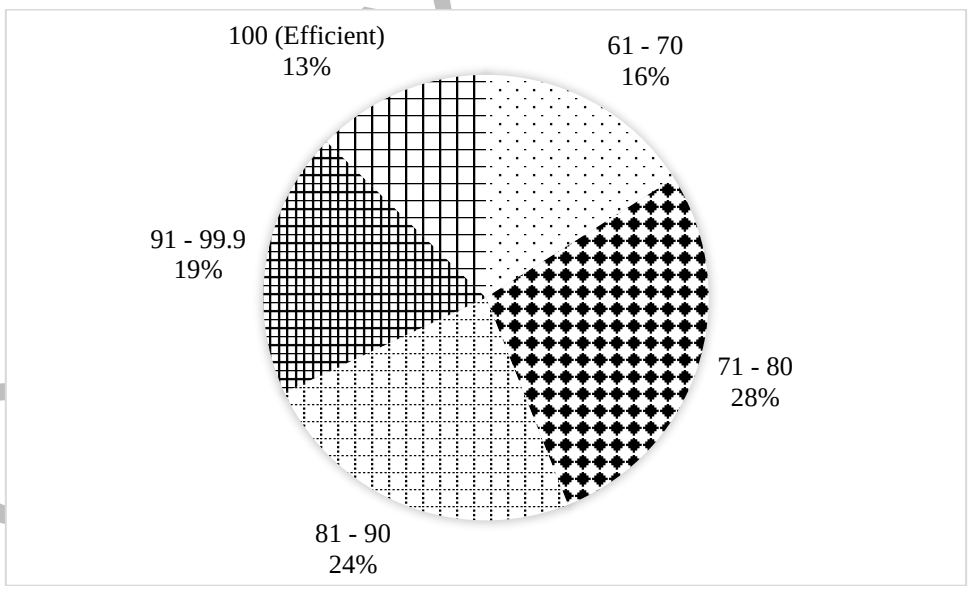

FIGURE 2. Distribution of Bank Technical Efficiency, 2012–2017
Sources: Banxia Output

Considering these low levels of efficiency, there is much potential for BPD West Kalimantan to increase efficiency in terms of both inputs and outputs. *Banxia Software* provides information on potential efficiency improvements. Table 3 summarises the potential improvements for the three least efficient banks, namely Bank Kalbar, Bank DIY and Bank Papua. The source of these three banks' inefficiency is mainly from the output side. From the input side, Bank Kalbar and Bank Papua have the potential to improve efficiency by increasing their utilization of fixed assets. Based on the financial data of these three banks during the study period, the proportions of fixed assets to total assets for Bank Kalbar and Bank Papua are 2.28 percent and 2.39 percent respectively, while the industry average is 1.47 percent. This could indicate that Bank Kalbar

and Bank Papua have too many fixed assets in the form of office buildings. Both banks could consider renting office buildings instead of owning them.

TABLE 3. Potential Optimisation of Input and Output Sides (%)

Inputs / Output	Bank Kalbar	Bank DIY	Bank Papua
Inputs			
Fixed Assets	(23.21)	0.00	(23.21)
Employee Costs	6.92	(1.50)	0.00
Third-party Deposits	0.00	0.00	0.00
Outputs			
Loans	50.09	39.13	58.19
Interest Income	50.09	39.13	58.37
Non-Interest Income	79.43	84.77	68.49

Sources: Banxia Output

Table 3 also reveals non-interest income to be the main source of inefficiency for the three banks in terms of output. The financial data of the three banks show that the proportions of non-interest income to total assets for Bank Kalbar, Bank DIY and Bank Papua are 0.57 percent, 0.56 percent and 0.62 percent, respectively. These figures are half the industry average of 1.17 percent, thus indicating that these banks need to develop and optimize a range of products that produce fees and commissions, such as bank guarantees, transfer services, syndicated loans, credit cards, ATMs, internet banking, m-banking, account maintenance, safe deposit boxes and wealth management.

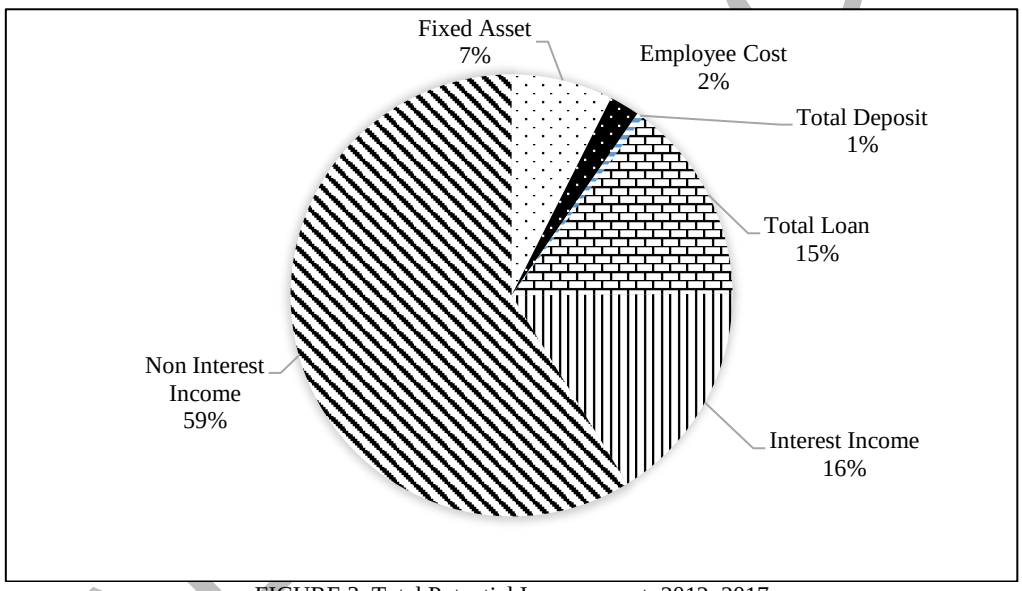

FIGURE 3. Total Potential Improvement, 2012–2017
Sources: Banxia Output

Figure 3 identifies a common problem with regard to RDB efficiency. It shows that 59 percent of the RDB inefficiency arises due to the lack of non-interest income. This is unsurprising as 20 of the 25 RDBs are categorized as Book 1 and Book 2 banks (see Table 1). Banks in these two categories have a limited scope of operations, namely conducting payment system activities and e-banking, foreign exchange trading, and treasury on a limited basis. One way in which to improve non-interest income would be to increase the banks' capital with the aim of moving them into Book 3, which would then enable them to carry out almost all banking activities. The banks can then use this additional capital to strengthen their e-banking infrastructure and activities.

DETERMINANTS OF BANK EFFICIENCY

A total of six factors determined the estimated bank technical efficiency studied, namely bank size, NPL, capital (CAR), LDR, NIM and composition of deposits (CoD). Table 4 shows the descriptive statistics of these independent variables.

Size is represented by bank assets (in million rupiahs) and is used to assess for the existence of economies of scale at the RDBs. Table 4 shows that the size of the RDBs varies greatly, from a maximum of Rp. 108,697 million categorized as Book 2 to a minimum of Rp. 1,358 million categorized as Book 1. The remarkable difference in the banks' respective asset sizes will affect their scope of operations and the products offered. A significant difference also occurs in the credit quality as reflected in the magnitude of NPLs. Bank Papua has the highest NPLs at 14.720 percent, which is far above the

regulatory provision of 5 percent. High NPLs will serve to both undermine and reduce profits and further reduce the bank's ability to lend.

The capital adequacy ratios (CARs) of Indonesian RDBs are far above the regulatory capital of 8 percent. Thus, no bank has a capital adequacy problem. However, these high CARs may indicate the presence of less productive capital that is not channeled in credit. This is a condition that can affect bank technical efficiency, mainly in the form of credit and interest income. The RDBs have an average LDR of 92.643 percent, which is above that required by the regulator. This average ratio is quite close to 94 percent as the upper-limit LDR set up by Bank Indonesia, which means the RDBs are quite expansive in terms of their lending. Many of the banks were also very expansive in their lending during the period 2012–2017, as shown by the maximum LDR in excess of 100 percent.

TABLE 4. Descriptive Statistics of the Bank Efficiency Determinants

	Mean	SD	Max	Min
Asset (million rupiah)	17,727	17,762	108,697	1,358
Non-Performing Loan	2.698	2.620	14.720	0.170
Capital Adequacy ratio	14.720	5.089	32.290	12.300
Loan-to-Deposit Ratio	92.643	12.544	128.430	55.770
Net Interest Margin	7.760	1.442	11.990	4.950
Composition of Deposits	34.331	13.974	68.560	6.240

Sources: Research Data

The RDBs generated a relatively high profit, as measured using NIM. This high NIM can be attributed either to the low cost of sources of funds or the high-interest rates charged to debtors for credit. Considering that the average figure for the CoD is 34.331 percent, then the largest source of RDB funds is demand deposits and savings at a very low rate of interest, ranging from 1 to 2 percent in Indonesia. RDBs benefit from substantial low-cost funds as they are used as local government payment banks and have a large customer base of government employees.

Table 5 shows the results of the panel data regression model for the determinants of bank technical efficiency using the PR, FE, and RE models. A Chow test was performed in order to identify the best option between the PR and FE models. If the probability of the cross-section is less than 5 percent, the best model is FE, otherwise, the PR model is preferred. Table 5 reveals that the F-probability is 0.000 < 5 percent. This means that the FE regression is more appropriate for use in analyzing bank efficiency in Indonesia. Next, the Hausman test is used to determine which model is best between FE and RE. If the probability of a random cross-section is less than 5 percent, then FE is the best model, otherwise, the RE model is preferred. Table 5 shows that the probability of a random cross-section is less than 5 percent, which means that the FE model is more appropriate for analyzing bank efficiency in Indonesia. Based on these two test results, the output of the FE model is used in the next explanation regarding the determinants of the level of bank efficiency.

TABLE 5. Results of Panel Data Regression Analysis

Variable	Expected Sign	PR		FE		RE	
		Coef.	Prob.	Coef.	Prob.	Coef.	Prob.
Constant		12.166	0.692	23.295	0.641	24.452	0.526
Size	+/-	1.213	0.186	1.342	0.417	1.238	0.318
Non-Performing Loan	-	-0.951	0.002*	-0.996	0.000*	-1.039	0.000*
Capital Adequacy Ratio	+	0.468	0.002*	0.581	0.000*	0.565	0.000*
Loan-to-Deposit Ratio	+	0.453	0.000*	0.272	0.000*	0.295	0.000*
Net Interest Margin	-	-1.410	0.007*	-0.372	0.378	-0.548	0.176
Composition of Deposits	-	-0.077	0.128	-0.320	0.000*	-0.273	0.000*
R-Square		0.505		0.884		0.655	
Adjusted R-Square		0.484		0.854		0.641	
F-Stat		0.000		0.000		0.000	
Chow test							
Cross section F (Prob.)				0.000			
Hausman test							
Cross section random (Prob.)						0.026	

Sources: EViews Output
* Significance at 5%

Although Table 5 shows that FE is the most appropriate model, FE still has econometric problems, such as heteroscedasticity and autocorrelation (Gujarati and Porter 2009). To overcome this problem, we re-estimated FE using White's robust standard errors, both White cross-section and White period. The results of this estimate are presented in Table 6. This table shows the results of FE that are not significantly different from those presented in Table 5. All the variables in the FE model that are significant in Table 5 remain significant in Table 6. Thus, the selection of FE as the best model is statistically robust.

TABLE 6. Fixed Effect Regression Model with Robust Standard Error

Variable	FE-White cross-section		FE-White period	
	Coef.	Prob.	Coef.	Prob.
Constant	23.295	0.598	23.295	0.692
Size	1.342	0.316	1.342	0.503
Non-Performing Loan	-0.996	0.000*	-0.996	0.067**
Capital Adequacy Ratio	0.581	0.000*	0.581	0.016*
Loan-to-Deposit Ratio	0.272	0.000*	0.272	0.000*
Net Interest Margin	-0.372	0.524	-0.372	0.527
Composition of Deposits	-0.320	0.000*	-0.320	0.000*

Sources: EViews Output

* Significance at 5%, ** Significance at 10%

Table 5 and Table 6 contain the results of the FE model and show that capital and LDR have a significant positive effect on the level of DEA-based technical efficiency of the Indonesian RDBs, while NPL and CoD negatively influence bank technical efficiency. There is no significant evidence of the influence of bank size and NIM on efficiency.

The positive influence of capital on bank technical efficiency suggests that the availability of excess capital will enable banks to increase lending without being overly concerned with being unable to cover the credit risk that arises as it has sufficient capital to cover this risk. Adequate capital availability also means banks are able to take advantage of various profitable investment or credit opportunities that will eventually generate an increase in their interest income (Osei-Assibey and Asenso 2015). A strong capital balance is also a sign of a healthy bank and means depositors are willing to save their funds at the bank without having to ask for a high rate of return (Fatima 2014). The impact is that the cost of bank funding is low, credit interest is low and the quality of its debtors is good, which ultimately increases bank profits. Thus, the amount of capital can improve the technical efficiency of banks (Altunbas et al. 2000; Altunbas et al. 2007).

LDR is shown to positively affect bank technical efficiency. A higher ratio indicates a greater level of bank loans relative to third-party deposits. In the context of an RDB where lending is the main asset placement activity (Keuangan 2016), the ability to channel credit is an important aspect in determining bank efficiency. Lending is the main source of bank growth (Caprio et al. 2007) and is especially crucial for RDBs with a limited range of fee-based income activities. This credit disbursement will further improve the bank's ability to generate interest income (Dietrich and Wanzenried 2011; Anbar & Alper 2011; Gul et al. 2011; Molyneux & Thornton 1992).

Another significant determinant of bank technical efficiency in the FE model is NPL. This variable negatively influences bank efficiency. A high NPL means that banks will spend a lot of time, effort and cost on managing loan-related problems (Kwan & Eisenbeis 1996; Rajaraman & Vasishtha 2002; Tan & Floros 2013). All of this raises costs and means management to have less time to spend on activities that create added value for the bank. Banks also need to allocate capital to cover the large credit losses and this reduction in the capital will diminish the bank's ability to lend. An increase in cost and a decline in lending will ultimately reduce bank profitability (Masood & Ashraf 2012; Bolt et al. 2012).

The composition of deposits has a negative effect on efficiency. The greater the composition of third-party deposits originating from time deposits, the higher the cost of funds borne by the bank. This high cost of funds makes it difficult for banks to extend credit, and even if this is possible, the quality of debtors tends to be poor, which in turn leads to problem loans. The high cost of funding also reduces bank net interest income (Deans & Stewart 2012). For RDBs, interest is a vital component of income as it accounts for around 91 percent of their income.

Table 5 and Table 6 also reveal that bank size does not significantly influence bank efficiency. This can indicate that the effect of bank size on efficiency is not linear but quadratic (U-shaped). To examine this possibility, we include the square of size (size^2) in the FE regression model. The results of this test can be seen in Table 7, where it is shown that there is no significant difference in the effect of all variables on bank efficiency compared to the results in Table 5 and Table 6, except for size. Size does not have a significant effect on efficiency in Table 5 and Table 6, but it does have a positive effect on efficiency when size squared has a negative effect on it. In other words, the effect of size on efficiency is U-shaped (Hadad et al. 2013; Karray & Chichti 2013; Muazaroh et al. 2012). An increase in bank assets means that banks initially benefit from economies of scale due to a reduced cost per unit of transactions (Altunbas et al. 2000; Hughes et al. 2001; Pasiouras 2008; Perera et al. 2007). Larger banks can reduce their employee unit costs and improve their efficiency by spreading this cost over many transactions. However, these benefits of economies of scale are negated if banks become too big. When banks become too large, with many branches and employees, they may suffer from coordination and monitoring problems, as well as delays in decision-making. The impact is that they lose many opportunities to grow and make profits, thereby reducing their efficiency.

TABLE 7. Fixed Effect Regression Model by Including Square of Size

Variable	FE		FE-White cross-section		FE-White period	
	Coef.	Coef.	Prob.	Prob.	Coef.	Prob.
Constant	-21.292	-2.190	0.000	0.004	-2.190	0.036
Size	15.034	15.034	0.000*	0.003*	15.034	0.032*
Size^2	-2.505	-2.505	0.000*	0.004*	-2.505	0.033*
Non-Performing Loan	-0.987	-0.987	0.000*	0.002*	-0.987	0.041*
Capital Adequacy Ratio	0.589	0.589	0.000*	0.000*	0.589	0.014*
Loan-to-Deposit Ratio	0.284	0.284	0.000*	0.000*	0.284	0.000*
Net Interest Margin	-0.574	-0.574	0.284	0.166	-0.574	0.287
Composition of Deposits	-0.304	-0.304	0.000*	0.000*	-0.304	0.000*

Sources: EViews Output
* Significance at 5%

SUMMARY AND CONCLUSIONS

This study has analyzed the technical efficiency of Indonesia's RDBs using a two-stage DEA procedure. The first stage of the analysis revealed that, in general, the RDBs had yet to become efficient during the period 2012–2017. The main causes of inefficiency were on the output side, namely credit disbursement, interest income, and non-interest income. The most important source of inefficiency is non-interest income. One means of optimizing this income would be to increase the banks' capital with the aim of shifting them into the Book 3 category, which would enable them to perform almost all banking activities. Banks can utilize their capital to develop fee-based income products, such as internet and mobile banking and bank guarantees.

The second stage of the analysis revealed that capital and the LDR improved the level of DEA-based technical efficiency of the Indonesian RDBs, while NPL and deposit composition reduced bank technical efficiency. The positive impact of bank size and the negative impact of the square of size may suggest that as banks increase their assets they enjoy economies of scale up to a certain point, after which any further increase produces diseconomies of scale. In addition, the RDBs need to further increase their loan disbursements. Banks with a low LDR should seek to increase their lending up to the point at which their LDR reaches the maximum regulatory limit of 94 percent. RDBs also need to control the interest they charge to borrowers in order to reduce the composition of time deposits with high-interest rates as these may impede credit expansion, increase problem loans and reduce interest income.

There are some policy implications from this study. The Indonesian Financial Services Authority (OJK) needs to encourage RDBs and local governments as owners to accelerate their capital increase, either internally or through strategic alliances, so that these banks can further expand activities beyond lending so that RDBs can improve their non-interest income which is the main source of inefficiency of RDBs. Bank Indonesia also needs to further relax the upper limit of the LDR, which is currently 94 percent to close to 100 percent, thereby reducing unproductive depositor's funds at the Central Bank and increasing the capacity of RDBs in lending, which in turn could increase RDBs interest income.

REFERENCES

Abidin, Z. & Endri, E. 2010. Kinerja efisiensi teknis bank pembangunan daerah: Pendekatan Data Envelopment Analysis (DEA). *Jurnal Akuntansi dan Keuangan* 11**:** 21-29.

Akhtar, M. H. 2010. Are Saudi banks productive and efficient? *International Journal of Islamic and Middle Eastern Finance and Management* 3**:** 95-112.

Al-Faraj, T. N., Alidi, A. S. & Bu-Bshait, K. A. 1993. Evaluation of bank branches by means of data envelopment analysis. *International Journal of Operations & Production Management* 13**:** 45-52.

Al-Khasawneh, J. A., Bassedat, K., Aktan, B. & Darshini Pun Thapa, P. 2012. Efficiency of Islamic banks: case of North African Arab countries. *Qualitative Research in Financial Markets* 4**:** 228-239.

Altunbas, Y., Carbo, S., Gardener, E. P. & Molyneux, P. 2007. Examining the relationships between capital, risk and efficiency in European banking. *European Financial Management* 13**:** 49-70.

Altunbas, Y., Liu, M.-H., Molyneux, P. & Seth, R. 2000. Efficiency and risk in Japanese banking. *Journal of Banking & Finance* 24**:** 1605-1628.

Anbar, A. & Alper, D. 2011. Bank specific and macroeconomic determinants of commercial bank profitability: Empirical evidence from Turkey. *Business and Economics Research Journal* 2**:** 139-152.

Banker, R. D., Charnes, A. & Cooper, W. W. 1984. Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management Science* 30**:** 1078-1092.

Berger, A. N. & Deyoung, R. 1997. Problem loans and cost efficiency in commercial banks. *Journal of Banking & Finance* 21**:** 849-870.

Bolt, W., De Haan, L., Hoeberichts, M., Van Oordt, M. R. & Swank, J. 2012. Bank profitability during recessions. *Journal of Banking & Finance* 36**:** 2552-2564.
Bonin, J. P., Hasan, I. & Wachtel, P. 2005. Bank performance, efficiency and ownership in transition countries. *Journal of Banking & Finance* 29**:** 31-53.
Caprio, G., Laeven, L. & Levine, R. 2007. Governance and bank valuation. *Journal of Financial Intermediation* 16**:** 584-617.
Casu, B., Girardone, C. & Molyneux, P. 2004. Productivity change in European banking: A comparison of parametric and non-parametric approaches. *Journal of Banking & Finance* 28**:** 2521-2540.
Charnes, A., Cooper, W. W. & Rhodes, E. 1978. Measuring the efficiency of decision making units. *European Journal of Operational Research* 2**:** 429-444.
Chen, T.-Y. & Yeh, T.-L. 1998. A study of efficiency evaluation in Taiwan's banks. *International Journal of Service Industry Management* 9**:** 402-415.
Chen, T.-Y. & Yeh, T.-L. 2000. A measurement of bank efficiency, ownership and productivity changes in Taiwan. *Service Industries Journal* 20**:** 95-109.
Cook, W. D., Tone, K. & Zhu, J. 2014. Data envelopment analysis: Prior to choosing a model. *Omega* 44**:** 1-4.
Deans, C. & Stewart, C. 2012. Banks' funding costs and lending rates. *Reserve Bank of Australia Bulletin* 2012: 37-43.
Defung, F., Salim, R. & Bloch, H. 2016. Has regulatory reform had any impact on bank efficiency in Indonesia? A two-stage analysis. *Applied Economics* 48: 5060-5074.
Dietrich, A. & Wanzenried, G. 2011. Determinants of bank profitability before and during the crisis: Evidence from Switzerland. *Journal of International Financial Markets, Institutions and Money* 21**:** 307-327.
Dong, Y., Hamilton, R. & Tippett, M. 2014. Cost efficiency of the Chinese banking sector: a comparison of stochastic frontier analysis and data envelopment analysis. *Economic Modelling* 36**:** 298-308.
Färe, R. & Lovell, C. K. 1978. Measuring the technical efficiency of production. *Journal of Economic Theory* 19**:** 150-162.
Farrell, M. J. 1957. The measurement of productive efficiency. *Journal of the Royal Statistical Society. Series A (General)* 120**:** 253-290.
Fatima, N. 2014. Capital adequacy: A financial soundness indicator for banks. *Global Journal of Finance and Management* 6: 771-776.
Favero, C. A. & Papi, L. 1995. Technical efficiency and scale efficiency in the Italian banking sector: a non-parametric approach. *Applied Economics* 27**:** 385-395.
Felix, A. O., Adebayo, A. O. & Omolehinwa, E. 1998. Bank performance measurement in a developing economy: an application of data envelopment analysis. *Managerial Finance* 24: 5-16.
Ferari, N. & Sudarsono, H. 2011. Tingkat Efisiensi Perbankan Syariah Dan Konvensional Dengan Mengunakan Data Envelopment Analysis (DEA). *Jurnal Ekonomi dan Keuangan Islam* 1**:** 141-148.
Fukuyama, H. 1993. Technical and scale efficiency of Japanese commerical banks: a non-parametric approach. *Applied Economics* 25**:** 1101-1112.
Gardener, E., Molyneux, P. & Nguyen-Linh, H. 2011. Determinants of efficiency in South East Asian banking. *The Service Industries Journal* 31**:** 2693-2719.
Golany, B. & Storbeck, J. E. 1999. A data envelopment analysis of the operational efficiency of bank branches. *Interfaces* 29**:** 14-26.
Gujarati, D. N. & Porter, D. 2009. *Basic Econometrics* Mc Graw-Hill.
Gul, S., Irshad, F. & Zaman, K. 2011. Factors Affecting Bank Profitability in Pakistan. *Romanian Economic Journal*, 14.
Hadad, M., Hall, M. J., Kenjegalieva, K. A., Santoso, W. & Simper, R. 2012. A new approach to dealing with negative numbers in efficiency analysis: An application to the Indonesian banking sector. *Expert Systems with Applications*, 39**:** 8212-8219.
Hadad, M., Hall, M. J., Santoso, W. & Simper, R. 2013. Economies of scale and a process for identifying hypothetical merger potential in Indonesian commercial banks. *Journal of Asian Economics* 26**:** 42-51.
Hadad, M., Santoso, W., Ilyas, D. & Mardanugraha, E. 2003a. Analisis Efisiensi Industri Perbankan Indonesia: Penggunaan Metode Nonparametrik Data Envelopment Analysis (DEA). *Research Paper*, 7.
Hadad, M., Wibowo, S., Handoko, S., Yuniar, M. & Noviati, N. Kajian Mengenai Efektivitas Kebijakan Obligasi Rekap. Bank of Indonesia Working Paper, 2003b. Bank of Indonesia.
Haslem, J. A., Scheraga, C. A. & Bedingfield, J. P. 1999. DEA efficiency profiles of US banks operating internationally. *International Review of Economics & Finance* 8**:** 165-182.
Hassan, T., Mohamad, S. & Khaled I. Bader, M. 2009. Efficiency of conventional versus Islamic banks: evidence from the Middle East. *International Journal of Islamic and Middle Eastern Finance and Management* 2**:** 46-65.
Havrylchyk, O. 2006. Efficiency of the Polish banking industry: Foreign versus domestic banks. *Journal of Banking & Finance* 30**:** 1975-1996.
Hawdon, D. 2003. Efficiency, performance and regulation of the international gas industry—a bootstrap DEA approach. *Energy Policy* 31**:** 1167-1178.
Howland, M. & Rowse, J. 2006. Measuring bank branch efficiency using data envelopment analysis: managerial and implementation issues. *INFOR: Information Systems and Operational Research* 44**:** 49-63.

Hughes, J. P., Mester, L. J. & Moon, C.-G. 2001. Are scale economies in banking elusive or illusive?: Evidence obtained by incorporating capital structure and risk-taking into models of bank production. *Journal of Banking & Finance* 25**:** 2169-2208.
Jarzebowski, S. 2013. Parametric and Non-Parametric Efficiency Measurement–The Comparison of Results. *Metody Ilościowe w Badaniach Ekonomicznych* 14**:** 170-179.
Jemric, I. & Vujcic, B. 2002. Efficiency of banks in Croatia: A DEA approach. *Comparative Economic Studies* 44**:** 169-193.
Kalis, R., Amin, P. & Prasetyo, P. E. 2012. Tingkat Efisiensi Bank Di Indonesia. *Dinamika Akuntansi Keuangan dan Perbankan*, 1.
Karim, M. Z. A., Chan, S.-G. & Hassan, S. 2010. Bank efficiency and non-performing loans: Evidence from Malaysia and Singapore. *Prague Economic Papers* 2**:** 118-132.
Karray, S. C. & Chichti, J. E. 2013. Bank size and efficiency in developing countries: intermediation approach versus value added approach and impact of non-traditional activities. *Asian Economic and Financial Review* 3**:** 593.
Keuangan, O. J. 2016. Annual Report OJK 2015. *Available at www. ojk. go. id.[download at 29 September 2016]*.
Keuangan, O. J. 2018a. Direktori Perbankan Indonesia. Jakarta: Otoritas Jasa Keuangan.
Keuangan, O. J. 2018b. Laporan Profil Industri Perbankan Triwulan IV 2017.
Kurnia, A. S. 2004. Mengukur efisiensi intermediasi sebelas bank terbesar indonesia dengan pendekatan Data Envelopment Analysis (DEA). *Jurnal Bisnis Strategi*, 13**,** 126-140.
Kwan, S. & Eisenbeis, R. A. 1997. Bank risk, capitalization, and operating efficiency. *Journal of Financial Services Research* 12: 117-131.
Kwan, S. H. & Eisenbeis, R. A. 1996. An analysis of inefficiencies in banking: A stochastic cost frontier approach. *Economic Review-Federal Reserve Bank of San Francisco***,** 16.
Masood, O. & Ashraf, M. 2012. Bank-specific and macroeconomic profitability determinants of Islamic banks: The case of different countries. *Qualitative Research in Financial Markets* 4**:** 255-268.
Miller, S. M. & Noulas, A. G. 1996. The technical efficiency of large bank production. *Journal of Banking & Finance* 20**:** 495-509.
Mokhtar, H. S. A., Abdullah, N. & Alhabshi, S. M. 2008. Efficiency and competition of Islamic banking in Malaysia. *Humanomics* 24**:** 28-48.
Molyneux, P. & Thornton, J. 1992. Determinants of European bank profitability: A note. *Journal of Banking & Finance* 16: 1173-1178.
Mostafa, M. M. 2011. Modeling Islamic banks' efficiency: a non-parametric frontier approach. *International Journal of Islamic and Middle Eastern Finance and Management* 4**:** 7-29.
Muazaroh, M., Eduardus, T., Husnan, S. & Hanafi, M. 2012. Determinants of bank profit efficiency: Evidence from Indonesia. *International Journal of Economics and Finance Studies* 4**:** 163-173.
Muharam, H. 2007. Analisis perbandingan efisiensi bank syariah di Indonesia dengan metode data envelopment analysis (Periode tahun 2005). *Jurnal Ekonomi dan Bisnis Islam* 2**:** 80-166.
Mukherjee, A., Nath, P. & Nath Pal, M. 2002. Performance benchmarking and strategic homogeneity of Indian banks. *International Journal of Bank Marketing* 20**:** 122-139.
Novandra, R. 2017. Analisis Perbandingan Efisiensi Perbankan Syariah dan Konvensional di Indonesia. *Jurnal Ekonomi dan Pembangunan* 22**:** 183-193.
Omar, M. A., Majid, M. S. A. & Ronald, R. 2007. Efficiency and productivity performance of the private national banks in Indonesia. *Gadjah Mada International Journal of Business* 9**:** 1-18.
Osei-Assibey, E. & Asenso, J. K. 2015. Regulatory capital and its effect on credit growth, non-performing loans and bank efficiency: Evidence from Ghana. *Journal of Financial Economic Policy* 7**:** 401-420.
Pasiouras, F. 2008. Estimating the technical and scale efficiency of Greek commercial banks: the impact of credit risk, off-balance sheet activities, and international operations. *Research in International Business and Finance* 22**:** 301-318.
Perera, S., Skully, M. & Wickramanayake, J. 2007. Cost efficiency in South Asian banking: The impact of bank size, state ownership and stock exchange listings. *International Review of Finance* 7**:** 35-60.
Pramuka, B. A. 2011. Assessing profit efficiency of Islamic banks in Indonesia: An intermediation approach. *Journal of Economics, Business & Accountancy Ventura (JEBAV)* 14**:** 79-88.
Rajaraman, I. & Vasishtha, G. 2002. Non-performing loans of PSU banks: Some panel results. *Economic and Political Weekly***:** 429-435.
Resti, A. 1997. Evaluating the cost-efficiency of the Italian banking system: What can be learned from the joint application of parametric and non-parametric techniques. *Journal of Banking & Finance* 21**:** 221-250.
Rose, P. S. & Hudgins, S. C. 2013. *Bank management & financial services*, McGraw-Hill.
Rosyadi, I. 2017. Komparasi Efisiensi Perbankan Syariah Dan Perbankan Konvensional Di Indonesia. *Riset Akuntansi dan Keuangan Indonesia* 2**:** 61-74.
Sadalia, I. & Kautsar, M. H. 2018. Analysis of the efficiency performance of Sharia and conventional banks using stochastic frontier analysis. *Banks and Bank Systems* 13**:** 27.
Sakar, B. 2006. A study on efficiency and productivity of Turkish banks in Istanbul stock exchange using Malmquist DEA. *Journal of American Academy of Business* 8**:**145-155.

Salas, V. & Saurina, J. 2002. Credit risk in two institutional regimes: Spanish commercial and savings banks. *Journal of Financial Services Research* 22**:** 203-224.
Sathye, M. 2001. X-efficiency in Australian banking: An empirical investigation. *Journal of Banking & Finance* 25**:** 613-630.
Sathye, M. 2003. Efficiency of banks in a developing economy: The case of India. *European Journal of Operational Research* 148: 662-671.
Seiford, L. M. & Zhu, J. 1999. Profitability and marketability of the top 55 US commercial banks. *Management Science* 45**:** 1270-1288.
Sinkey, J. F. & Greenawalt, M. B. 1991. Loan-loss experience and risk-taking behavior at large commercial banks. *Journal of Financial Services Research* 5: 43-59.
Staub, R. B., E Souza, G. D. S. & Tabak, B. M. 2010. Evolution of bank efficiency in Brazil: A DEA approach. *European Journal of Operational Research* 202: 204-213.
Sufian, F. & Noor, M. A. N. M. 2009. The determinants of Islamic banks' efficiency changes: Empirical evidence from the MENA and Asian banking sectors. *International Journal of Islamic and Middle Eastern Finance and Management* 2**:** 120-138.
Sutanto, H. A. 2015. Analisis Efisiensi Teknis Bank Pembangunan Daerah. *JEJAK: Jurnal Ekonomi Dan Kebijakan* 8.
Tan, Y. & Floros, C. 2013. Risk, capital and efficiency in Chinese banking. *Journal of International Financial Markets, Institutions and Money* 26**:** 378-393.
Vassiloglou, M. & Giokas, D. 1990. A study of the relative efficiency of bank branches: an application of data envelopment analysis. *Journal of the Operational Research Society* 41**:** 591-597.
Vincova, K. 2005. Using DEA models to measure efficiency. *Biatec* 13**:** 24-28.
Wardhani, P. I. & Mongid, A. 2019. Strategies to increase production efficiency in Indonesian Sharia commercial banks using Stochastic Frontier Approach (SFA). *Journal of Economics, Business & Accountancy Ventura* 21**:** 379-389.
Widiarti, A. W., Siregar, H. & Andati, T. 2015. The Determinants of Banks Efficiency in Indonesia. *Bank Indonesia: Buletin Ekonomi Moneter dan Perbankan* 18**:** 129-156.
Wu, D. D., Yang, Z. & Liang, L. 2006. Using DEA-neural network approach to evaluate branch efficiency of a large Canadian bank. *Expert Systems With Applications* 31**:** 108-115.
Zenios, C. V., Zenios, S. A., Agathocleous, K. & Soteriou, A. C. 1999. Benchmarks of the efficiency of bank branches. *Interfaces* 29: 37-51.

Lutfi*
Undergraduate Program - Department of Management
STIE Perbanas Surabaya
Nginden Semolo 34-36, Surabaya, Indonesia
E-mail: lutfi@perbanas.ac.id

Suyatno
Postgradute Program - Department of Management
STIE Perbanas Surabaya
Nginden Semolo 34-36, Surabaya, Indonesia
E-mail: suyatno_bjtm@yahoo.com

*Corresponding author