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The technical efficiency of rice farming and mobile phone usage: a stochastic frontier analysis

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Abstract

Although there is growing literature on the role of mobile phones in shaping the price and market structure of agricultural products, the role of mobile phones in farming practices is mostly unexplored. This paper aimed to fill the gap in the literature by investigating whether the mobile phone is a determinant in improving the technical efficiency of rice farming in Indonesia. Rice is the most important agricultural commodity in Indonesia because it is the staple food for around 270 million people. In addition, it also plays a major role in carving the country's inflation expectation as well as economic stability. This study uses a production function that includes labour, harvest area and seeds as inputs. The stochastic frontier analysis is employed to examine the level of technical efficiency of rice farming in Indonesia as well as whether mobile phone usage can improve technical efficiency. This study utilizes 2120 rice farm household data obtained from Indonesia Family Life Survey (IFLS)-5 in 2014. The results from the inefficiency model show that mobile phone usage is significantly correlated to the decrease in inefficiency in rice farming along with farmers' education and irrigation implementation. However, rice farming on farmers' land is significantly correlated to the increase in inefficiency, which implies that rice farming on rented land is more efficient. The technical efficiency level of rice farming In Indonesia obtained from the production function model is 0.59. In addition, the size of the harvest area and the use of superior seeds are positively and significantly correlated to output. However, the number of labour is not significantly correlated to the level of rice production.

1. Introduction

Information and communication technology (ICT) has been growing rapidly and becoming more accessible and affordable to a rising share of the global population. ICT has outreached even areas in which livelihoods still highly depend on subsistence farming. Understanding how ICT transform society as well as contribute to development is one of the major issues nowadays. Considerable studies have investigated the role of mobile phones in farming. Studies done by Aker and Ksoll (2016) found that mobile phones could reduce farmers' households' costs of searching for private information, especially as compared with traditional mechanisms, such as personal travel, newspapers or landlines. Particularly in a developing country context, the literature on information technology and agriculture has focused on how mobile phones can increase information in agricultural markets and potentially lead to improved market efficiency (Jensen, 2007; Muto and Yamano, 2009; Aker, 2010; Fafchamps and Minten, 2012; Aker and Fafchamps, 2015; Shimamoto, Yamada, and Gummert, 2015; Tadesse and Bahiigwa, 2015; Mitra, Mookherjee, Torero, and Visaria, 2018).

In addition, mobile phone usage in farming in some cases could affect price formation. Studies from Aker and Fafchamps (2015) show that the rollout of mobile phone coverage reduced farm-gate price dispersion in Niger, but did not affect farm-gate prices. Fafchamps and Minten (2012) found that while a mobile phone-based price and weather information system in India increased farmers' access to information and crop grading, it had no effect on other agricultural outcomes, including farm-gate prices. Camacho and Conover (2011) discovered similar effects of an SMS-based weather and price information system in Colombia. Furthermore, mobile phones reduce consumer and producer price dispersion spatially as well as over time (Jensen, 2007).

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Moreover, mobile phone coverage in farming also improves market participation in cash food crops in Uganda (Muto and Yamano, 2009). A study from Zanello (2012) shows that receiving market information via mobile phones has a positive and significant impact on market participation, with a greater impact on households with a surplus of food crops. On top of that, farm households that use mobile phones planted a more diverse basket of crops, particularly marginal cash crops grown by women (Aker and Ksoll, 2016). Mobile phones also allow households to obtain information about potential shocks, which they can use such information to make planting and harvesting decisions, which can have important effects on yields (Rosenzweig and Binswanger, 1993).

Despite ample findings related to increased market efficiency due to mobile phone usage in farming, there are very few studies related to the effect of ICT on agricultural practices (Kaila and Tarp, 2019). A study by Mwalupaso *et al.* (2020) on maize farms discovered that the technical efficiency of corn farmers who used mobile phones in the production process was greater than those who did not use them. As for the case of Indonesia, hardly any studies have shed light on mobile phone usage in farming practices. Subejo *et al.* (2019) discovered the usage of ICT which include mobile phones among farmers in coastal Yogyakarta, Indonesia. However, this study merely focuses on capturing the characteristics of farmers that are more likely to use mobile phones in farming which usually are young and well-educated, have a higher income, and experience better infrastructure and telecommunication networks. The study from Feryanto and Rosiana (2021) found that gender, marital status, number of adult household members, education, land ownership status, land area, and counselling are factors that affect the likelihood of using mobile phones in marketing agricultural products. This study observed that the use of mobile phones by 10.7% or 276 out of 1,557 farmers has had a positive impact as seen from the farm revenue for one year. Still, this study focuses mainly on mobile phone usage in marketing agricultural products instead of on farming practices.

Like many other countries in the developed and developing world, Indonesia has experienced a significant increase in the number of mobile phone users for the past decade. At the beginning of 2010, mobile phone users constitute only 38.05% of the total population, while in 2019 it had reached 63.53% (Sutarsih *et al.,* 2019). A survey on ICT usage among farmers and fishermen in Indonesia found that 66.8 % of farmers already have mobile phones with 20.8% of them having internet facilities. The interesting thing is that the farmers' main reason for not having mobile phones is because they don't know how to use it (50% of respondents), they don't like to use mobile phones (20.7%) and actually, only about 6% of them saying they don't have a mobile phone because they can't afford it (Anandhita, *et al.,* 2015). In addition, particularly for rice farming, only 19.5% of rice farmers in Indonesia use mobile phones in farming practices (IFLS, 2015).

This research aimed to fill the gap in the previous studies by investigating whether mobile phone usage is a determinant in improving the technical efficiency of rice farming. Most literature focus on how mobile phone usage in farming impact price formation and market structure, however, they are leaving behind how it impacts the farming practice. This research is also by far the first study in Indonesia that discusses how mobile phone usage in rice farming is a determinant in improving technical efficiency.

2. Rice farming in Indonesia

According to the Indonesian Central Bureau of Statistics (2020), the contribution of the agricultural sector in Indonesia is currently around 13% of the Gross Domestic Product (GDP) in which the trend continues to decline from year to year. In early 2000, the agricultural sector's contribution stood at around 17% of GDP. Even so, the agricultural sector still contributes greatly to job creation, about 30% of workers in Indonesia are in agriculture. With the strategic position of the agricultural sector for the national economy, especially in creating jobs and meeting domestic needs, the right policies are the main focus. Particularly rice is the most important commodity because it is the staple food for around 270 million people in Indonesia. Apart from being a staple food, rice plays a main role in shaping expectations of inflation and economic stability (Widodo, 1989).

Policies in the agricultural sector, especially rice production and price policies, have gone through several phases since the early 1970s. The New Order government focused on the agricultural sector as stipulated in the Five-Year Development Plan (Repelita) I to V. The oil boom which benefited the Indonesian government as an oil exporter had encouraged investment in research, infrastructure development and agricultural intensification. In addition, the government also provided agricultural input subsidies which contributed to the rapid growth rate of rice production until finally Indonesia achieved rice self-sufficiency in 1985 and received an award from the Food and Agricultural Organization (FAO). In addition to policies in rice production, during this period until the Reformation Era in 1998, the government also implemented policies to regulate prices for basic commodities including rice through the National Logistics Agency (Bulog).

After Indonesia achieved rice self-sufficiency, almost at the same time the oil boom ended and created an impact on rice policy. The government's strong support for the agricultural sector, which used to be supported by oil boom funds, has decreased drastically which has resulted in decreased rice production growth so that Indonesia has again returned to being a rice importer. In 1998 when the Asian crisis reached its peak, Bulog's authority to import monopoly was revoked to maintain price stability, it had to go through free trade. The policy direction changed again in 2004 with the implementation of a rice import ban with the aim of protecting the welfare of local farmers. Apart from the popularity of the restricted rice imports policy, two out of thirds of farmers in Indonesia are actually net consumers and the increase in food prices also makes it difficult for them (Bank, 2019). In the era of former president Susilo Bambang Yudhoyono's administration, the agricultural sector has again become a priority. The government then launched an agricultural revitalization program covering general policies on land and agricultural spatial planning, rural infrastructure development, trade in agricultural products and most importantly food security.

Food security itself is a condition when the population of a country has access to sufficient food at any time to support an active and healthy life (FAO, 1996) both through domestic and imported food production (Clapp, 2017). The desire to increase food security and even achieve food sovereignty was also echoed in the current president Jokowi’s administration through the Special Efforts (Upsus) program for rice, corn and soybean (pajale) and food estate. Upsus pajale which is initiated in 2015 is aimed at achieving sovereignty, especially rice, corn and soybean. The food estate started in 2020, is a food development concept in an integrated area covering agriculture, plantations and even livestock. This project uses ex-peat land in an effort to expand the land as a producer of national food reserves.

Every year the Economist Intelligence Unit (EIU) issues a Global Food Security Index which is assessed based on three main indicators; affordability, availability and quality of food. In 2020 Indonesia was ranked 65th out of 113 countries. The country’s ranking was still below the peer countries in the ASEAN region (Association of Southeast Asian Nations) such as Singapore (19th), Malaysia (43rd), Thailand (51st) and Vietnam (63rd). In addition, currently, there is around 19.6% of Indonesian children are underweight, which is a fairly large number and is a public health problem, the incidence of stunting is also considered large for a country with an economic growth rate of around 5% (Bank, 2019).

The aforementioned challenges make increasing food security imperative and particularly in the production of rice as a staple food. Two main things that deserve attention in the food security of rice commodities are in terms of availability and affordability. In terms of availability, because rice self-sufficiency has not been achieved, part of the domestic demand for rice must be met through imports. When viewed from Figure 1, it can be seen that Indonesia’s rice imports are quite volatile. For example, in 2017 rice imports were only around 300 thousand tons, but in 2018 they rose sharply to 2.2 million tonnes.

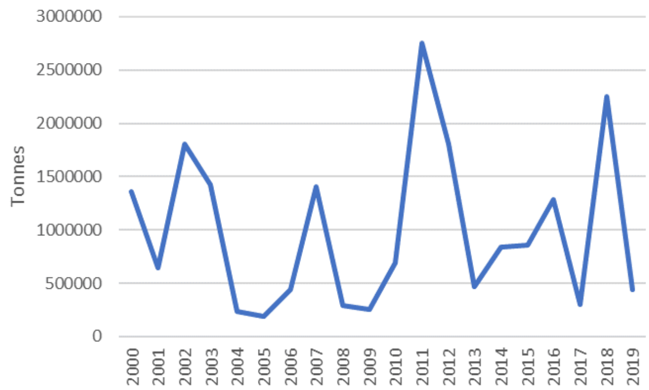

Figure 1. Indonesia’s rice imports year 2000-2019. Source: Indonesian Central Bureau of Statistics (2020)

Meeting food needs through the international trade process is considered more efficient and encourages the country to advance its comparative advantage. Even food self-sufficiency is considered inefficient and creates market distortions (Naylor and Falcon, 2010). However, several studies have shown that high import concentrations of some commodities can result in a fragile global food system that is highly sensitive to instability triggered by economic disruption and natural disasters (Suweis *et al.,* 2015; Puma *et al.,* 2015) Thus, it is not surprising that many countries view food self-sufficiency as an important political goal to achieve, not only as a strategy to build national pride but also to reduce vulnerability to the world's political map that is rooted in excessive dependence on food supply on other countries (O'Hagan, 1976). Especially for the rice commodity, which is a commodity with a limited number of suppliers, price spikes such as the 2007/2008 crisis have the potential to recur as self-sufficiency in rice is something that should be considered (Clapp, 2017).

From the various arguments above, increasing the capacity of domestic rice production to reduce excessive dependence on other countries is very plausible. In

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addition, increasing domestic rice production will help increase rice supply so that domestic rice prices will fall, assuming there are no changes in rice export and import policies. Aside from the availability factor, the affordability of rice is also prominent. The level of food prices greatly affects the level of vulnerability of poor families this is because food expenditure from poor families reaches 76.7% of the total expenditure of all households (World Bank Group, 2020). Figure 2 shows a comparison of rice prices in Indonesia with prices of rice of similar quality in other rice-producing countries. The price of rice in Indonesia is more expensive than the price of rice in other countries which is suspected to be due to tight import policies, the high cost of rice production which includes wages for agricultural labour, land rent and high logistics costs (World Bank Group, 2020).

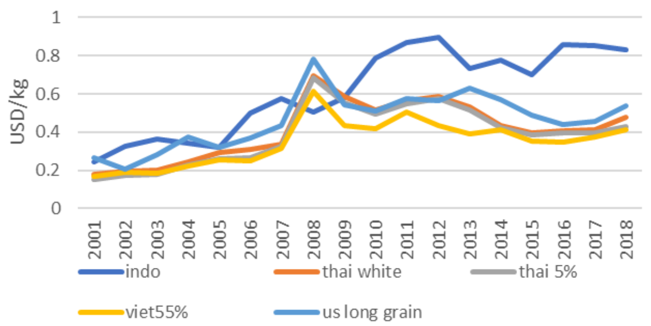

Figure 2. Rice price comparisons among rice producer countries year 2001-2018. Source: FAO database (https://www.fao.org/faostat/en/#home)

To increase rice production, Indonesia needs to increase productivity as well as the number of factors of rice production. Figure 3 shows the productivity of our rice compared to the largest rice-exporting countries in the world. Indonesia is able to produce around 5 tonnes of rice per hectare, ahead of Thailand, Pakistan and India, although still below the productivity of China and Vietnam. This shows that Indonesia's rice productivity is good enough, although there is still room for improvement. However, looking at the amount of rice produced in a country divided by the total population as shown in Figure 4, Indonesia's per capita rice production is still far behind compared to Thailand and Vietnam. Likewise, when viewed from the harvest area divided by the population in Figure 5, the per capita harvest area in Indonesia is still smaller than in Thailand and Vietnam. This indicates that the amount of land as a factor for its rice production is still lagging behind those two countries.

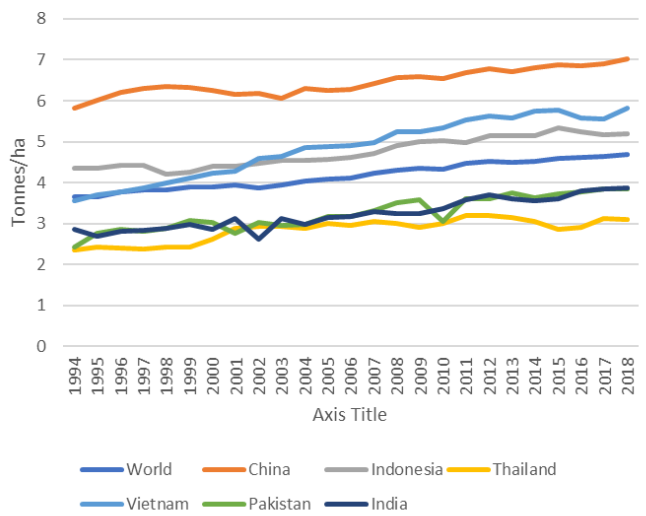

Figure 3. Rice productivity year 1994-2018 (tonnes/ha). Source: FAO database (https://www.fao.org/faostat/en/#home)

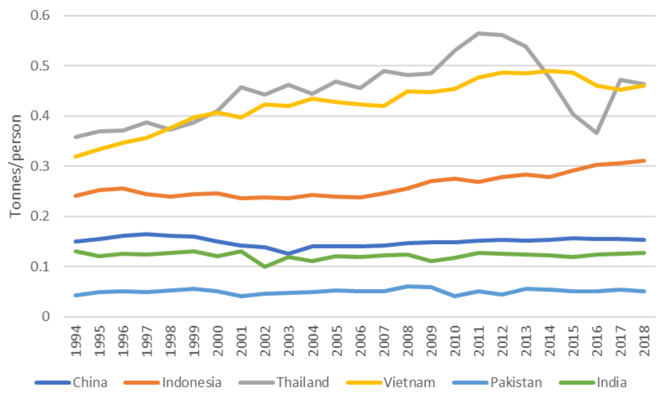

Figure 4. Rice production per population year 1994-2018 (tonnes/pop). Source: FAO database (https://www.fao.org/faostat/en/#home)

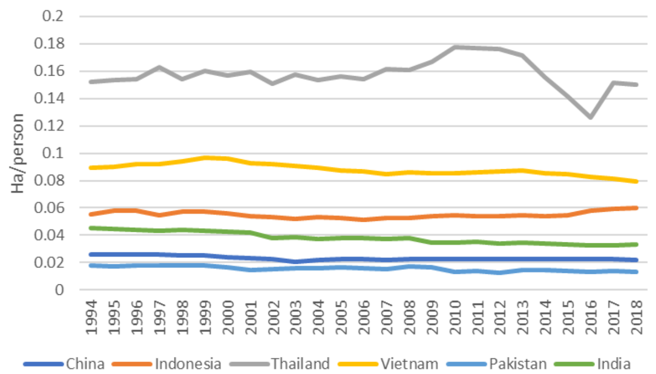

Figure 5. Harvested area per population year 1994-2018 (ha/person). Source: FAO database (https://www.fao.org/faostat/en/#home) and WB database (https://data.worldbank.org/indicator/SP.POP.TOTL/)

3. Literature review on the technical efficiency of rice farming

Various studies aimed at finding the technical efficiency of rice production have been carried out. The study by Boubacar *et al.* (2016) found that the technical efficiency of agriculture in Nigeria was 0.48 using a survey of 148 from 3 districts in Nigeria. Studies to find agricultural technical efficiency were also carried out in Iran and it was found that the technical efficiency of agriculture averaged 0.67 (Hormozi *et al.*, 2012). Koirala *et al.,* (2016) used a loop survey from the International Rice Research Institute (IRRI) in 2007-2012 and found that the technical efficiency of agriculture in the Philippines was 0.79. Cambodia, a country easily affected by the weather, has a technical agricultural efficiency of 0.6 (Mishra *et al.,* 2018). The technical efficiency in China is quite high at 0.8-0.91 (Tan *et al.,* 2010) and in Vietnam at 0.8 (Kompas *et al.,* 2012).

Several different factors are determinants of inefficiency. Several factors were found to reduce agricultural inefficiencies, such as the size of the farm where the larger the scale of agriculture, the more efficient (Tan *et al.,* 2010; Pedroso *et al.,* 2017), the level of mechanization (Hormozi *et al.,* 2012), the length of education of farmers and access to credit to farmers (Mishra *et al.,* 2018). Several factors can increase inefficiency, such as land ownership (Boubacar *et al.,* 2016; Koirala *et al.,* 2016) if the gender of farmers is women and education (Koirala *et al.,* 2016).

In Indonesia, several studies to find agricultural technical efficiency and its determinants have also been carried out. A study conducted by Widodo (1989) found that small-scale rice farming had greater technical efficiency than large-scale farming, however (Esparon and Sturgess, 1989; Squires, 1995) found that the scale of rice farming did not affect its technical efficiency. A study from Mariyono (2014a) using panel data of rice farmers from 1993-2013 from 23 provinces in Indonesia found that the technical efficiency of rice production in Indonesia was 0.62 where irrigation and training significantly reduced the inefficiency of rice production. The importance of irrigation is also in line with findings from (Laksana and Damayanti, 2013). Makki *et al.* (2012) found that farming in swamps has higher technical efficiency than upland farming. Using 358 rice farming data in 2003, 2008 and 2013, it is found that the technical efficiency of rice production was 0.68 where work experience, length of education, size of agriculture, the proportion of paid and voluntary agricultural labour and mechanization can reduce inefficiency (Mariyono, 2014b). Meanwhile, Saeri *et al.* (2019) found that participation in agricultural field schools, farmer groups, and using superior seeds significantly reduced inefficiency. Having access to finance for farmers and younger farmers can also reduce agricultural inefficiency (Heriqbaldi *et al.,* 2015).

4. Data and methodology

4.1 Data

The main data used in the study is household survey data from the 2014 Indonesian Family Life Survey (IFLS)-5 managed by RAND (2015). The characteristics of rice farm households obtained from IFLS include the number of farmers in each household, the area planted, the use of superior seeds, the location of the province, the use of mobile phones in farming practice, the farmers' years of schooling, the use of tractors, the scale of the rice farm, the age of the farmer, the status of land ownership and irrigation. The sampling carried out at IFLS used the stratified random sampling method by using the province and the regency/city category as the strata. Samples were randomly selected based on these strata. From these secondary data sources, 2120 rice farm household data were obtained.

4.2 Methodology

This study uses the stochastic frontier analysis method with the Cobb Douglas production function which has been widely used to measure Technical Efficiency (TE) in various sectors including agriculture, especially rice production (Battese and Coelli, 1995; Khai and Yabe, 2011; Kompas *et al.,* 2012; Mariyono, 2014a; Heriqbaldi *et al.,* 2015; Pedroso *et al.,* 2017). This method can decompose the catch variation from random noise and inefficiency effects. In addition, the advantage of the stochastic frontier analysis method is its ability to decompose the error term so that it can be separated between technical efficiency and random shock that affects the output.

The basic equation of the rice production function in Indonesia using the stochastic frontier approach is as displayed in equation (1).

$$X_i = f(Z_i\,;\beta) exp\,(v_i - u_i) \tag{1}$$

Where X_i is the amount of rice production i in kilograms, $f(Z_i;\beta)$ is a function consisting of the determinant of the production function, (Z_i) while β is the vector of the unknown parameters which will be estimated by the method stochastic frontier. The v_i is the technical efficiency and u_i is the error term. Furthermore, v_i is assumed to be normally distributed with a zero-mean value with the variant σ^2_v representing other random factors. In addition, u_i is assumed to be truncated normal with mean μ and variance σ^2_u. The use of the truncated normal frontier model based on studies from Stevenson (1980) and the log likelihood function on these different models can be found in Kumbhakar and Lovell (2000).

Equation (2) is the production function model derived from Mariyono (2014a) with minor modifications:

$$\begin{aligned} lnOutput_i = \alpha + \beta_1 lnlabor_i + \beta_2 lnharvestarea_i + \beta_3 superiorseed_i \\ + \beta_4\, provcode_i + v_i - u_i \end{aligned} \tag{2}$$

Where $Output_i$ is the amount of rice produced by each rice farming household *i*, $Inlabor_i$ is the number of labour in each rice farming household *i*, $harvestarea_i$ is the area of the cultivated land of household *i*,

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$superiorseed_i$ is the dummy variable to distinguish the use of superior seeds where the dummy of superior seeds will be worth 1 if the rice farming household uses superior seeds and $provcode_i$ is a province dummy. The v_i is the technical efficiency and u_i is the inefficiency of rice farming in the production function.

The maximum likelihood (ML) method is considered more efficient for estimating parameters from equation (2) (Coelli *et al.*, 2005). Furthermore, according to (Aigner *et al.,* 1977), the ML estimator of

β, σ^2_s and γ are obtained by getting the maximum value of the likelihood function consistent and asymptotically efficient where $\sigma^2_s = \sigma^2_v + \sigma^2_u$ and $\gamma = \frac{\sigma^2_u}{\sigma^2_s}$.

The parameter represents the total variation associated with the specific characteristic of the farmer.

Stochastic Frontier Methodology is based on the assumption that there is a gap between the potential and actual output of a firm (Baten and Kamil 2010). Thus, Coelli *et al.* (2005) reported that technical efficiency can be defined as displayed in equation (3).

$$TE = \frac{\exp(x_i'\beta + v_i - u_i)}{\exp(x_i'\beta + v_i)} = \exp(-u_i) \quad (3)$$

The expected value of TE is between 0 and 1 since TE is a ratio. The rice farming practice is at the most optimum efficiency level if its TE value is equal to one and vice versa.

The model in equation (4) is the inefficiency model, where u_i is the inefficiency in rice farming obtained from equation (2), $phone_i$ is a dummy of whether the farmers use mobile phones in their farming activities, $yearsofschooling_i$ is the farmers' years spent at school or level of education, $tractor_i$ is a dummy of whether the farmers use a tractor in rice farming, $bigfarm_i$ is the dummy of the rice farming scale whether it's a big or small rice farm, age_i is the age of the farmers, $ownland_i$ is a dummy whether the farmers work on their rice fields or rent them, and $irrigation_i$ is a dummy of whether the rice farm is using irrigation.

$$u_i = \lambda_1 phone_i + \lambda_2\, \text{yearsofschooling}_i + \lambda_3 tractor_i + \lambda_4 bigfarm_i + \lambda_5 age_i + \lambda_6 agesquare_i + \lambda_7 ownland_i + \lambda_8\, irrigation_i + \varepsilon_i \quad (4)$$

The model is then processed in STATA 15 software using the frontier package.

5. Results and discussion

5.1 Description of research variables

Table 1 shows that the average amount of rice produced in one harvest time per rice farm household is 833 kg and the number of agricultural workers in each household is an average of 2 people. The average area of harvest area managed by farmers is 4056 m^2. The average length of school for farmers is 9 years for junior high school graduates. The average farmer's age is 41 years old. Farmers in the sample are dominated by small farmers, where 72% of rice farm households own less than 0.5 hectares of land, 24% of their own land between 0.5 to 2 hectares and only 4% of rice farm households own more than 2 hectares of land. Around 73% of farmers cultivate their own land, while the rest rent. The number of rice farm households using superior seeds is 65%. The percentage of rice households that use mobile phones in their farming activities is 19.5% and 6% of the rice farm households use tractors. As many as 53% of rice farm households are located on Java island, 19% on Sumatra island and the rest are scattered on other islands in Indonesia. As much as 50% of the rice farm households sample uses irrigation in rice farming.

5.2 Rice agriculture production function

The model in Equation (2) is used to estimate the parameters of the stochastic production frontier model. Table 2 shows that not all production inputs are statistically significant. Harvest area is significantly positively correlated to rice production, implying that the bigger the size of the harvest area the bigger the output that can be obtained. A 1% increase in the harvest area is significantly correlated with the increase in the rice produced by 0.42%. In addition, superior seeds are also positively and significantly correlated to rice production, suggesting that superior seeds are highly likely enhance rice production. The use of superior seeds in rice farming is positively and significantly correlated to the increase in output by 16% on average. This finding is in line with a study from (Saeri *et al.,* 2019) where the use of superior seeds can encourage an increase in output. However, the number of labourers in one household is not significantly affecting rice production. The possible explanation could be that in Indonesia there is an excess number of workers in the agricultural sector who often become underemployed (World Bank Group, 2020). In addition, stochastic frontier analysis is more appropriate than the ordinary least square (OLS) method because lambda has a positive value and is very different from zero. If the lambda value is equal to zero, then the stochastic frontier analysis results will be the same as OLS (Coelli, 1996).

The average technical efficiency of rice production in Indonesia is found to be 0.59. This finding is almost similar to the results from a study done by Mariyono (2014a) who found that the average technical efficiency of rice production in Indonesia between 1993 and 2013 is 0.62. The value of technical efficiency of rice production in Indonesia is equivalent to Cambodia

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Table 1. Summary of statistics for rice farm household based on IFLS-5 data

Variable	Mean	Standard Deviation
Output (kg)	833.09	1551.05
Number of labour per household (person)	1.84	0.96
Harvest area (m^2)	4056.14	6651.57
Log of output	6.01	1.19
Log of labour	0.50	0.47
Log of harvest area	7.41	1.49
Superior seed	0.65	0.48
Province	37.49	16.74
Mobile phone dummy	0.19	0.40
Years of schooling (year)	8.85	2.52
Tractor dummy	0.06	0.24
Big farm dummy	0.04	0.19
Age (year)	41.02	11.39
Own land dummy	0.73	0.44
Irrigation dummy	0.50	0.50

Source: IFLS-5 database (https://www.rand.org/well-being/social-and-behavioral-policy/data/FLS/IFLS/ifls5.html

Table 2. *Stochastic frontier* model using IFLS-5 data

Variable	Coefficient	Standard error	Z value
Log of labour	-0.064	0.043	-1.510
Log of harvest area	0.423***	0.014	30.090
Superior seed	0.160***	0.043	3.760
Province	0.006***	0.001	4.700
Constant	3.190	0.121	26.380
γ	0.619		
σ^2_u	1.328***		
σ^2_v	0.761***		
λ	1.745***		
Wald Chi2 (4)	1082.530		
Prob>Chi2	0.000		
Number of observations	2120		

Source: IFLS-5 database (https://www.rand.org/well-being/social-and-behavioral-policy/data/FLS/IFLS/ifls5.html), author's calculation

(Mishra *et al.,* 2018) and Iran (Hormozi *et al.,* 2012). This value is still higher than the technical efficiency of rice production in Nigeria (Boubacar *et al.,* 2016), but this result is lower than the technical efficiency in China, which is around 0.8 (Tan *et al.,* 2010), Thailand (Nunti *et al.,* 2019) which ranges from 0.8 and Vietnam (Kompas *et al.,* 2012) which also ranges from 0.8. These both pose challenges as well as an opportunity to improve the technical efficiency of rice farming in Indonesia.

5.3 Mobile phone usage in improving technical efficiency of rice farming

The inefficiency model is presented in Table 3. The use of the mobile phone in farming practice is negatively and significantly correlated to inefficiency. Mobile phone use in rice farming is significantly correlated to the lower inefficiency by 1.84. This finding implies that information and communication accessibility obtained through mobile phone usage is paramount. The average technical efficiency of rice households using mobile phones in the production process is 0.69, which is much higher than the average technical efficiency of rice households that do not use mobile phones, which is only 0.55 as shown in Figure 6. This finding is in line with findings from (Mwalupaso *et al.,* 2020) in maize production, where they found that the technical efficiency of corn farmers who used mobile phones in the farming process was greater than those who did not.

Other factors that have a negative sign in Table 3 are farmers' years of schooling, use of tractors and irrigation. However, only mobile phones, years of

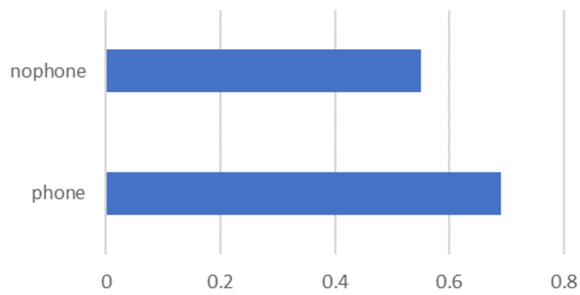

Figure 6. Technical efficiency of farmers in Indonesia based on mobile phone usage

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Table 3. Inefficiency model for rice farmers in Indonesia using IFLS-5 data

Variable	Mean	Standard Deviation
Mobile phone dummy	-1.843***	0.611
Years of Schooling (year)	-0.091*	0.055
Tractor dummy	-45.797	39.745
Big farm dummy	0.303	0.699
Age (year)	-0.019	0.054
Age (year) square	0.000	0.001
Own land dummy	0.641**	0.317
Irrigation dummy	-0.519**	0.248
Constant	-0.640	1.444
Number of observations	2120	

*** p<0.01, **p<0.05, *p<0.1. Source: IFLS-5 database (https://www.rand.org/well-being/social-and-behavioral-policy/data/FLS/IFLS/ifls5.html, author's calculation

schooling and use of irrigation are negatively and significantly correlated to inefficiency. A one-year increase in the year of schooling is significantly correlated to a decrease in inefficiency by 9.1%. This implies that education for farmers is very important. Farmers' education level affects their knowledge and skills and this finding is in line with studies from (Khai and Yabe, 2011; Mariyono, 2014b; Koirala *et al.,* 2016; and Mishra *et al.,* 2018). In addition, the use of irrigation is found to be significantly correlated with a decrease in inefficiency by 0.52. This is in line with findings from (Khai and Yabe, 2011; Laksana and Damayanti, 2013; Mariyono, 2014a; Koirala *et al*., 2016) because rice grown in irrigated rice fields can grow better.

Business scale, age and land ownership have a positive correlation with inefficiency as displayed in Table 3, but only land ownership is statistically significant. Rice farming on the farmers' land is found to be significantly correlated with the increase in inefficiency by 0.64 which implies that farming on rented land would have been more efficient. This finding is consistent with the study done by Boubacar *et al.* (2016). The possible explanation would be that farmers who work on rented land have bigger motivation to obtain optimal output such that they can pay back the rent. Another explanation in the case of renting land, farmers can choose to rent the land that is more fertile which has more potential to produce a greater output. Furthermore, as displayed in Figure 7, Sulawesi is the island with the highest technical efficiency of rice production with a value of 0.73. The possible explanation is that Sulawesi has the highest number of farmers using mobile phones and the highest use of new seeds in Indonesia. While Kalimantan is the region with the lowest estimated technical efficiency of rice production, the possible explanation because only 2% of its rice farms use irrigation.

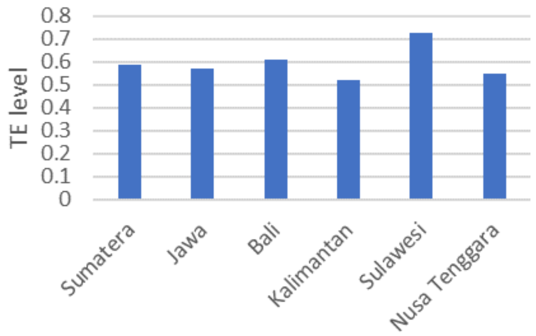

Figure 7. Average technical efficiency (TE) per island in Indonesia

6. Conclusion

Analysis using the stochastic frontier production function shows the technical efficiency of rice production in Indonesia is 0.59, where the size of the harvest area and the use of superior seeds are positively and significantly correlated to the output. A one per cent increase in the harvest area is significantly correlated with the increase in the rice produced by 0.42%. Furthermore, the use of superior seeds in rice farming is positively and significantly correlated to the increase in output by 16%. However, labour does not have a significant effect on the estimated rice output. The possible explanation is that there has already been excess labour in rice farming, so those workers are possibly underemployed

The results of this study suggest that mobile phone usage is significantly correlated to the inefficiency by 1.84. This finding indicates that farmers get the benefit of using mobile phones in rice farming. The possible explanation is that farmers who use mobile phones may obtain better means of communication and information which can support their farming practice. In addition, farmers' level of education is also paramount, an addition of 1 year of schooling is significantly correlated to the decrease in inefficiency by 9.1%. This implies the importance of education to boost farmers' knowledge and learning ability. The use of irrigation was also found to be significantly correlated to the decrease in inefficiency by 0.52. The possible explanation is that rice that is planted in a field with irrigation can grow better. On the opposite, land ownership is found to be significantly correlated to the higher inefficiency by 0.64, suggesting that rented land gives better yields compared to the farmers' owned land. The possible explanation because farmers who rent have bigger motivation to get a high yield such that they can pay their rent. An alternative explanation is farmers who rent have the privilege to choose more fertile land.

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