Technical Efficiency of Smallholder Banana Production: A Case study in Viet Nam

Hoang Van Hung
Hung Yen University of Technology and Education (UTEHY), Hung Yen, Vietnam
Email: Davidhoang8585@gmail.com

Nguyen Van Huong *
Hung Yen University of Technology and Education (UTEHY), Hung Yen, Vietnam
Email: Vanhuong75hy@gmail.com

Le Thi Thuong
Hung Yen University of Technology and Education (UTEHY), Hung Yen, Vietnam
Email: lethuongkt.utehy@gmail.com

Thai Thi Kim Oanh
Vinh University (VU), Vinh City, Vietnam
Email: thaithikimoanhkt@gmail.com

Nguyen Van Chuong
University of Financial – Business Administration (UFBA), Hung Yen, Viet Nam
Email: nguyenchuong.edu@gmail.com

Nguyen Cong Tiep
Viet Nam National University of Agriculture (VNUA), Ha Noi, Viet Nam
Email: nctiep@vnua.edu.vn

Thai Van Ha
Ha Noi University of Business and Technology (HUBT), Vinh Tuy, Hai Ba Trung, Ha Noi
Email: vanha280182@gmail.com

Nguyen Thi Luong
Can Tho University (CTU), Can Tho City, Viet Nam
Email: ntluong@ctu.edu.vn

** Corresponding Author: Vanhuong75hy@gmail.com*

Bananas are considered one of the leading trading crops due to their high demand all over the globe. Since the increasing demand leads to the expansion of global import, the existing literature is in dire need of updating, especially from the producing economies that fall in the category of developing nations. The study, thus, intends to estimate the critical efficiency of said area. Along with it, the study aims to determine the elements of banana production in the context of Vietnam using a stochastic frontier approach and technical efficiency technique. The sample of the study is the province of Vietnam named Hung Yen, and it made sure to collect the data from 160 farmers in 2022. Results of the study reveal that the farmers' technical efficiency fluctuates between the range of 89.68- 97.81%. However, the average technical efficiency of banana farmers was reported to be 95.92%. From the result, it is gauged that factors such as potassium, manure, distance, capital, and training showed positive signs at a 0.01 significance level. Also, the education and area coefficient show a positive sign at a 0.05 significance level. Finally, distance and district variables, which were the dummy variable, show a negative sign at 0.01 and 0.05 significance levels, respectively.

Key words: Technical efficiency, productivity, and Stochastic Frontier Production Function.

1. INTRODUCTION

Bananas are ranked as one of the leading crops, not in agriculture production but also in trading. The reason is the fast population growth of producing economies and the expansion of global import demand. Due to this overall demand, rapid production of banana crops has been observed in recent decades, enhancing the trade volumes. However, getting authentic and concrete on global banana production is difficult as the sector falls in the informal income category, which is also looked after by smallholder farmers. According to the calculated estimates, the world has witnessed a rise in average global banana production, which jumped from 69 million tons (2000-2002) to 115 million tons in 2017-2019. This upsurge endorses approximately 40 billion value in US dollars (FAO, 2019; Kamarudin et al., 2021).

Banana is viewed as an important crop in Vietnam. It unleashes a greater significance for other emerging economies as it helps such nations combat poverty-related issues. The claims are proved by various pieces of evidence piled in literature; one such is Kushtia district, considered one of Bangladesh's leading producers. The evidence reveals that technical and sales efficiency in the Kushtia district is 87% and 97%, respectively, covering both input and output VRS. Moreover, the evidence of Tobit regression reveals that technical efficiency varies due to certain attributes such as farmers' experience, age, education, and firm size. All these elements enhance the efficiency of the farmer in a significant manner. The study thus sheds light on the inefficiencies that could be diminished via training methods, policy interventions and the adaption of improvised agricultural processes. Scholars argued that the sector could minimize underdevelopment (Chien, 2022; Hossain et al., 2018; Lan et al., 2022). As already mentioned, bananas are essential for Hung Yen province and Vietnam in general. However, according to the author's limited knowledge, the literature appears to have limited studies that have done an in-depth analysis regarding assessing the technical efficiency of banana production, particularly in Vietnam.

Regardless of the sector's significance, the banana industry of Vietnam is in trouble, affecting not only the industry's performance but also the livelihood of farmers and the environment. The reason is due to several issues such as low-quality products, the priority of small-scale producers, less productivity, fragmentation of cultivated area and finally, absurd exploitation of pesticides and fertilisers. However, with evidence, it is reported that the said region has the potential to improve its production efficiency.

According to statistics, the planting area of Vietnam in total was 133,000 hectares in 2015, which later increased to 154,200 hectares in 2021. Also, the production of bananas increased from 1981000 tons to 2345900 tons from 2005 to 2021 (VGSF, 2021). However, even with the increase in production, the quality is not up to the mark to compete in the market.

It is argued that resource-based efficiency in agricultural production holds a greater significance and has been one of debate, especially in the context of developing nations. The reason is that, in these regions, most farmers struggle due to the absence of relevant resources. It is argued that the brilliant use of resources provides a pleasant outcome, such as expanding production, which could be further sustainable with farmers' help.

Agricultural production is the series of activities that transforms the raw material and resources into goods/services called output in the economics dictionary. The inputs could be fertilisers, capital, labour, pesticides etc. The ultimate motive for using resources is to optimise output and profit with minimal cost. In such a production process, the farmer must use resources to achieve the goal efficiently. Further, estimation of efficiency offers knowledgeable data that would be helpful for farmers to decide the utilisation of input to produce goods/services. Amongst all, technical efficiency is one of the predominant types. Technical efficiency is the ratio of observed output and maximum output under the conditional situation where fixed inputs are assumed means it is output based. Alternatively, it is also the ratio of minimum input to observed out where it is assumed that the outputs are fixed. Hence, they are input-oriented (Chien et al., 2022; T. J. Coelli et al., 2005; Farrell, 1957).

With this debatable statement, the current study has a specific objective: to estimate the role of resource-based efficiency and identify the critical determinants of banana production by utilising a stochastic frontier approach and technical efficiency technique in Vietnam. Based on technical details, the study thus offers insightful evidence on the methods which could be helpful for farmers to make effective use of resources to produce quality bananas with enhanced production.

As the banana market is competitive all over the globe and there seems to be high production cost involvement, we can say that production efficiency is now viewed as a crucial factor which could shape the banana industry of Vietnam in future, if not neglected and compromised. It is obvious from the earlier debate that either designing or adopting novel production technology is a great asset for the industry as it increases production efficiency. Moreover, the industry with the said gains could have the leverage to maintain its economic viability. In other words, we can say that the total output of said industry may get the chance to be increased without increasing cost production, thus shifting focus towards effective utilisation of available resources and technology. The debate is enough to show the need for study; thereby, the study intends to investigate the efficiency level of banana production at individual and industry both levels. With the evidence, the study sheds light on the unveil determinants which could be of greater use to make the improvements. Also, the association of efficiency level with critical factors provides a better insight that may help restructure the existing policies.

2. METHODOLOGY

2.1 Research Area

Vietnam's Hung Yen province is located in the Red River Delta. The region consists of flat land. Hence there are no mountains or hills. The proportion of agricultural land in this province is approximately 61,037 hectares, with annual crops accounting for 91% of the land. The remainder of the land is devoted to perennial crops, aquaculture water, and other uses. In addition, the province possesses around 7,471 hectares of vacant land, which may be utilised for agricultural purposes.

The province is recognised as one of Vietnam's greatest banana plantation regions. Statistics reveal that this province's total banana area is approximately 2736 hectares and can produce 72798 tons of bananas annually. Khoai Chai, Kim Dong, and Hung Yen are among the cities in the provinces with the most banana acreage and, thus, the highest productivity. According to data from 2021, the area grew to 2736 hectares, of which 2603 hectares were used for banana harvesting (HYSO, 2021).

The three districts and cities of Hung Yen province were chosen for this study. In 2022, 160 farmers were to be selected as the study sample and interviewed. The selection of the sample was based on a stratified sampling methodology. It should be emphasised that the selected banana farms are indicative of the topography of Hung Yen province's banana production regions.

2.2 TE Theory

Technical efficiency, abbreviated as TE, refers to a farmer's capacity to achieve the greatest possible output from a series of inputs and available technology. To conceptualise it, we can say that it measures the difference between farmers' average and best yields and provides the maximum output from the production system. TE is the ratio between the actual output of an operation (Y) and the maximum possible output (Y*) given the available resources and technology. Prior research employed TIE as a substitute for TE and measured it using the formula: TE = 1 - TIE.

Estimating the TE or TIE of farmers in the study site provides numerous crucial data from which alternatives for enhancing farmers' productivity can be derived. There are distinct categories of farmers depending on their variable production operation efficiency. Additionally, some farmers are inefficient at managing production activities. Consequently, these two situations necessitate distinct strategies that enhance farmers' productivity. For example, if farmers have no efficiency to demonstrate in their production system, the tactics/strategy must be heavily focused on those factors that will aid in increasing efficiency. This demonstrates that the factors directly related to inefficient behaviour must be identified, as it would be difficult to address the issue without doing so. In a different scenario, where farmers are already efficient, a different strategy would be required to increase efficiency or maintain it to the extent that would increase productivity. These strategies focus on introducing novel methods or technologies to increase the input level.

There are numerous techniques for measuring TE. However, among numerous approaches, the stochastic frontier model has gained popularity and become one of the most effective models for determining the efficiency of farmers. The technical efficiency model of Sin Tan et al. (2009), which is based on the work of Aigner et al. (1977) and Meeusen et al. (1977), explains the production function as follows:

$Y_i = f(X_i; \beta) \exp(V_i - U_i)$

Where:

- Y_i Represents the output of the i^{th} farm (i = 1, 2, 3,, n);
- X_i is a l x k vector of input quantities applied by the i^{th} farm;
- B is a k x l vector of model parameters to be estimated;
- U_i Represents a non-negative random error term associated with technical inefficiency in production;
- V_i is a random error term assumed to be normally distributed with mean zero and variance σ^2_v, i.e., $V_i \sim N(0, \sigma^2_v)$ and is independent of U_i.

It is to be noted that the model has two kinds of error terms. First is V_i, associated with random effects in the proposed model, whereas, U_i explains the TIE in the production. Authors Sin Tan et al. (2009), following Battese et al. (1995), made this assumption that the second error term is to be distributed independently and contains half-normal distribution with truncation at zero, i.e., $U_i \sim |N(\mu_i, \sigma^2_u)|$.

Along with it, the farm-specific frontier production function (Y*) refers to the maximum possible outcome, which can be seen below:

$Y^*_i = f(x_i; ß) \exp(U_i)$

In the model, the TE of an individual farmer could be predicted based on the conditional expectation of exp $(-U_i)$. Also, the efficiency level depends on the error term. It can be explained in conditional ways, such as if U_i is greater than 0, the production is below the frontier function, showing that the farmer is inefficient. However, in the second condition, if Ui is equal to zero, the production is on frontier function, revealing the farmer's technical efficiency. Figure 1 illustrates the graphical representation of TIE, highlighting the yield difference between best and average farmers, represented by frontier and mean production functions. i^{th} farm of TE is constructed as follows:

$TE_i = Y_i / Y_i^* = \exp(-U_i)$

Also, the variance of the proposed model can be defined as the total sum of variance parameters :

$$\sigma^2 = \sigma_v^2 + \sigma_u^2 \gamma = \sigma_u^2 / \sigma^2$$

The range of γ is from 0 to 1, which depicts the variation of production level from the frontier production function. If γ=1, the deviations occur due to TIE (T. Coelli et al., 1998). Moreover, to find out the possible source of TIE. Technical efficiency can be written as $TE_i = \sigma Z_i$ where Z_i is a l x m vector of farm-specific variables. This might offer help to elaborate on the observed TIE among farms

3. THEORETICAL FRAMEWORK

The figure below explains the paradigm of proposed framework in which the series of IVs that affect banana production are listed.

As stated previously, 16 farmers from three districts in the province of Hung Yen were interviewed. Note that out of 160, 79 were from Khoai Chai district, 40 were from Hung Yen city, and the rest were from Kim Dong.

The descriptives of variables that must be conducted to evaluate the properties of data are displayed in Table 1. The data sample contains several input variables, social indices, etc. The table provides various estimates for the characteristics of banana production, household heads, and farms. The average yield per farmer is 35.27562 tons per hectare. Additionally, the yield per hectare is above average. The entire province's banana yield is 27,97 tons per hectare. Also, average. In terms of person-days, the amount of labour employed was 440.8.

Additionally, the table indicates that a farmer typically spends VND 3,256,875 per hectare on pesticides alone. In addition, the table reveals that the average banana farm size in Hung Yen is approximately 7,562.75 square meters. Table 1 also reveals that the average age of households in the sample ranged from 34 to 78 years, approximately 56 years.

Table 1 also shows that, on average, banana farmers spend nearly 7.887 years in school, which is a third of their secondary education. Additionally, farmers have an average of 10.84375 years of experience with banana farming. The average distance is approximately 1.11 kilometres, as shown in Table 1. In addition, the average. The average household size is 1-6 people, with a total of 2.9625 people per household. This indicates that the majority of farmers have small families.

Regarding seed usage, the average is 2304.672. From a training standpoint, the average number of trainings was 0.44375. This suggests that most banana farmers were unsuccessful in their training programs.

4. EMPIRICAL FINDINGS

4.1 Stochastic Frontier Production Model

As stated previously, the study utilised the stochastic frontier model to ensure the integrity and validity of the data. In addition, the study employed various tests to assess sampling errors and obtain estimates free of bias. To examine multicollinearity, the VIF test was utilised. VIF test is preferred over correlation because it yields conclusive results. The VIF threshold is 10, so a value greater than 10 indicates the presence of problematic multicollinearity. It is evident from the obtained results that multicollinearity is not an issue here. In conclusion, values less than ten indicate that the selected variables are not colinear, establishing the statistical significance of independent variables. In addition, a heteroskedasticity test was conducted, and the results indicate that the proposed model is sound and that there are no outliers in the data.

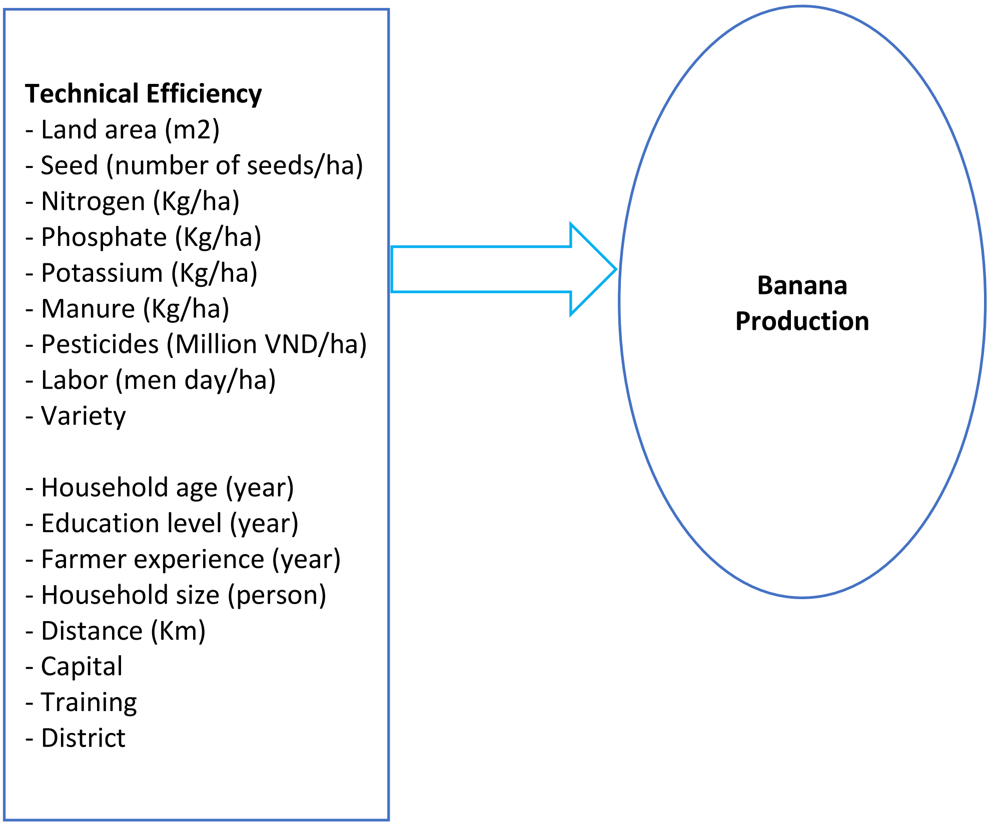

Figure 1. Conceptual Framework

5. Descriptive

Table 1: Description of Variables

Variables	Obs.	Mean	Max	Min	St. Dev.
Banana production characteristics					
Yield (tons)	160	35.27562	48.6	25	5.109244
Seed (number of seeds/ha)	160	2304.672	2777.8	1620.4	194.8955
Nitrogen (Kg/ha)	160	409.7569	880	133.33	175.7098
Phosphate (Kg/ha)	160	525.5399	888.89	139.68	185.0106
Potassium (Kg/ha)	160	182.7301	733.33	44.44	97.45834
Manure (Kg/ha)	160	7192.664	17857.14	0	4795.691
Pesticide (Million VND/ha)	160	3.256875	8.33	0	2.202854
Labor (man/day)	160	440.8658	694.44	187.5	100.8466
Variety	160	0.76875	1	0	0.4229557
Household head characteristics					
Household age (years)	160	55.55625	78	34	8.760795
Education (years)	160	7.887	12	2	2.500283
Experience (years)	160	10.84375	24	3	4.585384
Household size (persons)	160	2.9625	6	1	1.212552
Banana farm characteristics					
Distance (meters)	160	1.11	4	0.2	0.7971017

Land area (ha)	160	0.756275	7.2	0.036	5.109244
Capital (Loan/none)	160	0.36875	1	0	0.4839808
Training (times)	160	0.44375	1	0	0.4983858
District (Khoai Chau/Others)	160	0.49375	1	0	0.5015307

Table 2: Results of Stochastic Frontier Production Estimates

Variable	Coefficient	Std. Err.	Z	VIF
Ln (Area)	**0.0262****	**0.0129**	**2.03**	**1.62**
Ln (Seed)	-0.0267	0.1320	-0.20	1.21
Ln (Nitrogen)	-0.0175	0.0244	-0.72	1.39
Ln (Phosphate)	**0.0780*****	**0.0299**	**2.60**	**1.51**
Ln (Potassium)	0.**0702*****	**0.0258**	**2.72**	**1.69**
Ln (Manure)	**0.0066*****	**0.0018**	**3.50**	**1.08**
Ln (Pesticide)	-0.0099	0.0078	-1.27	1.08
Ln (Labor)	0.0240	0.0437	0.55	1.27
Variety	**-0.0632****	**0.0260**	**-2.43**	**1.23**
Constant	2.951	1.122	2.63	-
Wald chi2	69.57			
Log-likelihood	112.4777			

Note: significant at *** = 1%; ** = 5%, * = 10%
Source: Author's estimation

The study also used the Cobb-Douglas production frontier function, where the coefficient values of the variables might be interpreted as the direct elasticity of the function. Independent constructs elasticity demonstrates the extent to which banana yield can be predicted to alter in response to a change in production inputs. The factors are, phosphate, potassium, and manure are positively correlated with banana yield, as shown in Table 2. All the positive coefficient indications indicate that a 1% increase in each variable will improve banana yield by 2.6%, 7.8%, 7.1%, and 0.1%, respectively. This has a detrimental effect in the case of variety, as the "bisang awak" banana variety planted by farmers is not as productive as other varieties. The results indicate that the area variable favours banana production and is statistically significant at the 5% level. This indicates that the larger the household's land area, the higher the household's banana productivity, and because of the large scale, the farmers produce in a more specialised direction, the household will invest more in machinery and use better technical processes in production, resulting in more efficient production. In addition, households with big production areas will focus more on the care and administration of banana crops, making them more productive than those with smaller production areas.

The favourable impact of phosphate fertiliser on banana yield is statistically significant at 1%. This indicates that households using more phosphate fertilisers will increase banana crops. According to Dung (2021), phosphate fertiliser is crucial throughout the plant's early growth stage. During this stage, phosphorus deficiency significantly affects the output of banana plants. However, a real study indicates that the present average rate of phosphate fertiliser application by research households in the province of Hung Yen is 525.54 kg/hectare, which exceeds the required level for banana cultivation.

In addition to phosphate fertilisers, potassium fertilisers had a 1 per cent significant positive effect on banana yield. Thus, households utilising more potassium fertilisers will have increased yields. Potassium is also vital for yield, according to Nguyen Van Dung et al. The potassium requirements of banana plants are relatively low at the beginning of growth and peak during flowering. Potassium deficiency has a significant impact on banana yield and quality, especially if it occurs during the flowering period. However, banana-growing households consume an average of 182,73 kg of potassium fertiliser per hectare. Farmers fertilise based on their own and other people's experiences, not on a reasonable formula, because the fertiliser norm between different types of fertilisers has not followed a standard. This has a significant impact on the productivity of banana-growing households. Most banana-growing households in Hung Yen province have not received training on properly caring for and distributing fertilisers.

Manure is statistically significant at the 1% level and has a positive relationship with yield, which means that if households increase the amount of manure, productivity will increase. Because manure provides valuable nutrients such as N (Nitrogen), P (Phosphorus), S (Sulfur), and K (Potassium), it provides a variety of significant benefits. These are essential nutrients for the growth of banana plants.

The banana variety has an inverse relationship with banana yield. When households grow a "bisang awak" banana, the yield will be lower than when they grow a cavendish banana. The average yield of the "bisang awak" banana is 34.34 tons/ha, while that of the cavendish banana is 36.86 tons/ha, according to the survey results.

5.1 Technical Efficiency's Frequency Distribution

Based on production frontier function estimation, Table 3 provides a frequency distribution of TE.

As the range of TE for banana farmers is between 89.68% and 97.81%, with a mean of nearly 96%, this demonstrates a substantial variation. The results indicate that the maximum frequency range of TE in the sample of 121 farms is greater than 96%, or 75.625% of the total. 39 farms, or 24.375 per cent, fall within a frequency range of less than 96 per cent.

This demonstrates that the majority of farms meet the TE during production. The findings also indicate that farmers' average TE can potentially reduce costs by 1.96 % if they achieve maximum TE levels. This indicates that the relationship between TE and production cost is inverse. In addition, it is stated that farmers who are not technically efficient could save 8.31% on costs if they become more efficient.

6. EFFICIENCY EFFECTS MODEL

Table 3 Frequency distribution of TE for banana farming

TE (%)	Freq	Cumulative %
89 - 91	3	1.875
92 - 93	3	1.875
94 - 95	33	20.625
96 - 97	114	71.250
> 97	7	4.3750
Total	160	100
Minimum TE (%)	89.68	
Maximum TE (%)	97.81	
Mean TE (%)	95.92	

Table 4: Multiple Regression Estimates of the Sources of TE

Variable	Coefficient	Std. Err.	t	VIF	P
Age	-0.00009	0.00011	-0.83	1.63	0.410
Education	0.00105**	0.00045	2.32	1.66	0.022
Experience	0.00013	0.00016	0.81	1.21	0.418
Household size	0.00056	0.00068	0.82	1.20	0.414
Distance	-0.00355***	0.00120	-2.95	1.18	0.004
Capital	0.00450***	0.00153	2.94	1.15	0.004
Training	0.01393***	0.00161	8.66	1.35	0.000
District	0.00173	0.00196	0.88	1.34	0.380
Constant	0.94820	0.00838	113.11		0.000
Adjusted R^2					0.512
Root MSE					0.010

Note: significant at *** = 1%; ** = 5%, * = 10%

Source: Author's estimation

Examining the variables' signals in the regression model is essential, as it describes the farmers' TE capacity. The beneficial sign of beta coefficients implies that the variables will undoubtedly have a positive effect on the TE of the farms, whilst the negative sign indicates the opposite. The coefficient estimates derived from the TE model indicate that capital training has a positive and statistically significant influence since the coefficient has a positive sign and a significance level of 1%. Education appears to have positive and significant effects as it meets the criterion and demonstrates significance at 5%. In the case of distance, however, the relationship is inverted due to the negative sign. However, 1% is found to be the level of importance. Since education has a positive and significant effect, this explains the conclusive evidence that farmers with a higher level of education behave more effectively. As predicted, the distance variable had a negative effect, which might be explained by the fact that farmers who reside far from banana fields do not exhibit efficient behaviour since the longer it takes to reach the field, the less time they will spend on the field.

Additionally, the travel would damage their energy. In contrast, farmers who live close to their fields have sufficient time and energy to care for them and efficiently use inputs. Consequently, we may assert that distance is significant and could enhance farmers' technological efficiency.

At 1%, the capital variable had a positive correlation with TE. This indicates that farmers with easy access to financing and who can invest as much as possible in banana cultivation may experience larger TE. The findings are rational and consistent with the stated explanation that the more capital farmers have, the more opportunities they have to acquire machinery. In addition, with such a large amount of wealth, they could employ creative approaches. This would allow them to demonstrate their efficiency more tangibly. In addition, borrowing money to produce bananas makes farmers more focused on making investments, resulting in greater productivity.

As anticipated, training had a good effect, which can also be justified. Farmers who have access to training courses will acquire the skills and information necessary to cultivate bananas of standard quality. This implies that their intelligence will be unleashed as a result of their participation in training, as they will gain more information and knowledge about factors such as the effective use of fertilisers, pest control, and planting density. In addition, with a precise education in preservation and harvesting, they will be more creative in applying theoretical knowledge, increasing their technical efficiency relative to others.

7. CONCLUSION AND RECOMMENDATIONS

The study made a modest effort to assess banana production's technical efficiency and identify its determining factors in the Vietnamese context. The Province of Hung Yen served as the study's sample, and stochastic frontier analysis was used. According to the evidence, the average level of technical efficiency in the chosen sample is 95.92%, indicating that farmers can achieve maximum output at minimal cost by utilising existing technology effectively. In addition, it is evident from the results that there is room for technological improvement in the given sample, which indicates that production can be increased further if inputs are utilised efficiently.

The increase in banana yield also depends on the quantity of land, nitrogen, phosphate, potassium, manure fertilisers, labour, and cultivar. As farm inputs are essential for increasing banana yield, additional policies must be implemented to increase the proportion of land, labor, fertiliser, and new variety investments.

In addition, the findings reveal that demographic and socioeconomic factors, such as experience, education, capital, and specific training, will be useful in maximising the technical efficiency of banana production in the selected sample. As a result, it is suggested that government institutions encourage farmers to educate themselves through workshops and short training courses, as this may increase their technical efficacy. In addition, it would be beneficial to educate farmers on the need for loans, which would improve the situation.

8. ACKNOWLEDGMENT

This research is funded by Hung Yen University of Technology and Education, Vietnam, under grant number UTEHY.L.2022.05.

REFERENCES

Aigner, D., Lovell, C. K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics, 6*(1), 21-37. doi: https://doi.org/10.1016/0304-4076(77)90052-5

Battese, G. E., & Coelli, T. J. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics, 20*(2), 325-332. doi: https://doi.org/10.1007/BF01205442

Chien, F. (2022). The mediating role of energy efficiency on the relationship between sharing economy benefits and sustainable development goals (Case of China). *Journal of Innovation & Knowledge, 7*(4), 100270. doi: https://doi.org/10.1016/j.jik.2022.100270

Chien, F., Hsu, C.-C., Sibghatullah, A., Hieu, V. M., Phan, T. T. H., & Hoang Tien, N. (2022). The role of technological innovation and cleaner energy towards the environment in ASEAN countries: proposing a policy for sustainable development goals. *Economic Research-Ekonomska Istraživanja, 35*(1), 4677-4692. doi: https://doi.org/10.1080/1331677X.2021.2016463

Coelli, T., Rao, D. P., & Battese, G. (1998). An Introduction to Efficiency and Productivity Analysis", Kluwer Academic Publishers, Boston. In: DordrechtiLondon. Retrieved from https://link.springer.com/book/10.1007/978-1-4615-5493-6.

Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., & Battese, G. E. (2005). *An introduction to efficiency and productivity analysis*: springer science & business media. Retrieved from https://books.google.ae/books?hl=en&lr=&id=V2Rpu8M6RhwC&oi=fnd&pg=PA1&dq=Coelli

Dung, N. V. (2021). Technical guidance manual for banana cultivation suitable for climate change. Agricultural publisher.

FAO. (2019). FAOSTAT Agriculture Data.

Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society: Series A (General), 120*(3), 253-281. doi: https://doi.org/10.2307/2343100

Hossain, M. M., & Majumder, A. K. (2018). Analysis of Factors Affecting the Technical Efficiency: A Case Study. *International Journal of Economics and Statistics, 6*, 10-13. Retrieved from https://d1wqtxts1xzle7.cloudfront.net/56785359/a062015-017

HYSO. (2021). Hung Yen Statistic Office.

Kamarudin, F., Anwar, N. A. M., Chien, F., & Sadiq, M. (2021). Efficiency of Microfinance Institutions and Economic Freedom Nexus: Empirical Evidence from Four Selected Asian Countries. *Transformations in Business & Economics, 20*(2B), 845-868. Retrieved from https://web.p.ebscohost.com/abstract?direct=true&profile=ehost&scope=site&authtype=crawler&jrnl

Lan, J., Khan, S. U., Sadiq, M., Chien, F., & Baloch, Z. A. (2022). Evaluating energy poverty and its effects using multi-dimensional based DEA-like mathematical composite indicator approach: Findings from Asia. *Energy Policy, 165*, 112933. doi: https://doi.org/10.1016/j.enpol.2022.112933

Meeusen, W., & van Den Broeck, J. (1977). Efficiency estimation from Cobb-Douglas production functions with composed error. *International Economic Review, 18*(2), 435-444. doi: https://doi.org/10.2307/2525757

Sin Tan, K., Choy Chong, S., Lin, B., & Cyril Eze, U. (2009). Internet-based ICT adoption: evidence from Malaysian SMEs. *Industrial Management & Data Systems, 109*(2), 224-244. doi: https://doi.org/10.1108/02635570910930118

VGSF. (2021). Vietnam General Statistic Office.