Annals of Biology **39** (2) : 292-297, 2023

**Impact Score : 0.32 (Scopus)**

# Technical Efficiency Analysis of Local Garlic (*Allium sativum* L.) Production in Karanganyar Regency, Indonesia

ISNAINI ROHMAWATI*, MASYHURI[1] AND ANY SURYANTINI[1]

*Department of Agricultural Economics, Graduate School, Faculty of Agriculture, Universitas Gadjah Mada (UGM), Bulaksumur, Caturtunggal, Depok, Sleman, 55281, Yogyakarta, Indonesia*
**(e-mail: isnaini.rohmawati@mail.ugm.ac.id; Mobile: 628 78154 26682)*

(Received: January 8, 2023; Accepted: February 14, 2023)

**ABSTRACT**

Garlic (*Allium sativum* L.) is the primary horticultural commodity in Indonesians. Production efficiency is one of the critical factors of garlic farming in productivity. This study was aimed at analyzing technical efficiency and assessing technical inefficiency. The analysis used maximum likelihood estimation, and the stochastic production frontier model's parameters were estimated using the Frontier 4.1 version computer program. The results showed that the average value of technical efficiency was 0.727. Moreover, the results of the one-sample t-test for garlic farming showed 0.022 < 0.05. The results of maximum likelihood estimation showed that technical inefficiency could explain the social factors of garlic farming which affected optimal productivity.

**Key words:** Garlic, technical efficiency, inefficiency, stochastic frontier

## INTRODUCTION

Garlic *(Allium sativum* L.) is essential for human nutrition and economic benefit in Indonesia. Garlic productivity is significantly lower than it should be. The productivity of local garlic is 8-12 tonnes per hectare. Consumption of garlic is very high in Indonesia, both on a household and industrial scale. Domestic garlic production needs to cover the demand for public consumption. Indonesia has the potential for environmental topography suitable for garlic cultivation, which can maximize support for food security, specifically by increasing the efficiency of garlic farming. Garlic has a history of human use of over 7.000 years, and it is the essential bulb crop. Garlic has been used throughout recorded history for both medicinal and culinary purposes. It is used to flavour dishes, pickles and sauces. During COVID-19 Pandemic, the demand for garlic products and prices increased. As far as the researcher's field observation, more than 90% of garlic producers used local seed varieties (Wubet and Region, 2022). Based on the analysis of costs and financial benefits (private) garlic farming both in the dry and high lands in Indonesia is still profitable, most of which is only cultivated in the dry season, such as in Karanganyar, Central Java, etc. (Saptana *et al.*, 2021). The average value of a farmer's technical efficiency in Temanggung Regency is 0.811. It means that respondents in this study have been technically efficient. The socio-economic factors affecting technical inefficiency are age, the number of workers in a family, the level of education, and the participation rate within the farmer group. The technical efficiency of garlic farming can be improved by optimizing the farmer group's contribution as a facility to access information (Wardani and Darwanto, 2018).

Increasing garlic production is a priority to address dependence on imported garlic supply. It is challenging to increase garlic production by extending the area of land under cultivation, but garlic consumption needs to continue to increase as the population increases. In 2021, total production was 25544.6 tonnes from 3.875 thousand hectares of garlic. Between 2012 and 2021, garlic production fluctuated by 6.47%, and garlic cultivated area increased by 7.90% (BPS, 2022). In order to fill the gap, a study was conducted to estimate the technical efficiency of increasing the productivity of local garlic.

FAO data for 2021, Indonesia ranks first for the largest garlic importing country in ASEAN, with an average volume of imported garlic of

[1]Department of Agricultural Economics, Faculty of Agriculture, Universitas Gadjah Mada (UGM), Bulaksumur, Caturtunggal, Depok, Sleman, 55281, Yogyakarta, Indonesia.

509.62 thousand tonnes. The productivity of local garlic is 8-12 tonnes per hectare, while the productivity of imported garlic reaches 25 tonnes per hectare so it is necessary to increase garlic productivity. Based on the observations, farmers need to be more efficient in using factors of production in farming.

In the narrow sense, agricultural production efficiency measures the utilization efficiency of the input resources by the planting industry; it is essential to take agricultural production efficiency. The basis of production efficiency measurement is factor input and output to increase agricultural production efficiency leading to higher yields in farming (Zhu and Huo, 2022). The research on the efficiency of garlic production is to increase productivity for garlic demand. The strategy to increase production by increasing farming efficiency has the potential in garlic. This study was aimed at analyzing the technical efficiency in garlic production of small holder farmers and analyzing the factors that influenced the technical inefficiency of garlic farmers in the Karanganyar Regency, Indonesia.

## MATERIALS AND METHODS

The sample in this study was garlic farmers of the Karanganyar Regency, one of the centers of Indonesian garlic production. The research location was at an altitude of more than 600 masl. The research was located at Kalisoro village of Tawangmangu district, Segoro Gunung village of Ngargoyoso district and Wonorejo village of Jatiyoso district in Karanganyar Regency, Central Java, Indonesia. The research data were collected based on a questionnaire, which were collected by interviewing the farmers of the garlic crop in the district for the 2022 agricultural season. Respondent garlic producers were selected using a snowball sampling technique to select 90 farmers.

The data used in this study were primary data, consisting of the socio-economic conditions of the respondents and the use of production inputs. This research used descriptive and quantitative statistical data to estimate garlic production function using the SPSS package and analysis using the statistical and econometrics measures. Stochastic frontier analysis (SFA) is a parametric method to estimate technical efficiency and inefficiency levels. The stochastic frontier production function is as follows: $Y_i = f(X_i; \beta) + e_i$,

Where, $Y_i$ was the average garlic production of the $i^{th}$ farmer, $X_i$ was the use of production factor i, $\beta$ was function parameters and $e_i$ was the coefficient of random error. The function was linear or logarithmic. The form that had the best fit included 10 independent variables for garlic technical efficiency as:

$$\begin{aligned}\text{Ln } Y = \text{Ln } \beta_0 + \beta_1 \text{Ln } X_1 + \beta_2 \text{Ln } X_2 + \beta_3 \text{Ln } X_3 \\ + \beta_4 \text{Ln } X_4 + \beta_5 \text{Ln } X_5 + \beta_6 \text{Ln } X_6 + \beta_7 \text{Ln } X_7 \\ + \beta_8 \text{Ln } X_8 + \beta_9 \text{Ln } X_9 + \beta_{10} \text{Ln } X_{10} + (V_i - U_i)\end{aligned}$$

Where, Y was the production size of garlic (kg), $X_1$ was the total of garlic cultivated land (ha), $X_2$ was the number of seeds (kg/ha), $X_3$ was farm labour (person-days), $X_4$ was the quantity of organic manure (kg), $X_5$ was the number of urea fertilizers (kg), $X_6$ was the quantity of SP-36 fertilizers (kg), $X_7$ was the quantity of ZA fertilizers (kg), $X_8$ was the quantity of NPK fertilizers (kg), $X_9$ was the number of solid pesticides (kg) and $X_{10}$ was the number of liquid pesticides (liters). The technical inefficiency of the garlic production model was:

$$\begin{aligned}\mu i = \delta_0 + \delta_1 \ln Z_1 + \delta_2 \ln Z_2 + \delta_3 \ln Z_3 + \delta_4 \ln \\ Z_4 + \delta_5 D_1 + \delta_6 D_2 + \delta_7 D_3\end{aligned}$$

Where, $\mu_i$ was technical inefficiency level (0-1), ln was the natural logarithm, $\delta_n$ was parameter coefficient of the estimated variable, $Z_1$ was the age of garlic farmer (year), $Z_2$ was the education level (year), $Z_3$ was the farming experience (year), $Z_4$ was the frequency of attending counseling (times), $Z_5$ was the dummy land ownership (D=1 own, D= 0 not own), $Z_6$ was the dummy use of superior varieties (D = 1 superior variety/ Tawangmangu Baru, D = 0 not superior variety) and $Z_7$ was the dummy slope (D = 1 sloping land, D = 0 not sloping land).

Technical measurement of garlic production efficiency was measured using:

$$TE = \frac{Y_i}{Y_i} = \frac{\exp(X_i\beta + V_i - U_i)}{\exp(X_i\beta + V_i)}$$

Where, $Y_i$ was actual garlic production from observations, and $Y_i$* was potential production estimation from stochastic frontier functions. TE took the value on the interval (0-1).

Technical efficiency had a value opposite of the effect of technical inefficiency.

## RESULTS AND DISCUSSION

Technical efficiency is vital for small garlic farmers with small income. Farmers' characteristics were essential and influenced garlic farming activities. The production function showed the relation between the economic variables used in garlic production. The farming socio-economic factors were: farm size reaching about 0.1106 ha, and the mean output was 0.974 tonnes, so the average output of respondent farmers was 8.80 tonnes/ha. The average farm labour was 46.02 (person-days) during one garlic planting season, from processing the land until it was harvested and the family labour was employed (Table 1).

The average organic fertilizers used by garlic farmers in Karanganyar Regency were 5974.8 (t/ha); types were chicken manure and rabbit manure. The chemical fertilizer used by garlic farmers in the Karanganyar district was urea (218 t/ha), SP-36 (193 t/ha), ZA (194 t/ha) and NPK (147 t/ha). Fertilizer application was also in line with Jiku *et al.* (2020), which suggested that garlic yield increased with increasing potassium fertilizer, where K application at 200 kg/ha was suitable for obtaining maximum yield.

**Table 1.** Characteristics of garlic farmers sample in Karanganyar Regency

| Variables | | | Mean |
|---|---|---|---|
| Production size of garlic (t) | | | 0.974 |
| Farm size (ha) | | | 0.1106 |
| Farm labour (person days) | | | 46.02 |
| Organic manure (kg) | | | 597.48 |
| Urea fertilizers (kg) | | | 21.80 |
| SP-36 fertilizers (kg) | | | 19.36 |
| ZA fertilizers (kg) | | | 19.41 |
| NPK fertilizers (kg) | | | 14.76 |
| Solid pesticides (kg) | | | 1.03 |
| Liquid pesticides (liter) | | | 1.01 |
| Age of garlic farmer (year) | | | 49.62 |
| Level of education (year) | | | 8.13 |
| Farming experience (year) | | | 17.86 |
| Frequency of attending counseling (times) | | | 2.62 |
| Land ownership | Dummy | Sum | Per cent |
| | 1 = Yes | 80 | 88.8 |
| | 0 = No | 10 | 11.1 |
| The use of superior varieties | 1 = Yes | 55 | 61.1 |
| | 0 = No | 35 | 38.8 |
| Land slope | 1 = Yes | 54 | 60.0 |
| | 0 = No | 36 | 40.0 |

*Source*: Field Survey Data, 2022.

The farmer management of production systems used liquid and solid pesticides to protect garlic plants from pests and diseases. The average age of onion producers was 49.62 years. Level of education: an average of the demo farmer's 8.13 years was equivalent to junior high school graduates. The farming experience of the onion producer of 17.86 years improved the farmer's skill for garlic production. Farmer frequency of attending counseling from farmers group was just 2-3 times a year. Owned lands were dominant (84%) in Karanganyar Regency. The garlic farmers owned ancestral land given by their parents. The land occupied the highest output elasticity, indicating that it was the main factor of production (Koye *et al.,* 2022).

The superior garlic variety in this study was the Tawangmangu Baru, a local variety from Karanganyar Regency. Based on the decision of the Indonesian Minister of Agriculture number 771/Kpts/TP.240/11/1989. The morphology of the Tawangmangu Baru variety was plant age 120-140 days, productivity 8-12 t/ha, having bluish green leaf and 8-10 leaves per plant. Garlic had the shape of an ovoid bulb. Based on the research a total of 61.1% planted best variety. The majority of garlic farmers' land had slopes (60%), according to the topography of the research site in the Lawu mountain area. According to Wubie and Mohammed (2020), the land's slope affected the soil content's density. The total porosity of the soil increased with decreasing slope. A higher total porosity made the soil workable for favourable plant root conditions.

The factors affecting the technical efficiency of garlic production are given in Table 2. A sigma-square $\sigma^2$ value (0.076) and significance at 0.01 indicated a normally distributed error term, indicating a good fit and correctness of the given distributional assumption of the composite error term. The gamma ($\gamma$) value was (0.999) and significance at 0.01 showed 99.9%, which was the residual variation caused by technical inefficiencies deviation by random variables. The LR test value of the one-sided error was 84.133, and the value of the number of restrictions was 1. The LR test value of the one-sided error was greater than the mixed chi-square distribution value. The stochastic frontier production function ($X^2_R$) ($\alpha = 0.05$, 1) = 2.706 (listed in the upper and lower bound table for the critical value for jointly testing equality

and inequality restrictions). This result meant that the stochastic frontier production function could explain production inefficiencies. The results of the stochastic frontier production analysis function (SFPF) are given in Table 2. The farm size had a significant adverse effect on technical efficiency levels. This opinion also aligned with Sui *et al.* (2022) that the degree of arable land fragmentation had negative impacts on farmers' arable land input behaviour. The farm size negatively impacted scale efficiency and could be more conducive to improve farmers technical production efficiency. The seeds, labour and NPK fertilizers had a significant positive effect on the technical efficiency of garlic production (Table 3).

The findings showed that technically efficient garlic farming in Karanganyar Regency ranged between 0.39-0.88, with the average efficiency number of 0.727. Technical efficiency of 72.70% indicated that most garlic farmers could produce 72.70% of the total production inputs. The majority of garlic farmers had technical efficiencies that were between 0.71 and 0.80. The estimation results showed that 61.2% of garlic farmers had a technical efficiency value of 0.71-0.90, according to the respondents who were concentrated in the technical efficiency ranges. Figs. 1 and 2 show each farmer's boxplot and distribution of technical efficiency values.

**Table 3.** Distribution of technical efficiency values of garlic producers

| Technical efficiency level | Frequency | Per cent |
|---|---|---|
| 0.39 - 0.60 | 13 | 14.4 |
| 0.61 - 0.70 | 24 | 24.4 |
| 0.71 - 0.80 | 32 | 35.6 |
| 0.81 - 0.90 | 23 | 25.6 |
| Total | 90 | 100 |
| Minimum | 0.394 | |
| Maximum | 0.889 | |
| Mean | 0.727 | |

*Source*: Field Survey Data, 2022.

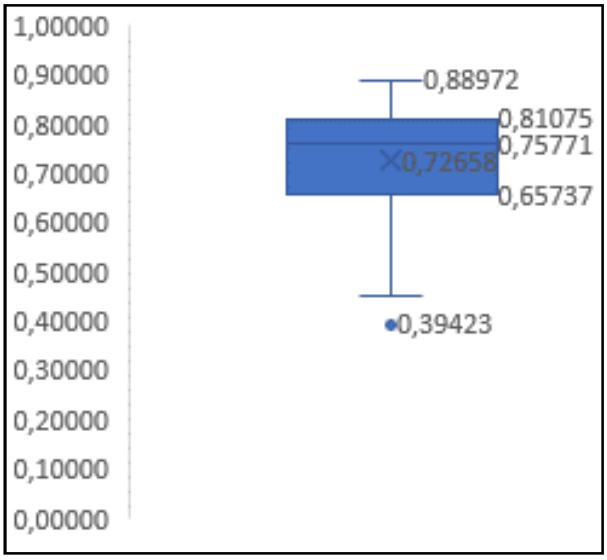


Fig. 1. Technical efficiency boxplot based on garlic farming.

**Table 2.** Estimates of the stochastic frontier production function in garlic

| Variables | Science expectations | Coefficient | Std. error | T-ratio |
|---|---|---|---|---|
| Constant | +/- | 0.375*** | 0.854 | -4.391 |
| Farm size ($X_1$) | + | -0.105*** | 0.848 | -12.450 |
| Seeds ($X_2$) | + | 0.760*** | 0.238 | 3.193 |
| Labour ($X_3$) | + | 0.757*** | 0.244 | 3.091 |
| Organic manure ($X_4$) | + | 0.212 | 0.250 | 0.848 |
| Urea fertilizers ($X_5$) | + | -0.279 | 0.244 | -1.143 |
| SP-36 fertilizers ($X_6$) | + | 0.106 | 0.223 | 0.447 |
| ZA fertilizers ($X_7$) | + | 0.656 | 0.230 | 0.284 |
| NPK fertilizers ($X_8$) | + | 0.850*** | 0.252 | 3.369 |
| Solid pesticides ($X_9$) | + | 0.926 | 0.647 | 1.431 |
| Liquid pesticides ($X_{10}$) | + | 0.466 | 0.461 | 10010 |
| Sigma-squared | | 0.076*** | 0.020 | 3.678 |
| Gamma | | 0.999*** | 0.003 | 287.845 |
| Log-likelihood function OLS | | 33.347 | | |
| Log-likelihood function MLE | | 42.100 | | |
| LR test of the one-sided error | | 84.133 | | |
| Number of restrictions | | 1 | | |

*Source*: Field Survey Data, 2022
***Mean significance at the 1% level.

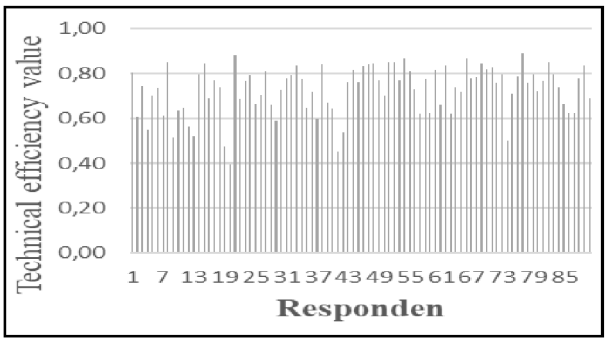


Fig. 2. Distribution of the technical efficiency value.

The majority of garlic farmers had more efficiency, below the average value (0.727) of 60.4% and above the average value of 39.6%. Based on the one sample t-test technical efficiency of garlic farming in Karanganyar Regency, the value of 0.022 < 0.05 rejected H0. The test result indicated that garlic production in Karanganyar Regency was not technically efficient.

The average technical efficiency was 72.70%, so the produced garlic typically suffered 27.30% output potential loss due to technical inefficiency. The results of maximum likelihood estimation can explain the social factors of farming that affect optimal productivity (Table 4).

The levels of education and farming experience had a significant and positive effect on technical inefficiency. With higher education and the experience of farmers, the value of technical inefficiency will increase. The opposite result (Wijayanti *et al.*, 2020), with a negative value in formal education, showed that higher education owned by farmers produced less technical inefficiency. The farmer age, superior dummy varieties and land slope dummy negatively affected technical inefficiency. Farm size had a significant adverse effect on technical inefficiency levels. According to Maniriho *et al.* (2020), education and household size affected technical efficiency positively and significantly, while age, experience, extension and credit access affected negatively but significantly.

The actual output value of garlic and predictions from the technical efficiency value showed that the average difference in yield of garlic was 3.75 kg/ha, with an average value of actual and potential products of 9.7 and 13.49 kg/ha, respectively (Table 5). This result showed that the average garlic production in Karanganyar Regency was 3.75 kg/ha less than their yield potential, so there are opportunities to increase garlic activation by farming practices in Karanganyar Regency. According to Mina *et al.* (2021), the average garlic production in the province of Occidental Mindoro, Philippines, can be increased from 3.40 to 4.15 mt/ha, and this potential yield is still relatively low compared to the 6.50 mt/ha.

**Table 4.** Stochastic frontier model estimates for the inefficiency influencing factors

| Variables | Science expectations | Coefficient | Std. error | T-ratio |
|---|---|---|---|---|
| Constant | +/- | 0.423** | 0.221 | 1.907 |
| Farmer age ($Z_1$) | +/- | -0.941*** | 0.212 | 4.421 |
| Level of education ($Z_2$) | - | 0.123*** | 0.491 | 2.502 |
| Farming experience ($Z_3$) | - | 0.114** | 0.593 | 1.922 |
| Frequency of counseling ($Z_4$) | - | 0.136 | 0.403 | 0.337 |
| Dummy land ownership ($D_1$) | +/- | 0.488 | 0.712 | 0.685 |
| Dummy superior variety ($D_2$) | - | -0.586*** | 0.162 | -3.617 |
| Dummy land slope ($D_3$) | - | -0.758*** | 0.252 | -3.007 |

**, ***Significance at the 5 and 1% levels, respectively.

**Table 5.** Garlic production gap due to technical inefficiency

| Variables | Minimal | Maximal | Mean | Std. deviation |
|---|---|---|---|---|
| Actual production (kg/ha) | 5.71 | 14.60 | 9.7 | 1.5434 |
| Technical efficiency estimates | 0.39 | 0.88 | 0.73 | 0.1078 |
| Potential/frontier production (kg/ha) | 8.30 | 18.11 | 13.49 | 1.9109 |
| Production gap/loss (kg/ha) | 1.40 | 9.93 | 3.75 | 1.8443 |

*Source*: Field Survey Data, 2022.

## CONCLUSION

Garlic is the major horticultural commodity for Indonesian. However, local garlic production does not cover domestic consumption; consequently, increasing the area of garlic planting and farming efficiency is the goal. The technical efficiency value of garlic farmers varies between 0.394-0.889 with average value of technical efficiency as 0.727. Moreover, the results of the one-sample t-test showed that the technical efficiency of garlic farming in Karanganyar Regency was 0.022 <0.05. The garlic farming in Karanganyar Regency was not technically efficient. The results of maximum likelihood estimation showed that technical inefficiency explained the social factors of farming that affect optimal productivity. Factors that reduced the technical inefficiency of garlic farming in Karanganyar Regency were the farmer's age, the use of superior varieties and the slope of the land. Garlic farmers were not fully efficient, so they reduced costs and the number of input factors that had no significant effect on increasing production. The Ministry of Agriculture should set policies for expanding production by increasing efficiency.

## REFERENCES

Central Bureau of Statistics (BPS) (2022). Production of vegetable plants (garlic). Jakarta, Indonesia. https://www.bps.go.id/indicator/55/61/1/produksi-tanaman-sayuran.html (accessed on 13 October 2022).

Jiku, M. A. S., Alimuzzaman, M., Singha, A., Rahaman, M. A., Ganapati, R. K., Alam, M. A. and Sinha, S. R. (2020). Response and productivity of garlic (*Allium sativum* L.) by different levels of potassium fertilizer in farm soils. *Bull. Natl. Res. Cent.* **44**. *https://doi.org/10.1186/s42269-020-0267-7.*

Koye, T. D., Koye, A. D. and Amsalu, Z. A. (2022). Analysis of technical efficiency of irrigated onion (*Allium cepa* L.) production in North Gondar Zone of Amhara regional state, Ethiopia. *PLoS ONE* **17**: e0275177. *https://doi.org/10.1371/journal.pone.0275177.*

Maniriho, A., Musabanganji, E. and Lebailly, P. (2020). Analysis of economic efficiency of small-scale onion production in Volcanic Highlands in Rwanda. *Montenegrin J. Econ.* **16**: 185-196.

Mina, C. S., Catelob, S. P. and Jimenezb, D. C. (2021). Productivity and competitiveness of garlic production in Pasuquin, Ilocos Norte, Philippines. *Asian J. Agric. Develop.* **18**: 49-63. *https://doi.org/10.37801/ajad2021.18.1.4.*

Miraj, N. and Shahid, A. (2014). Estimation of technical efficiency of garlic farms in district Peshawar, Pakistan: A stochastic frontier analysis. *Int. J. Innov. Scien. Res.* **9**: 140-149.

Saptana, Atika, D. P. and Syahrul, G. S. (2021). Analysis of garlic commodity competitiveness and impact of government policy in Indonesia. *E3S Web of Conferences* **316**: 02016. *https://doi.org/10.1051/e3sconf/202131602016.*

Sui, F., Yang, Y. and Zhao, S. (2022). What affects the production technology of labour-intensive agricultural industries in the context of labour aging? An empirical study based on the garlic production in lanling. *Sustain.* **14**. *https://doi.org/10.3390/su14010048.*

Wardani, A. N. T. and Darwanto, D. H (2018). The impact of GAP Sop on The production and technical efficiency of garlic in Temanggung Regency. *Agro. Ekonomi.* **29**: 299-309.

Wijayanti, I. K. A., Jamhari, J., Darwanto, D. H. and Suryantini, A. (2020). Stochastic frontier analysis on technical efficiency of strawberry farming in Purbalingga Regency Indonesia. *Jurnal Teknosains* **9**: 105-115.

Wubie, M. A. and Mohammed, A. (2020). Effects of land cover changes and slope gradient on soil quality in the Gumara watershed, Lake Tana basin of North-West Ethiopia. *J. Model. Earth Syst. Environ.* **6**: 85-97.

Wubet, G. K. and Region, Z. A. (2022). Value chain analysis of garlic in Libo Kemkem district: In the era of COVID-19, South Gondar Zone Amhara Region, Ethiopia Value chain analysis of Garlic in Li boKemkem District : In the era of COVID-19, South Gondar. *Cogent Bus. Manag.* **9**. *https://doi.org/10.1080/23311975.2022.2076298.*

Zhu, Y. and Huo, C. (2022). The impact of agricultural production efficiency on agricultural carbon emissions in China. *Energies* **15**: 4464. *https://doi.org/10.3390/en15124464.*