Volume XIII Number 3, 2021

# An Analysis of Technical Efficiency of Vegetables' Household Production in Mongolia

Amar Uuld[1], Robert Magda[2], Yuriy Bilan[3]

[1] Doctoral School of Management and Business Administration, Szent Istvan University, Hungary

[2] Faculty of Economic and Social Sciences, Szent Istvan University, Hungary; North-West University, South Africa

[3] Alexander Dubcek University of Trencin, Slovakia; Sumy State University, Sumy, Ukraine

## Abstract

Vegetable production is one important agricultural product in crop production after wheat and potatoes production in Mongolia. Currently, household production dominates in total vegetable production (approximately 80 percent). Thus, the purposes of this paper were to measure technical efficiency and to determine influencing factors inefficiency on vegetable household production in Mongolia by using Stochastic production frontier analysis (SFA). Primary data was collected from randomly selected 260 vegetable households of Mongolia in 2019. The empirical result indicated that the average technical efficiency of the sampled vegetable household was 64.6 % (range between 43.2% and 99.9%) or they lost about 35.4% of the potential output due to technical inefficiency. We found that land and labor are the main influencing input factors of the household's vegetable production. Also, the result of the technical inefficiency model, variables of age, sex, experience, and credit use obtained a negative relationship with inefficiency. The other variables are family size, education level, land fragmentation index was positively affected by technical inefficiency.

## Keywords

Vegetable production, technical efficiency, stochastic frontier analysis, determinants of technical inefficiency.

Uuld, A., Magda, R. and Bilan, Y. (2021) "An Analysis of Technical Efficiency of Vegetables' Household Production in Mongolia", *AGRIS on-line Papers in Economics and Informatics*, Vol. 13, No. 3, pp. 101-111. ISSN 1804-1930. DOI 10.7160/aol.2021.130310.

## Introduction

Agriculture is a traditional sector of Mongolia and it is still a dominant role in its economy. It contributed to 10.9 % of GDP and employed 25.6 % of the total workforce in 2019 (National Statistics office of Mongolia, 2019). Also, it has been providing food for the population and raw materials for manufacturing industries. The agriculture sector is divided into livestock and crop production. The livestock sector accounts for approximately 89 % of agricultural production, while the remaining 11 % accounts from the crop sector (National Statistics Office of Mongolia, 2018). Although crop production contributed a small share of the agriculture sector, it has been the main condition to supply the population with safety and quality food. Mongolia has a vast land area but arable land is only 0.4 % of total land. For example, in 2019, the total sown area was 526.1 thousand hectares (0.3 % of the total land) that were accounted 65.3 percent for wheat, barley, rye and oats, 2.8 % for potato, 1.6 % for vegetables and the remaining area for fodder crops, technical crops and medical crops (National Statistics Office of Mongolia, 2019).

Since 1959, the crop sector started to develop in Mongolia. In 1989, a total of arable land was 1.38 a million hectares, which was the peak point for the crop sector. After shifted to political and economic transition in 1990, the total sown area had been dropped to 189.5 thousand hectares until 2005. Mongolian Government started to pay attention to this situation and implemented the 3$^{rd}$ Land Rehabilitation Programme between 2008 and 2010. As a result, the total sown area increased to a fully supplied level for wheat, potato demand, and approximately 50 % supplied for vegetable demand. Since 2016, the Mongolian government has started to implement some national subprograms namely, "Mongolian vegetable" and "Mongolian fruit" to increasing domestic production of vegetables and fruit (Ministry of food and Agriculture, 2017).

The national average monthly vegetable consumption was very low level which is expressed that 6 times and 3.5 times below from daily intake by recommended World Health Organization (WHO) and the Ministry of the Health of Mongolia (former name) respectively. Therefore, Mongolia has one of the highest incidences of cardiovascular disease (rank was #14 in the world), which is also the country's leading cause of death. One of the main reasons is lower fruit and vegetable consumption to increase the risk of noncommunicable diseases. It is evidenced that Mongolian people do not use to not too many vegetables every daily diet. For example, according to statistics, 2019, national average monthly vegetable consumption was only 2.1 kg (National Statistics Office of Mongolia, 2019).

In Mongolia, there are planting a few varieties of vegetables due to the climatic extreme condition such as cabbage, carrots, turnips, onions, garlic, cucumber, tomatoes, watermelon, and a small number of peppers, beet, etc. In 2018, total vegetable production was 100.7 thousand tons, the Central and Western regions constituted 81.3% of its and while the remaining 18.7% accounted East, Khangai and Ulaanbaatar regions. Therefore, Selenge, Darkhan-Uul, Tuv (Central region), and Khovd (Western region) are four main growing areas of vegetable production composition with a share of 34.4%, 15.9%, 11.6%, and 11.4%, respectively (National Statistics Office of Mongolia, 2018). Also, the households' production dominates in vegetable production (approximately 80% of total vegetable production).

In recent years, there were implemented many projects to increase vegetable domestic production and possible to supply domestic consumption. For example, "Mongol potato" (2004) and "Inclusive and sustainable vegetable production and marketing" (2016) projects by Swiss Development Cooperation (SDC) (SDC, 2015), "Vegetable value chain program in Mongolia" project by (USAID, 2014), "Current situation analysis of vegetable value chain in Mongolia" (2016) SECiM project by FAO and European Union (SECim, 2016), "Community vegetable farming for livelihood improvement" (2017) project by Japan Fund (Japan Fund for Poverty Reduction, 2017), etc. All the projects focused on how to improve vegetable market situation especially, vegetable value chain mapping (sales, transportation), how to increase household revenue, and to determine faced challenges to household vegetable production. Such as, according to SDC report, the vegetable sector has a lot of challenges, for instance, there is a lot of old sorts of vegetable, lack of machinery, equipment and warehouse, profession and technical advice is not enough, households' cooperative is low, lack of market information and lack of correspondence between household and public sector (SDC, 2015). Therefore, as a result of the SDC project, there has improved seed production of vegetables, brought about a more convenient market for vegetables, and increased household production. Productivity is a very important economic factror in international trade and investment (Makieła, Wojciechowski and Wach, 2021). However, agricultural productivity and efficiency studies (including Bayarsaihan and Coelli (2003); Bhattarai (2019)) still seem to be rare but, there is no efficiency analysis of household-level vegetable production. Many policymakers need to focused on improving productivity and efficiency as an important source of potential growth in vegetable production. Therefore, the objectives of this study are to measure technical efficiency and to determine influencing factors inefficiency on vegetable households level in Mongolia.

## Materials and methods

### Literature review

Efficiency is one of the most important concepts in production. Specifically, technical efficiency is expressed as the side of production and defined as the level of production that ratio between the observed output to the potential output (Coelli, Battese, 2005; Kocisova et al., 2018). Most of the technical efficiency analysis mainly focused on farm-level efficiency and socio-economic characteristics affecting technical inefficiency and efficiency level. (Nyemeck et al., 2008; Galnaitytė et al., 2017) the study provided technical efficiency of groundnut and maize-based systems farmers in the slash and burn agriculture zone of Cameroon, and to identify farm-specific characteristics that explain the variation inefficiency of individual farmers. An understanding of these relationships could provide the policymakers with information to design programs that can contribute to measures needed to expand the food production potential of the nation. Also, they representing socio-economic characteristics of the farm to explain inefficiency, including education (number of completed years of schooling for the farmer), age (number of years of the farmer), distance of the plot from the main access road (kilometers), soil fertility index, club (a dummy variable to measure if the farmer is a member to a peasant club or association), extension contact (dummy variable to measure the influence of agricultural extension on efficiency) and access to cash credit (dummy variable to measure the influence of credit access on efficiency). The study results show that the distance of the plot from the main access road, the soil fertility index, the credit access, and the variable club have a significant impact on technical inefficiency of farmers among farming systems in the slash and burn agriculture zone, while the educational level has only a significant impact on the technical inefficiency of the farmers practicing the maize mono-cropping system.

(Bozoglu, 2007) studied focusing on especially vegetable household production in Samsun province Turkey by using Stochastic frontier analysis. For Turkey, one of the main producer countries in the world. Thus, they defined the technical efficiency of household level and influencing factors (including the age of farmers, the experience of farmers, schooling, family size, off-farm income, credit use, and farm size) of technical inefficiency level. The study results showed that schooling, experience, credit use, women's' participation, and information score negatively influenced technical inefficiency, while age, family size, off-farm income, and farm size showed a positive relationship with inefficiency. Also, schooling, experience, information score, credit use, women's' participation in the exception of family size, farm size, and off-farm income had a significant. (Abdulai and Eberlin, 2001; Vasylieva and James, 2020) this study examines the significance of some major factors that are believed to influence levels of farm production and efficiency, including education, liquidity constraint, and experience. Although the importance of these factors has often been raised in policy debates on Nicaraguan agriculture. The study results reveal that larger families appear to be more efficient than smaller families, level of education, access to formal credit, family size, and tractor use each has a positive impact on efficiency. Participation in non-farm work, however, appears to have a negative effect on efficiency. The negative sign for the education variable indicates that higher levels of education increase efficiency. The negative and significant relationship between access to credit and inefficiency suggests that farmers who face credit constraints on purchased inputs experience higher technical inefficiency.

Battese and Coelli (1996) and Battese (1995) studied inefficiency factors for Indian farms and found that age, education, and farm size were important factors for the technical efficiency of Indian farms. They used two-stage SFA with panel data, that is they put in one model the production inputs and inefficiency determinants or factors. Results of their studies, land, labor, coefficient of the proportion of irrigated land are positive, reflecting the higher productivity of irrigated land. The coefficient of the ratio of hired labor to total labor, was negative, indicating that hired labor is less productive than family labor. Also, the age of farmers, education level, and coefficient of the year was a negative sign. For example, the older farmer tends to have smaller inefficiencies than younger farmers. For education, farmers with greater years of formal education tend to be more efficient in agricultural production. In other words, if greater these factors tend to be more efficient in agricultural production.

## Stochastic frontier analysis

Efficiency concept is pioneered by Farrell (1957), there are two widely used methods of measuring the efficiency of a decision-making unit: The Data Envelopment Analysis (DEA) - non-parametric approach and the Stochastic Frontier Analysis (hereafter SFA)- parametric approach. The SFA approach independently proposed by Aigner and Lovell (1976) and Wim and Broeck (1977). The stochastic frontier production function has two error components: one is to account for the existence of technical inefficiency of production and the other one is express random error. The two-step estimation approach was utilized to early efficiency analysis, such as Bravo-Ureta and Pinheiro (1993), Kalirajan (1981). But this two-step estimation approach contradicts the assumption on the independence of inefficiency effects in the stochastic frontier model. The number of researchers solved this problem in their studies using a single-step estimation approach. For example Seok, Moon, Kim and Reed (2018), Nyemeck et al. (2008), Hung-Jen Wang (2002), Mehmet Bozoglu (2007), Battese (1995), Huang (1994), Reifschneider (1991), etc. The single-step estimation approach defined by the following equation.

$$y_i = \exp\left(f(x_i, \beta) + v_i - u_i\right) \quad (1)$$

Where $y_i$ represents the household production, $x_i$ denotes a set of inputs and $\beta$ is parameters to be estimated, $i$ is the i$^{th}$ household, $v_i$ is the random error and distributed to be normal distribution as N(0; $\sigma_v^2$), and $u_i$ is the non-negative random variable of the technical inefficiency part. The error component $u_i$ needs to satisfy the assumption $u_{it} \geq 0$. The technical inefficiency function defined as:

$$\mu_i = \alpha z_i + w_i \quad (2)$$

Where $\mu_i$ is represented the mean of $\alpha z_i$ with truncation normal distribution at zero and $\sigma^2$ variance, $\alpha$ is estimated parameters, $z_i$ is the technical inefficiency explanatory variables, and $w_i$ is determined by the truncation of the normal distribution with zero mean and variance, $\sigma_2$. The Cobb-Douglas and Translog production function mostly dominate in stochastic frontier analysis using cross-section and panel data. For our estimation frontier production function described by following the Cobb-Douglas production function. The SFA model can be written as:

$$ln y_i = \beta_0 + \sum_{j=1}^{5} \beta_j \, ln z_j + v_{it} - u_{it} \quad (3)$$

Where, *ln* is expressed natural logarithm, $y_i$ is the total income from vegetable production of i[th] household, $x_j$ is denotes of j[th] inputs, $j$ is the number of inputs variables, $j$ = 1, 2, 3 …. 5, namely, sown area (ha), seed cost (million MNT, MNT is the abbreviation of Mongolian currency tugrik, hereafter MNT), labor (man/days), used manure (ton), capital (million MNT) is aggregated value of total machinery cost plus total expenditure on machinery rent cost for cultivation, harvesting, manure, pesticide and diesel cost on cultivation, harvesting and transportation cost to market. $\beta_0$, $\beta_j$ are to be estimated coefficients.

The technical inefficiency function is defined as:

$$\mu_i = \alpha_0 + \alpha_1 size + \alpha_2 age + \alpha_3 sex + \alpha_3 edu + \alpha_4 exp + \alpha_5 nfi + \alpha_6 cre + \alpha_7 lfi + w_i \quad (4)$$

Where, $\alpha$ is estimated parameters, *size* is the number of family members, *age* is the age of household leader, *sex* is the household head's sex, which is variable value is one if has female, two is male, *edu* is the household head's education level, *exp* is the experience of a household heads in vegetable production, *nfi* is the non-farm income dummy variable (non-vegetable income = 1, otherwise 0), *cre* is the credit also dummy variable (if the household has a credit = 1, otherwise 0) and *lfi* is the land fragmentation index. Maximum-likelihood estimates of the parameters for the stochastic frontier production function were obtained using the Stata.14 computer program. An important test to check the existence of the technical inefficiency exists is one-sided error specification. This amount to a test for the presence of $u_i$ in the model, and a generalized likelihood ratio (LR) test for the null hypothesis of no one-sided error can be constructed based on the log-likelihood values of the OLS (restricted) and the SF (unrestricted) model. The LR test statistic is -2[$L(H_0)$ - $L(H_1)$], where $L(H_0)$ and $L(H_1)$ are log-likelihood values of the restricted model and the unrestricted model, respectively, and the degree of freedom equals the number of restrictions in the test (Kumbhakar, Wang, and Horncastle, 2015).

Description of data collection area: Mongolia is located in Central Asia and has a total area of 1564.2 thous.km square. It is divided into five sized economic regions, namely Western, Khangai, Central, Eastern, and Ulaanbaatar area. The country consists of 21 provinces and the capital city. The provinces are divided into 330 soums (sub-provinces). The Mongolian population is nearly 3.2 million, while the population density was 2 persons per kilometer, but 311 persons per kilometer in Ulaanbaatar (NSO, 2017). Mongolia has an extreme climatic condition. The country is dryland and has a low level of precipitation (average is from 250 to 400 mm a year), and absolutely temperature is from -28° to -54° Celsius in winter and from +40° to +45° Celsius in the summer. The vegetable main growing area is the Western and Central regions. Currently, vegetable household production consists of approximately 80 percent of total vegetable production in Mongolia. Also, there were 15862 households and 1422 enterprises (National Statistics Office of Mongolia, 2018). Vegetable household is mainly growing potato, carrot, turnips, cabbage, onion, garlic, cucumber, tomato, watermelon, and melons.

Descriptive statistics for variables: To examine the technical efficiency of vegetable household production, primary data was collected through a semi-structured questionnaire using a random sample technique. Our research was carried out between November 2019 and January 2020. The total random sample was 300 vegetable households. The response rate was 86.7%. For the household production function, we use one output- sales income of the household and four inputs including sown area, seed cost, labor, and capital. Sales income calculated by household vegetable sales income, price, and sales quantity were gathered from the household. All vegetable sales were aggregated into one output value (Mongolian tugrik, hereafter MNT).

Sown area, labor, and used manure are measured in hectare (ha), man/days, and ton respectively. Therefore, capital and seed costs are accounted for in value terms. We calculated capital including the value of cash expenditures on manure, pesticide, maintenance, diesel cost for transportation, cultivation, and harvesting, rental machinery cost within the year, measured as the sum of depreciation of machinery. The annual depreciation of machinery was calculated by the straight-line method. Table 1 shows the summary statistics of our variables. Vegetable household averaged approximately 2.03 ha and their sales income was 15.2 million MNT. The sample vegetable household average seed cost was 1.8 million MNT and average labor 179.6 man/days. Most of the household used to manure to cultivated areas. The sample household average used manure was 24.14 tons. For the capital, most of the household has a truck, car, and motorcycle. The average capital value was 15.3 million MNT.

In the technical inefficiency model, there were eight factors of household vegetable production. These explanatory variables have to choose based on previous studies. Sample vegetable households averaged 4.33 family members and 95% of the total household head was male. Our hypothesis for family size and head‘s sex are fewer family members more efficient than larger family and male‘s decision more than female in the household, respectively. For the education variable, if have education level has a higher, it enhances farm technical efficiency (Fuwa, Edmonds, and Banik, 2007). It shows that the education of the household head and, i.e. education value of one if household head is illiterate, two if has a primary school, three if has a secondary school, four if has associate and five is a bachelor (graduate university). Household head's averaged 46.7 years old and their experience in vegetable production was 15.3 years. Age and experience variables are indicated the possibility of farmers to adopt innovations and more technical skills. Thus, these variables negatively affected to technical inefficiency. We gathered data on non-farm income, it represents the relationship between technical efficiency and the existence of non-farm income. Because some of the households have another source of income. For example, in the exception of vegetable production, there has livestock and some of the family members work public sector and retirement. Non-farm income variable was a dummy if the household has a non-farm income is equal to 1, otherwise 0. Also, we check the relationship between technical inefficiency and credit use. Credit can help to increase technical efficiency because the household decides to overcome financial constraints for the purchase of inputs (Abdulai and Eberlin, 2001). For example, seed, rent a tractor during the cultivating period. Credit use indicates dummy variable if the household used credit to 1, otherwise 0. Sample vegetable households are growing comparative many vegetables including potato,

| Variables | Mean | Standard deviation | Minimum | Maximum |
|---|---|---|---|---|
| Sales income, million MNT | 15.17 | 12.04 | 1.50 | 74.20 |
| Sown area, ha | 2.03 | 1.62 | 0.088 | 10.00 |
| Seed cost, million MNT | 1.78 | 1.71 | 0.026 | 12.72 |
| Labor man/days | 179.57 | 140.27 | 25.00 | 873.62 |
| Used manure, ton | 24.14 | 28.30 | 2.00 | 160.00 |
| Capital, million MNT | 15.31 | 9.94 | 1.31 | 66.28 |
| Family size | 4.33 | 1.69 | 1 | 10 |
| Household head's age | 46.73 | 11.10 | 24 | 74 |
| Household head's sex | 1.95 | 0.21 | 1 | 2 |
| Education | 3.60 | 0.94 | 1 | 5 |
| Owner's experience | 15.34 | 9.61 | 2 | 42 |
| Non-farm income | 0.37 | 0.48 | 0 | 1 |
| Credit use | 0.73 | 0.44 | 0 | 1 |
| Land fragmentation index | 0.54 | 0.29 | 0.11 | 1.25 |

Notes: All the figures are based on randomly selected 260 households observations from Mongolia

Source: Field survey conducted in Mongolia

Table 1: Descriptive statistics of households' vegetable production in 2019.

carrot, cabbage, onion, garlic, tomato, cucumber, watermelon, and melons. The household sown area plot was higher and the land fragmentation average index was 0.54. The land plot is higher, which means the cause of inefficiency. But if the household could manage that, land fragmentation positively affected technical efficiency.

## Results and discussion

### Estimation of SFA model

The results of the estimated stochastic frontier function are presented in Table 2. We used the Maximum Likelihood Estimation (MLE) method to estimate the parameters of the stochastic production frontier and inefficiency effect models jointly in a single-stage estimation procedure. Also, we tested there is technical inefficiency exists or not can be conducted by the null hypothesis. The estimated value of the variance parameter of the model (γ) was close to 1 (γ = 0.89), indicating that an inefficiency exists. Based on the likelihood ratio (LR) test was higher than the critic value (LR = 36.28) and LR test rejected the null hypothesis (Kumbhakar et al., 2015). In other words, there are technical inefficiency effects exist and stochastic. The result of the estimation of the SFA model showed an expected sign of variables and all variables were significant in the frontier function. A 1 % increase in the land area increased output by 0.26 % while a 1% increase in labor and seed cost increased output by 0.42% and 0.13% respectively.

Also, a 1 % increase in manure and capital increased output by 0.12 % and 0.14 % respectively. The land and labor were the highest effects on the output followed by seed cost and capital. It means that the land and labor are major influencing factors of the vegetable production. This result was reported by Bozoglu and Ceyhan (2007), Anang et al. (2016), and Abdulai and Eberlin (2001). Those authors found that the main highest influencing factors are land and labor in crop production. The sum of the values of the inputs is 1.07 which means that increasing returns to scale for vegetable household production in Mongolia. As a result, if all inputs by 1 % will increase vegetable output by 1.07 %.

The technical efficiency's score was estimated between 43.2% and 99.9% (average 0.646). The mean technical efficiency was 64.6 percent, which means that the maximum output of vegetable household production. In other words, a vegetable household will lose about 35.4 percent

| | Variables | Coefficient | Standard error |
|---|---|---|---|
| *Frontier function* | *lnland* | 0.256*** | 0.054 |
| | *lnlabor* | 0.418*** | 0.032 |
| | *lnseedcost* | 0.131*** | 0.035 |
| | *lnmanure* | 0.122*** | 0.033 |
| | *lncapital* | 0.135*** | 0.049 |
| *Inefficiency effect* | *Family size* | 0.131* | 0.069 |
| | *Household head's age* | -0.232 | 0.153 |
| | *Household head's sex* | -0.020 | 0.133 |
| | *Education* | 0.012 | 0.063 |
| | *Household head's experience* | -0.102** | 0.052 |
| | *Non-farm income* | -0.155** | 0.066 |
| | *Credit use* | -0.078 | 0.067 |
| | *Land fragmentation index* | 0.205*** | 0.065 |
| | *Constant* | 1.526** | 0.632 |
| | *Observations* | 260 | |
| | $\sigma_u^2$ | 1.68 | |
| | $\sigma_v^2$ | 0.2*** | |
| | *Log-likelihood* | -160.19 | |

Notes: *, **, *** are 10, 5 and 1% significance levels respectively

Source: Stata's result with truncated normal distribution

Table 2: Maximum likelihood estimation of the Cobb-Douglas stochastic frontier production function and inefficiency model for a vegetable household in Mongolia.

of the potential output due to technical inefficiency. The 40 percent of the sample households had technical efficiency level below 0.6 (or 60%), whereas 50.8 percent of the household had technical efficiency level between 0.61-0.8 (or between 61-80%), the rest of household had technical efficiency level more than 0.81 (or 81%) (Figure 1). In other words, 90.8 percent of sample vegetable household technical efficiency level was below than 0.8.

Based on technical efficiency level results, we determined to mean technical efficiency level concerning land size (sown area) (Table 3). The study revealed that households with large plots of land are more technically efficient at producing vegetables than households with small and medium-sized plots of land. This finding is confirmed by the study of (Battese Coelli, 1996), (Asefa, 2011). However, some of the researchers found that small farms are more efficient (Masterson, 2007), Bozoglu and Ceyhan (2007).

| | *Technical efficiency* |
|---|---|
| *Small (0-2 ha)* | 0.65 |
| *Medium (2-5 ha)* | 0.64 |
| *Large (more than 5 ha)* | 0.66 |

Source: Calculation result

Table 3: Mean efficiency level, by household's land size.

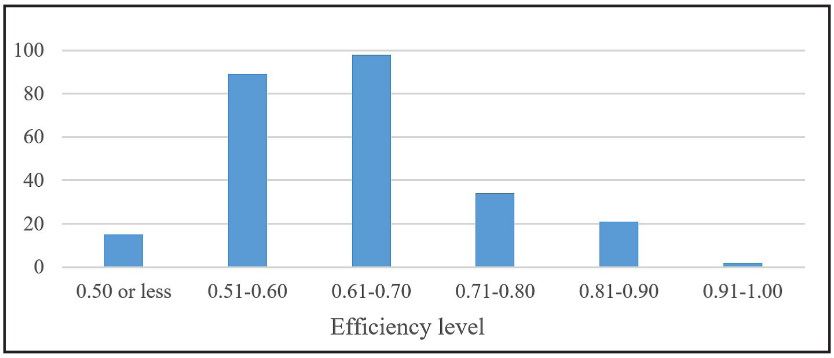
## Technical inefficiency analysis

The result of the inefficiency model (Table 2) indicated the effect of explanatory variables to technical inefficiency, and the number of the variables including family size, household head's experience, non-farm income, and land fragmentation index were significant with the exception of the household head's age, sex, education, and credit use. A negative sign on a parameter that is explaining technical inefficiencies means that the variable is decreasing technical inefficiency (or improving efficiency), while for a positive sign the reverse is true.

The family size positively affected technical inefficiency. It is clearly showed that a smaller family (fewer members) is more efficient than a larger family. This finding is consistent with the work of Bravo-Ureta and Pinheiro (1993). Some empirical studies' result show larger families appear to be more efficient than smaller families. For example, Abdulai and Eberlin (2001) mentioned that larger family size has a more expensive (i.e. for clothing and food comparative to the small member), but it ensures the possibility of enough family labor for farm operations.

The negative sign of experience variable, which indicated that households heads had more experience leading to improving efficiency, a finding that is consistent with the results reported in 3 studies (Bozoglu and Ceyhan (2007); Anang, Tetteh, Bäckman and Sipiläinen, 2016; Addai and Owusu, 2014).

Non-farm income had a negative coefficient and highly affected technical inefficiency more than other variables. In other words, if a household earns more non-farm income that is causing more efficient production. The households sampled sampled for our study answered that non-farm income (including salary, pension, and other activities income) has been spent on vegetable production activities like an investment. However, most of the empirical results have shown a positive relationship between non-farm income and technical inefficiency (Laha, 2006; Asefa, 2011, Anang et al., 2016; Abdulai and Eberlin, 2001; Addai and Owusu, 2014). They mentioned that in greater non-farm activities tend to exhibit higher




Source: Estimated technical efficiency from Stata

Figure 1: Technical efficiency distribution of vegetable household's production in Mongolia, 2019.

levels of inefficiency because family members need to reallocate time for farm activities.

Besides, the land fragmentation index also has significant and positive sign of the coefficient. It means that larger plots may cause an increase in inefficiency. But if the management is better, it causes a positive impact on technical efficiency (Tan et al., 2010). Some of the authors found that the land fragmentation index impact too negatively (Kiprop et al., 2015).

Household head's age, sex, education, and credit use variables were negative and insignificant. There was a negative relationship between age and inefficiency, which means that older farmers were more efficient than younger ones. Some of the researchers have revealed conflicting results. For example, older farmers are more efficient in some studies (Battese, 1995; Broca, 1997), while other authors found younger farmers are more efficient (Abdulai and Eberlin, 2001; Bozoglu and Ceyhan, 2007; Seok et al., 2018). 95 percent of the total sampled vegetable household head was male. For the sex variable sign was negative as expected. This result is similar to some author's results (Anang et al., 2016). They found that males make better decisions than females in the household. Many researchers studied women's participation in household production. For example, (Bozoglu and Ceyhan, 2007) studied women's participation in vegetable production of Turkey. They found that higher women's participation is caused less efficiency.

The coefficient of education was negative to technical inefficiency. When education level is higher, it enhances farm technical efficiency and more educated farmers get enough information than low educated farmers. This result reveals that educated farmers are more likely to reduce their technical inefficiency. This finding also confirmed the result of (Fuwa et al., 2007).

The credit use coefficient sign was negative but insignificant, this means that credit is showed that gives good opportunities for improving technical efficiency. This finding was similar to result from other studies (Bozoglu and Ceyhan, 2007; Asefa, 2011; Laha, 2006; Addai and Owusu, 2014). The Mongolian government implements low-interest-rate credit with long term machinery loans and seed loan programs to increase vegetable production. But most of the sampled households answered that they could not access this credit. Because the credit is not enough and does not access the target group. Thus, vegetable household have to access higher rate credit during the cultivating period to purchase seed and financing for other costs (like renting a tractor for cultivation).

## Conclusion

The main goal of this paper was to determine the technical efficiency of vegetable households in Mongolia by using stochastic production frontier analysis. Our study using survey data was obtained from randomly selected 260 vegetable households in the main growing areas in Mongolia. As a result of our comparative efficiency analysis, the mean technical efficiency of the household was 0.64. This result suggests that this sample of the household could increase their output or decrease inputs through better use of available resources given the existing technology in the research area. Based on our technical efficiency results, only 9.2 percent of the sampled household technical efficiency level was higher than 90 percent.

The inefficiency model, explanatory variables are family size, household head's experience, non-farm income, and land fragmentation index were significant variables for positively affected technical efficiency. Other variables are the household head's age, sex, education, and credit use were insignificant and negative.

The main four findings are based on our study for vegetable production in Mongolia. First, the land and labor are main influencing factors in vegetable production. Second, the larger farmland (more than 5 ha) vegetable household are more efficient than small and medium sized farmland. Third, we found the positive impact of the experience of the household head on efficiency. Also, if the household has a larger non-farm income, it may cause improving technical efficiency. Thus, household needs another source of income. Finally, many types of vegetables growing households are more efficient than only one type of vegetable growing households. In addition, one of the important variables as a proxy for government policy was credit. Our study result found that credit use positively affected technical efficiency and insignificant.

Overall, this study tried to indicate the technical efficiency of vegetable household production and explore to determining factors of technical inefficiency first time in Mongolia. Furthermore, the government will apply this study to strengthen the agriculture policy at national level in Mongolia.

Future studies should seek how to include new technologies (Sieja and Wach, 2019) and the omgoing industrial revolution achievements (Rymarczyk, 2020; Modz, 2018) into the research on the efficiency production of farms.

## Acknowledgments

This research was funded by the grant from the Ministry of Education and Science of Ukraine (№0120U102002).

*Corresponding authors*
*Yuriy Bilan, dr. hab. prof.*
*Alexander Dubcek University of Trencin, Študentská 2, 911 50 Trenčín, Slovakia*
*Sumy State University, Ryms'koho-Korsakova St. 2, Sumy, 400 00 Ukraine*
*Phone: +48506354648, E-mail: yuriy_bilan@yahoo.co.uk*

## References

[1] Abdulai, A. and Eberlin, R. (2001) "Technical efficiency during economic reform in Nicaragua: Evidence from farm household survey data", *Economic Systems*, Vol. 25, No. 2., pp. 113-125. ISSN 0939-3625. DOI 10.1016/S0939-3625(01)00010-3.

[2] Addai, K. N. and Owusu, V. (2014) "Technical efficiency of maize farmers across various agro-ecological zones of Ghana", *Journal of Agriculture and Environmental Sciences*, Vol. 3, No. 1, pp. 149-172. ISSN 2334-2404.

[3] Aigner, D. J., Lovell, C. A. K. and Schmidt, P. (1976) "Formulation and estimation of stochastic frontier production function models", *Journal of Econometrics*, Vol. 6, No. 1, pp. 21-37. ISSN 0304-4076. DOI 10.1016/0304-4076(77)90052-5.

[4] Anang, T. B., Bäckman, S. and Sipiläinen, T. (2016) "Agricultural microcredit and technical efficiency: The case of smallholder rice farmers in Northern Ghana", *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, Vol. 117, No. 2, pp. 189-202. ISSN 2363-6033.

[5] Asefa, S. (2011) "Analysis of technical efficiency of crop-producing smallholder farmers in Tigray, Ethiopia", *Munich Personal RePEc Archive*, Vol. 6. [Online]. Available: http://mpra.ub.uni-muenchen.de/40461/ [Accessed: 23 Jan. 2021].

[6] Battese. G. E. and Broca, S. S. (1997) "Functional forms of stochastic frontier production functions and models for technical inefficiency effects: A Comparative study for wheat farmers in Pakistan", *Journal of Productivity Analysis*, Vol. 8, pp. 395-414. ISSN 2363-6033. DOI 10.1023/A:1007736025686.

[7] Battese. G. E. and Coelli, T. J. (1996) "Identification of factors which influence the technical inefficiency of Indian farmers", *Australian Journal of Agricultural Economics*, Vol. 40, No. 2, pp. 103-128. E-ISSN 1467-8489. DOI 10.1111/j.1467-8489.1996.tb00558.x.

[8] Battese, G. E and Coelli, T. J. (1995) "A Model for technical inefficiency effects in a stochastic frontier production function for panel data", *Empirical Economics*, Vol. 20, pp. 325-332. E-ISSN 1435-8921, ISSN 0377-7332. DOI 10.1007/BF01205442.

[9] Bayarsaihan, T. and Coelli, T. J. (2003) "Productivity growth in pre- 1990 Mongolian agriculture: Spiralling disaster or emerging success?", *Agriculture Economics*, Vol. 28, pp. 121-137. ISSN 0169-5150. DOI 10.1016/S0169-5150(02)00102-0.

[10] Bozoglu, M. and Ceyhan, V. (2007) "Measuring the technical efficiency and exploring the inefficiency determinants of vegetable farms in Samsun province, Turkey", *Agricultural Systems*, Vol. 94, No. 3, pp. 649-656. ISSN 0308-521X. DOI 10.1016/j.agsy.2007.01.007.

[11] Bravo-Ureta, B. E. and Pinheiro, A. E. (1993) "Efficiency Analysis of Developing Country Agriculture: A Review of the Frontier Function Literature", *Agricultural and Resource Economics Review*, Vol. 22, No. 1, pp. 88-101. E-ISSN 2372-2614, ISSN 1068-2805. DOI 10.1017/s1068280500000320.

[12] Bhattarai, K. (2019) "Consumers' willingness to pay for organic vegetables: Empirical evidence from Nepal", *Economics and Sociology,* Vol. 12, No. 3, pp. 132-146. ISSN 2071-789X. DOI 10.14254/2071-789X.2019/12-3/9.

[13] Chen, Z., Huffman, W. E, and Rozelle. S. (2009) "Farm technology and technical efficiency: Evidence from regions in China", *China Economic Review*, Vol. 20, pp. 153-161. ISSN 1043-951X. DOI 10.1016/j.chieco.2009.03.002.

[14] Coelli, J. T., Prasada Rao, D. S, Donnell, O. J. C and Battese, E. J. (2005) "An introduction to efficiency and productivity analysis", Second edition, Springer. ISBN 978-0-387-25895-9.

[15] Reifschneider, D. and R. Stevenson, R. (1991) "Systematic Departures from the Frontier: A Framework for the Analysis of Firm Inefficiency", *International Economic Review,* Vol. 32, No. 3, pp. 715-723.ISSN 0020-6598.

[16] Farrell, M. J. (1957) "The Measurement of productive efficiency", *Journal of the Royal Statistical Society*, Vol. 120, No. 3, pp. 253-290. ISSN 0964-1998. DOI 10.2307/2343100.

[17] Fuwa, N., Edmonds, C. and Banik, P. (2007) "Are small-scale rice farmers in eastern India really inefficient ? Examining the effects of microtopography on technical efficiency estimates", *Agriculture Economics*, Vol. 36, pp. 335-346. ISSN 0169-5150. DOI 10.1111/j.1574-0862.2007.00211.x.

[18] Galnaitytė, A., Kriščiukaitienė, I., Baležentis, T. and Namiotko, V. (2017) "Evaluation of technological, economic and social indicators for different farming practices in Lithuania", *Economics and Sociology*, Vol. 10, No. 4, pp. 189-202. E-ISSN 2306-3459, ISSN 2071-789X. DOI 10.14254/2071-789X.2017/10-4/15.

[19] Huang, C. J. and Liu, J. (1994) "Estimation of a non-neutral stochastic frontier production function", *The Journal of Productivity Analysis*, Vol. 5, pp. 171-180. E-ISSN 1573-0441, ISSN 0895-562X. DOI 10.1007/BF01073853.

[20] Japan Fund for Poverty Reduction. (2017) "*Mongolia: Community vegetable farming for livelihood improvement*", Project Administration Manual. [Online]. Available: https://www.adb.org/sites/default/files/project-documents/50278/50278-001-pam-en.PDF [Accessed: 14 Feb. 2021].

[21] Kalirajan, K. (1981) "An Econometric analysis of yield variability in Paddy production", Canadian Journal of Agricultural Economics, Vol. 29, No. 3, pp. 283-294. ISSN 1744-7976. DOI 10.1111/j.1744-7976.1981.tb02083.x.

[22] Kiprop, N. I. S., Hillary, B. K., Mshenga, P. and Nyairo, N. (2015) "Analysis of technical efficiency among smallholder farmers in Kisii county, Kenya", *IOSR Journal of Agriculture and Veterinary Science*, Vol. 8, No. 3, pp. 50-56, E-ISSN 2319-2380.

[23] Kocisova, K., Gavurova, B. and Kotaskova, A. (2018) "A slack-based measure of agricultural efficiency in the European Union countries", *Journal of International Studies*, Vol. 11, No. 1, pp. 189-200. E-ISSN 2306-3483, ISSN 2071-8330. DOI 10.14254/2071-8330.2018/11-1/14.

[24] Kumbhakar, S. C., Wang, H. and Horncastle, A. (2015) "*A Practitioner's Guide to Stochastic Frontier Analysis Using Stata*", Cambridge University Press. E-ISBN 978-1-107-02951-4. DOI 10.1017/CBO9781139342070.

[25] Laha, A. (2006) "Technical efficiency in Agricultural production and access to credit in West Bengal, India: A Stochastic Frontier Approach", *International Journal of Food and Agricultural Economics,* Vol. 1, No. 2, pp. 53-64. ISSN 2147-8988. DOI 10.22004/ag.econ.160094.

[26] Masterson, T. (2007) "Productivity, technical efficiency, and farm size in Paraguayan agriculture", Working paper, No. 490, [Online]. Available: http://www.levyinstitute.org/pubs/wp_490.pdf [Accessed: 14 Feb. 2021].

[27] Meeusen, W. and van den Broeck, J. (1977) "Efficiency estimation from Cobb-Douglas production functions with composed error", *International Economic Review*, Vol. 18, No. 2, pp. 435-444. ISSN 0020-6598. DOI 10.2307/2525757.

[28] Ministry of Food and Agriculture (2017) "*Mongolian vegetable program*", National program, [Online]. Available: https://www.legalinfo.mn/annex/details/8024?lawid=12881 [Accessed: 10 Feb. 2021].

[29] National Statistics Office of Mongolia (2018) "*Agriculture statistics report*", yearbook, Ulaanbaatar, Mongolia. [Online]. Available: https://www.1212.mn/ [Accessed: 10 Feb. 2021].

[30] National Statistics Office of Mongolia (2019) "*Mongolian Statistical yearbook*", Ulaanbaatar, Mongolia. [Online]. Available: https://www.1212.mn/ [Accessed: 10 Feb. 2021].

[31] Nyemeck, J., Tonye, J., Nyambi, G. and Akoa, M. (2008) "Factors affecting the technical efficiency among smallholder farmers in the slash and burn agriculture zone of Cameroon", Vol. 29, No. 5, pp. 531-545. ISSN 0306-9192. DOI 10.1016/j.foodpol.2004.07.013.

[32] SECiM (2016) "*Current situation analysis of vegetable value chain in Mongolia*", Technical report, [Online]. Available: http://books.xxaa-zainii-surgalt.mn/bookshelf/b98 [Accessed: 15 Feb. 2021].

[33] Seok, J. H., Moon, H., Kim, G. S. and Reed, M. R. (2018) "Is aging the important factor for sustainable agricultural development in Korea? Evidence from the relationship between aging and farm technical efficiency", *Sustainability* (Switzerland), Vol. 10, No. 7. ISSN 2071-1050. DOI 10.3390/su10072137.

[34] Swiss Agency for Development and Cooperation (2015) "*Mongol potato program*", [Online]. Available: https://www.eda.admin.ch/countries/mongolia/mn/home/chegzhlijn/chevlel/publikationen.html [Accessed: 24v Jan. 2021].

[35] Tan, S., Heerink, N., Kuyvenhoven, A. and Qu, F. (2010) "Impact of land fragmentation on rice producers' technical efficiency in South-East China", *NJAS - Wageningen Journal of Life Sciences*, Vol. 57, No. 2, pp. 117-123, ISSN 1573-5214. DOI 10.1016/j.njas.2010.02.001.

[36] USAID (2014) "*Vegetable value chain program in Mongolia*", [Online]. Available: http://books.xxaa-zainii-surgalt.mn/bookshelf/b4 [Accessed: 24 Jan. 2021].

[37] Vasylieva, N. and James Jr., H. (2020) "Prospects of family farming: Ukrainian vs EU experience", *Journal of International Studies*, Vol. 13, No. 3, pp. 129-142 E-ISSN 2306-3483, ISSN 2071-8330. DOI 10.14254/2071-8330.2020/13-3/9.

[38] Wang, H. J. and Schmidth, P. (2002) "One-step and two-step estimation of the effects of exogenous variables on technical efficiency levels", *Journal of Productivity Analysis*, Vol. 18, pp. 129-144. E-ISSN 1573-0441, ISSN 0895-562X. DOI 10.1023/A:1016565719882.