Bayesian Stochastic Frontier Analysis of Agricultural productivity efficiency in CLMV

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Abstract. This paper examines the agricultural productivity efficiency in four countries consists Cambodia, Laos, Myanmar, and Vietnam (CLMV). The Bayesian Stochastic Frontier analysis is used to estimate in this study, this method has several advantages over the traditional method called Stochastic frontier analysis (SFA). The Bayesian method provide more information to be estimation under the uncertainty of parameters. The data consider the period 1991-2019 which comprises 4 countries for 29 years, with 116 observations. The results show that most of the average elasticity variables of agricultural input have a positive association with the agricultural output, this implies that the production frontier is well behave and increase in inputs. It can be concluded that the agricultural outputs of Cambodia, Laos, Myanmar and Vietnam (CLMV) countries in this sample were sensitive to changes in agricultural land followed by changes in agricultural fertilizer and labor. Therefore, the recommendation policy for these countries is governments should focus on enhance the productivity by increasing the technology or innovation in the CLMV countries.

1. Introduction
In order to examine the growth of the agricultural productivity, the four main countries such as Cambodia, Laos, Myanmar, and Vietnam were chosen to study. All the four countries share some common characteristics. These countries association within the Association of Southeast Asian Nations (ASEAN) comprise its newest, lowest income, and formerly closed-economy members. The agricultural sector in Cambodia still contributes the dominant quantity to the GDP. It is the most significant source of revenue and rural livelihood for around 80 percent of the Cambodian population. Moreover, the importance of Cambodia's agricultural sector has been extensively studied by many researchers (Mund [1]; Yu and Fan [2]; Yu and Diao [3]; Kea, Li and Pich [4]). The study of Mund [1] shows that the agriculture production is important to the domestic economy of Cambodia and also is the main employment factor in rural Cambodia. Rice production in Cambodia was previously studied by Yu and Fan [2]. The results of the study indicated that the yield of agricultural rice was significantly lower. Moreover, the results of the research can be concluded that increasing rice yield can be achieved by increasing the use of modern technologies and inputs such as fertilizers and
irrigation. Furthermore, Yu and Diao [3] studied about the Cambodia’s Agricultural Strategy for Rice sector. The strategy suggests that fertilizer is actually widely used by a majority of rice farmers in Cambodia and the Cambodian government should provide subsidized fertilizer to them. Kea, Li and Pich [4] investigated the technical efficiency of Cambodia’s rice production. The finding indicates that the overall mean efficiency of rice production is 78.4 percent. These amounts of percentage imply that at the same level of inputs and technology, there is still room for further improvement in technical efficiency. The production level of rice production or the amount of rice produced in Cambodia varies with different investment levels. This investment means investing in the agricultural area used for harvesting and fertilizing techniques within the province. They also demonstrate that there are main factors that play a role in Cambodia’s rice production. The results of the research indicate that irrigation, production techniques, and the number of employees who come to support agricultural work are the most important factors influencing the technical efficiency of rice production in Cambodia. The Lao PDR is a country with a predominantly agricultural economy with this sector accounting for 51% of GDP. According to the report from the Encyclopedia of the Nations, it shows that almost 80 percent of all the people of Laos is engaged in farming. The importance of the Lao agricultural sector has been greatly studied (Fujisaka [5]; Bourdet [6]; Mainuddin and Kirby [7]). In Myanmar, the main industry is the agriculture sector. The agricultural sector has added important contributions to Myanmar’s total gross domestic product (GDP) throughout the years. The study of the agricultural sector in Burma has been studied extensively by researchers (Fujita and Okamoto [8]; Than [9]). Than [9] studied the situation of the agricultural sector in Myanmar in year 2004. The study shows that the key to socio-economic and environmental reform in Myanmar is the development of agricultural sector. In Vietnam, the most important economic sector in the country is agriculture. The importance of agriculture in Vietnam is that it can be said that agriculture is an important source of raw materials for the processing industry and that agriculture is also a major contributor to the country’s exports. The efficiency of agricultural production in Vietnam was studied by Nguyen and Giang [10]. The finding indicates that the technical averages, allocations and estimates of economic efficiency are not very high. There will be a large gap for areas that need to be studied in improving agricultural production efficiency in Vietnam.

To investigate or measure the efficiency, the well-known method is Stochastic Frontier analysis (SFA) approach. The SFA approach can be widely used with many fields by many researchers (Kraft and Tirtroglu [11]; Jacobs [12]; Cullinane et al [13]; Wijeweera et al. [14]). The difference of this study from the previous study is applying the Bayesian method to the stochastic frontier estimation called Bayesian Stochastic Frontier analysis (BSFA) method. The BSFA method has several advantages over the traditional method. Firstly, BSFA method can be employed and it can eliminate the problem of affecting from outlying observations and nuisance in the data. Secondly, the small sample results can be obtained from BSFA method. It is the particular importance for the macroeconomic datasets. Thirdly, we can easily condition economic uniformity in production functions and test additional constraints or simplify the model. Lastly, the parametric method can provide additional information if the appropriate model is selected.

The purpose of this study is employing Bayesian Stochastic Frontier Analysis (BSFA) in order to examine the agricultural productivity efficiency in Cambodia, Lao, Myanmar, and Vietnam (CLMV countries). This study has the following structure. BSFA models used in the study are mentioned in Section 2 in Methodology. Next, in Section 3 we provide details on the data descriptions and, in Section 4, explain the results and discussion. Conclusion is discussed in Section 5 respectively.

2. Methodology
The stochastic frontier is proposed by Kumbhakar and Hjalmarsson [15] to analyse the stochastic production frontier. The equation of the single-output stochastic production frontier can be shown as

\[ y_i = f(x_i, \beta) \exp(-u_i), \] (1)
where \( y_i \) donates the value of agricultural production and \( x_i \) represent the input variables. The error component \( u_i \) use to show the technical efficiency.

In this paper, we apply the Bayesian approach to the stochastic frontier estimation which was introduced by Van den Broeck et al. [16]. The Bayesian stochastic frontier analysis can allow the prior assumption to be the cooperation of estimation and give the accurate small-sample inference on efficiencies which is more precise and appropriate method to represent the uncertain parameters through kernel densities. Stochastic frontier model is the complex method because this model requires numeric integration methods. A Markov chain Monte Carlo (MCMC) Gibbs sampler is applied to estimate with the Bayesian method in this paper (Griffin and Steel [17]). For the equation of loglikelihood assume that the two components of inefficiency (v and u) are independent. For simplicity, the Bayesian stochastic frontier equation can be rewritten as

\[
y_i = \alpha_i + \sum_{n=1}^{N} \beta_n x_{in} + \beta_t t + \frac{1}{2} \sum_{n=1}^{N} \beta_{nt} t^2 + \sum_{n=1}^{N} \beta_{nt} x_{in} t - v_i + u_i, \tag{2}
\]

The standard corresponding likelihood function is

\[
p(y|\alpha, \beta, \sigma_v^{-2}, z) = \prod_{i=1}^{N} \left( \frac{\gamma^{-\frac{1}{2}}}{(2\pi)^{\frac{N}{2}}} \right)^{\frac{1}{2}} \exp \left[ -\frac{1}{2} \sigma_v^{-2} (u_i)'(u_i) \right], \tag{3}
\]

where

\[
u_i = y_i - \alpha_i + \sum_{n=1}^{N} \beta_n x_{in} + \beta_t t + \frac{1}{2} \sum_{n=1}^{N} \beta_{nm} x_{in} x_{im} + \frac{1}{2} \beta_{tt} t^2 + \sum_{n=1}^{N} \beta_{nt} x_{in} t - v_i + u_i. \tag{4}
\]

The dependent variable is the normal distribution

\[
y_i \sim N(\alpha_i + \sum_{n=1}^{N} \beta_n x_{in} + \beta_t t + \frac{1}{2} \sum_{n=1}^{N} \beta_{nm} x_{in} x_{im} + \frac{1}{2} \beta_{tt} t^2 + \sum_{n=1}^{N} \beta_{nt} x_{in} t - v_i + u_i, \sigma_v^{-2}), \tag{5}
\]

where \( N(u, \sigma^2) \) represents a normal distribution. The component of the inefficient, \( v_i \), propose the implement of the best one and the real output which are supposed to be the truncated normal distribution, can be expressed as

\[
z_i \sim N^+(\zeta, \lambda^{-1}), \tag{6}
\]

where \( \lambda \) is the gamma distribution

\[
\lambda \sim Ga(\Theta, \lambda_0), \tag{7}
\]

with \( \lambda_0 = \emptyset (log(r))^2 \) where \( r \) is the prior efficiency, \( \eta_i \), referred a zero-mean normal distribution \((\eta = 0)\) with variance \( \Gamma = 0.25 \) characterizing the prior indifference between increasing and decreasing the pattern of inefficiency effects

\[
\eta_i \sim N(\eta_0, \Gamma), \tag{8}
\]

The parameters of production function \( \alpha \) and \( \beta \) is the multivariate normal distribution

\[
\alpha \sim N(\alpha, \Theta), \tag{9}
\]

\[
\beta \sim N(\beta, \Sigma), \tag{10}
\]

3. Descriptions of data

In order to investigate the Bayesian stochastic frontier analysis, the data collected from the Food and Agriculture Organization of the United Nations (FAOSTAT) database and the World Bank (WB) database which the descriptive statistics of the agricultural variables are shown in Table 1. The data include the former CLMV countries: Cambodia, Laos, Myanmar and Vietnam. The data consider the period 1991-2019 which comprises 4 countries for 29 years, with 116 observations. The agricultural
production is conducted from the net agriculture production value added. The data consist three input variables: Labor, Land and fertilizer which we considered to estimate the production frontier. The total population working in agriculture from the WB database is collected to estimate for the Labor variable. The land use for animal husbandry and cultivation of crops is used to represent the land variable. Furthermore, the material inputs are also the important factor to be considered when estimating the productivity of agriculture. The component of the fertilizer consists the material agricultural input that combine phosphate \((P_2O_5)\), potash \((K_2O)\) and nitrogen (N). Therefore, the final agricultural input that use to estimate in this study is the fertilizer in order to demonstrate the agricultural productivity. The data of agricultural production and the three agricultural inputs were transformed to the logarithm forms in the estimation.

| Variables                | Observation | Average | Standard deviation | Minimum | Maximum |
|--------------------------|-------------|---------|--------------------|---------|---------|
| Agricultural production  | 116         | 9,853,149.79 | 9,467,315.27 | 582,356.2 | 33,297,930 |
| (million)                |             |         |                    |         |         |
| Labor (%)                | 116         | 62.81   | 13.17              | 32.30   | 86.66   |
| Land (1000 hectare)      | 116         | 7087.97 | 3881.47            | 1662    | 12889   |
| Fertilizer (Ton)         | 116         | 326631.61 | 506129.66         | 500     | 1,862,285.6 |

Source: Computation

4. Results and discussion
The results of the Bayesian stochastic frontier analysis of production function are presented in Table 2. In this study, we use the Gibbs sampler method for the Bayesian approach which is the closed form for estimation, burn-in 10,000 iterations, 50,000 retained draws to decrease the problem of the autocorrelation. The precise of the estimation can be checked by using the error of the monte Carlo to measure the variability of the simulation in each estimation, including the posterior standard deviation. However, the Bayesian approach is different from the classical econometrics in term of the posterior kernel density is allowed to estimate to random parameters and cover all of range parameters instead of the fixed-point estimation in classical econometrics. Thus, the Bayesian method provide more information to be estimation under the uncertainty of parameters. At the sample average, the estimated result show the value of parameters in elasticities of agricultural variables. The estimates of the production elasticities of Labor is 0.0159, indicating that the agricultural production will increase 0.02% on the average when the agricultural input of labor increase 1%. Similarly, the value of variables in the elasticities of land is 0.1445, implying that the agricultural production will increase 0.14% when the agricultural input of land increase 1%. Moreover, we found that the agricultural production with respect to the fertilizer is 0.0641, the agricultural production will increase 0.06% when the agricultural input of fertilizer increase 1%. The average estimation of Land has larger uncertainty than the other parameter estimates that have a wider kernel density. We found that most of the average estimated variables have a positive association with the response variable. However, the estimated average variables of labor square and Labor multiply fertilizer is negative. Therefore, Land variable is the most import factor that impact to the increase of agricultural output followed by Fertilizer and Labor.
Furthermore, the empirical result of technical efficiency score showed that Vietnam is the country which has the best efficiency score equal to 0.9905. For the rest of countries in this CLMV group are Laos followed by Myanmar and Cambodia which the technical efficiency score is 0.9874, 0.9854 and 0.9747, respectively.

Table 2. The results of production function estimation

| Variables     | Avg.   | Std.   |
|---------------|--------|--------|
| Labor         | 0.0159 | 0.0922 |
| Land          | 0.1445 | 0.0923 |
| Fertilizer    | 0.0641 | 0.9214 |
| Labor*Labor   | -0.1222| 0.6356 |
| Land*Land     | 0.0559 | 0.0641 |
| Fertilizer*Fertilizer | 0.0275 | 0.0638 |
| Labor*Land    | 0.1032 | 0.8589 |
| Labor*Fertilizer | -0.0647| 0.0086 |
| Land*Fertilizer | 0.1206 | 0.0859 |
| Constant      | 1.1238 | 0.0763 |
| $\sigma_u^2$  | 0.0182 | 0.0029 |
| $\sigma_v^2$  | 0.0134 | 0.0017 |

Source: Computation

5. Conclusion
This paper investigated the agricultural productivity growth of four countries in Cambodia, Laos, Myanmar and Vietnam (CLMV) from 1991 to 2019 using the Bayesian stochastic frontier analysis to assess the development of agricultural sectors in these countries. A Bayesian approach was used to apply with the stochastic frontier analysis, defining the CLMV countries regularity conditions for each parameter estimate. The main results demonstrate that most of the average elasticity variables of agricultural input have a positive association with the agricultural output, this implies that the production frontier is well behave and increase in inputs. It can be concluded that the agricultural outputs of Cambodia, Laos, Myanmar and Vietnam (CLMV) countries in this sample were sensitive to changes in agricultural land followed by changes in agricultural fertilizer and labor. Based on the previous conclusion, the following policy recommendations are proposed to promote the productivity efficiency and development in CLMV countries. These countries should focus on improve the technology or innovation to increase the productivity because the number of land is limited and the most important factor of the agricultural output. Additionally, the government should support the
agricultural sector in their countries by increasing investment in the technology and innovation to enhance the productivity in the CLMV countries.

Furthermore, this study applies the suitable method to investigate the productivity efficiency in CLMV countries which is the Bayesian stochastic frontier analysis, avoiding the implement of P-values in the hypothesis that triggers a serious issue for economists.

6. References

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