Technical and Environmental Efficiency of Asian Agriculture

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INTRODUCTION

The agriculture sector plays a key role in the economy. Although the agricultural sector contributes to economic growth and enhances food security, it is responsible for environmental pollution and health hazards as well (Abbasi et al., 2014). Agricultural activities generate both positive and negative externalities (Wilson, 1999). Some of the negative externalities of agriculture, such as environmental pollution are generated by the very inputs that are used to boost agricultural production. Inorganic fertilizers and pesticides that are extensively used in the agriculture sector to increase production are some examples of this.

Agricultural production in Asia has substantially increased over the last few decades. The total value of agricultural output has increased from $1,068,207 million to $2,345,774 million (constant 2014-2016) during 1990-2018. Similarly, the use of chemical fertilizers and pesticides also have increased immensely. The chemical fertilizer usage has increased from 55,170,314 tons to 103,845,216 tons during 1990-2018. During the same period, the total chemical pesticide usage has increased from 1,108,398 tons to 2,161,869 tons (FAO, 2020).

Several studies have highlighted environmental problems associated with excessive use of chemical inputs. For instance, the excessive chemical fertilizer application releases nitrogen oxides causing air pollution (Savici, 2012). Furthermore, a huge quantity of chemical pesticides applied to soils could result in an increased level of heavy metals such as cadmium, arsenic, and lead in soil (Atafar et al., 2010).

Thus, it is imperative to take measures to enhance agricultural production while minimizing environmental damage. Improving technical and environmental efficiency are some of the options available to increase agriculture production without harming the environment. Thus, this study estimated the technical and environmental efficiency of agricultural production in Asia as done by Reinhard, Lovell, & Thijssen, 1999; Zhang and Di-Xue, 2005 and Wu, 2007. This study fills the research gap in the literature with respect to environmental efficiency focusing on the agrochemicals in agricultural production.

METHODOLOGY

Theoretical Framework

This research used the concept of efficiency from observed data based on a single output and multiple inputs which was estimated using a Stochastic Frontier Analysis (SFA).

The stochastic frontier production function can be expressed as follows:

$$y_{it} = f\,(x_{it}, t, \beta) \exp\,(v_{it} - u_{it}) \qquad \text{(Eqn 1)}$$

Where y_{it} is output, x_{it} is a vector of inputs, β is a vector of parameters to be estimated, v_{it} is a random error and u_{it} denotes technical inefficiency in the production process, i denotes country and t denotes time.

This study used a Cobb-Douglas production function and it is specified in Eqn (2).

$$ln(y_{it}) = \beta_0 + \beta_1 ln e_{it} + \beta_2 ln l_{it} + \beta_3 ln f_{it} + \beta_4 ln p_{it} + \beta_7 t + v_{it} - u_{it} \qquad \text{(Eqn 2)}$$

Where y_{it} is the total value of agricultural production of i^{th} country in the t^{th} year. The country, i=1, 2,…48 refers to Asian countries, t=1, 2,…28 denotes the year from 1990 to 2018, e_{it} is the agriculture land extent (ha) in the i^{th} country at the t^{th} time, l_{it} is labor (number of people employed in agriculture), f_{it} is fertilizer quantity used in the i^{th} country at the t^{th} time (tons), p_{it} is pesticides quantity (tons) used in the i^{th} country at the t^{th} time, t is time trend which captures Hicksian technical progress.

The technical efficiency (te_{it}) can be expressed as:

$$te_{it} = y_{it} / (f\,(x_{it}, t, \beta) \exp\,(v_{it})) = \exp\,(-u_{it}) \qquad \text{(Eqn 3)}$$

According to Reinhard, Lovell, & Thijssen, (1999), environmental efficiency (ee_{it}) can be defined as the ratio of least achievable of environmentally detrimental input (z^{o}_{it}) to the level of output observed (z_{it}) when other things are held constant. Symbolically:

$$ee_{it} = \min \{\theta_{it}: f(x_{it}, z^{o}_{it}; \beta) = f(x_{it}, \theta_{it} z_{it}; \beta) \geq y_{it}\} \leq 1 \quad \text{(Eqn 4)}$$

Chemical pesticide is treated as the only environmentally detrimental input in this estimation and the logarithm of the output of an environmentally efficient producer is obtained by replacing p_{it} with $\theta_{it}p_{it}$ and setting $u_{it} = 0$ in Equation (Eqn 2) to obtain:

$$ln(y_{it}) = \beta_0 + \beta_1 ln e_{it} + \beta_2 ln l_{it} + \beta_3 ln f_{it} + \beta_4 ln \theta_{it} p_{it} + \beta_7 t + v_{it} \quad \text{(Eqn 5)}$$

Subtracting equation (2) from equation (5):

$$\beta_4(ln\theta_{it}p_{it} - ln p_{it}) + u_{it} = 0 \quad \text{(Eqn 6)}$$

The environmental efficiency (θ_{it}) can be expressed as:

$$ee_{it} = \theta_{it} = (\exp(-u/\beta_4 + ln p_{it})) / p_{it} \quad \text{(Eqn 7)}$$

This study used a panel data set of 48 countries in Asia during 1990-2018. The data set used in the production function is taken from the Food and Agriculture Organization of United Nations (FAO) official website, the International Labor Organization (ILO) official website, and the World Bank official website.

Data analysis was done using the BayES software. Multivariate Normal priors with a mean 0 and a precision of 0.001 were used for model parameters. For the precision parameter of the noise component of the error term, v_i, a Gamma prior was used. Convergences of model parameters were assessed through the examination of trace plots.

FINDINGS

In the estimation of the stochastic production frontier, the inefficiency term was assumed to be distributed exponentially. This model recognized that producers may not be utilizing the full potential of the production technology, given the number of inputs they are using. The results were obtained after twenty thousand iterations of a collection phase and ten thousand iterations of a burn-in phase of the Markov Chain Monte Carlo (MCMC) sequence.

Table 1 reports the results of Bayesian estimation, including the input elasticity of coefficients, standard deviations, and the credible intervals of the model parameters. The input elasticities of land extent, labor, fertilizer, and pesticide are positive and significant. The Bayesian estimation coefficient of time is positive and significant at the 5 percent significance level, indicating that there was significant technological progress in the Asian region in agricultural production.

Table 1: Results of Bayesian estimation of the stochastic frontier

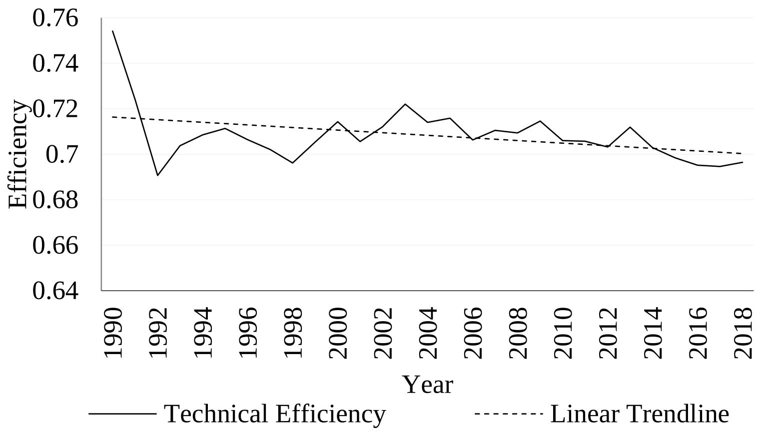
	Mean	**Standard Deviation**	**Credible Interval**	
			5%	95%
Constant	-33.390	5.345	-42.141	-24.559
lnlabor	0.077	0.015	0.051	0.102
lnland_extent	0.202	0.018	0.173	0.232
lnfertilizer	0.376	0.018	0.346	0.407
lnpesticide	0.167	0.013	0.146	0.189
trend	0.016	0.003	0.012	0.021

Technical and Environmental Efficiency in Asia

The average technical efficiency and the average environmental efficiency for pesticide use in Asia from 1990 to 2018 are given in Figures 1 and 2 respectively. After the estimation of a stochastic-frontier, the observation-specific estimates of the efficiency scores can be obtained.

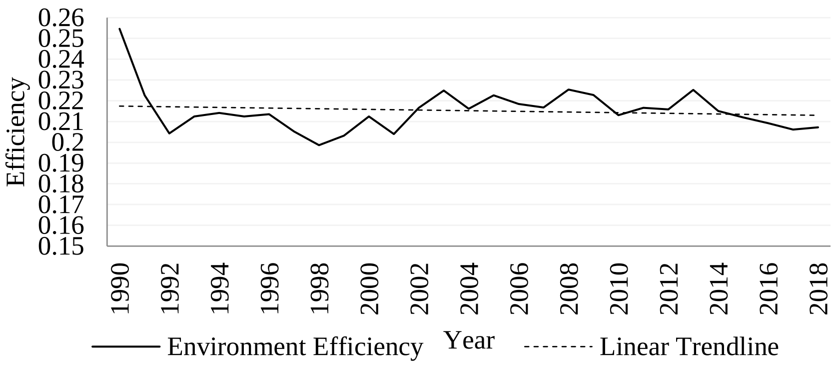
The average technical efficiency of agricultural production ranged from 0.69 to 0.75 in Asia, while the average score of technical efficiency was 0.71. As Figure 1 indicates average technical efficiency scores have decreased over the years.
The average technical efficiency score indicates that producers are on average executing about 71 percent of best practice output in their use of agricultural inputs and technology. Thus, there still is a potential to increase the production by 25 percent without increasing the level of the same inputs and technology, provided that technical inefficiency is eliminated.

Environmental efficiency for pesticide input usage in Asia was estimated using Eqn 7 for the period 1990 to 2018. As seen in Figure 2, the environmental efficiency estimates for pesticide input have minor variability, ranging from 0.20 to 0.25 with an average value of 0.22. The low average environmental efficiency indicates that the present level of agricultural production could be maintained by reducing excessive use of pesticides by 78 percent. Therefore, there is a great possibility for reducing the environmental impact of agricultural production by the correct use of pesticides and enhancing environmental efficiency of input use. Furthermore, average environmental efficiency scores have slightly decreased over time.



Source: Author’s illustration

Figure 1: Average technical efficiency in Asia



Source: Author’s illustration

Figure 2: Average environmental efficiency in Asia

CONCLUSIONS

In this study, a stochastic Cobb-Douglas production frontier is estimated to assess the technical efficiency and environmental efficiency of Agricultural production in Asia. The result of this study illustrates that agricultural production is positively influenced by land, labor, fertilizer and pesticide.

The results indicate that estimated environmental efficiency is lower than corresponding technical efficiency. This finding implies current pesticide use on agricultural production is inefficient and there is a possibility for reducing pesticide use and reducing the effect on the environment.

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