## Extended Abstract
## Please do not add your name or affiliation

| Paper/Poster Title | Smartphone use and environmental efficiency of maize production in China: Correcting for Selectivity Bias |
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| **Abstract** | ***200 words max*** |
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| While there is a broad literature on the impact of Information Technologies (IT) in the economic performance of different industries, only few studies have looked at the environmental effect of IT adoption in agricultural production from an economic perspective. This study aims to investigate the effect of smartphone use on the environmental efficiency of maize production in China, using a cross-sectional data covering 449 farmers. The Translog output distance function corrected for selectivity bias using Stochastic Frontier (SF) framework has been estimated to assess the environmental efficiency with carbon footprint, and then investigate how smartphone use affect environmental efficiency of maize farmers in China. Our results show that Greenhouse gas (GHG) emissions from maize production is on average 556.5 Kg·CE / Kg, and the mean environmental efficiency of maize production is 0.901. In addition, smartphone users are more environmentally efficient than nonusers, exhibiting an environmental efficiency higher by 6.43%. The parameter ρ of selection bias correction is significant for nonusers and not significant for users, which indicates that there is the presence of self-selectivity bias for nonusers. Our results suggest that smartphone use among maize farmers can contribute to sustainable agricultural development of maize production in China. | |



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| **Keywords** | Smartphone use; Environmental efficiency; Selectivity bias; Stochastic Frontier model;Translog output distance function; Greenhouse gas emissions. |
| **JEL Code** | D24, Q12, Q51<br>see: www.aeaweb.org/jel/guide/jel.php?class=Q) |


| **Introduction** | ***100 – 250 words*** |
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It is essential to improve agricultural productivity and efficiency so we can ensure food security. In many developing countries, increased use of intermediate inputs led to higher agricultural yields, but at the same time that had adverse effects in the environment, which hinders the agricultural sustainability.

Previous studies have shown that Information Technologies (IT), such as the Internet or smartphone use, can alter the environmental performance of different industries. However, in agricultural production, researchers have mostly focused on the effects of Information Technologies adoption on farm performance, such as income growth and off-farm work opportunities, without paying attention to the environmental impact of IT adoption.

The aim of this study is to estimate the environmental (technical) efficiency of maize production in China, and then investigate how smartphone use can be further associated with the environmental performance of maize farmers.

| **Methodology** | ***100 – 250 words*** |
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First, we apply a Translog output distance function with SF model to estimate the environmental efficiency (EE). Greenhouse gas (GHG) emissions were used as a bad output and were calculated using the carbon footprint method, which is based on relative emission factors from input uses and openly burnt maize straw in the whole process of maize production. The Translog output distance function is:

$$-\ln y_M = \alpha_0 + \sum_{i=1}^{N} \alpha_i \ln x_i + \frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N} \alpha_{ij} \ln x_i \ln x_j + \sum_{m=1}^{M-1} \beta_m \ln\frac{y_m}{y_M} + \frac{1}{2}\sum_{m=1}^{M-1}\sum_{n=1}^{M-1} \beta_{mn} \ln\frac{y_m}{y_M}\ln\frac{y_m}{y_M} + \sum_{i=1}^{N}\sum_{m=1}^{M-1} \zeta_{im} \ln x_i \ln\frac{y_m}{y_M} + u + v \quad (1)$$

Where $y_M$ is defined as maize yield; $y_m$ is defined as carbon footprint from maize production (the undesirable output); $x_i$ and $x_j$ denote all intermediate inputs. u and v, the inefficiency term and a disturbance term accounted for statistical noise respectively, are conditionally independent. The environmental efficiency can be computed by $E[\exp(-u)]$.

Second, we correct for selection bias when it comes to the adoption of smartphone using the Greene (2010)'s selectivity bias corrected SF model and FIMLE to estimate the differences of environmental efficiency between smartphone users and nonusers.

$$y_i = \beta x_i + v_i - u_i$$
$$D_i^* = \gamma z_i + w_i$$
$$(v, w) \sim N_2\left[\begin{matrix}0\\0\end{matrix}, \begin{pmatrix}\sigma_v^2 & \rho\sigma_v \\ \rho\sigma_v & \sigma_w^2 = 1\end{pmatrix}\right] \quad (2)$$

Where $D_i^*$ denotes a latent variable (1 for users and 0 otherwise); $z_i$ denotes a vector of explanatory variables; $\gamma$ represents parameters to be estimated; and $w_i$ is an error term accounting for statistical noise. More importantly, $\rho$ indicates the correlation between $w_i$ and $v_i$ capturing the sample selection bias. Through maximizing the likelihood function, environmental efficiency can be finally computed as $\exp[-\hat{E}[u_i|\varepsilon_i]]$, and $\varepsilon_i = v_i - u_i$ .

| **Results** | ***100 – 250 words*** |
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Carbon footprint from maize production is around 566.5 Kg·CE/ Kg, which is mainly induced by the use of chemical fertilizer. The results of the Probit model reveal that farmer's income level have a significantly positive effect and farmer's age have a significant negative effect on the decision to use their smartphone. Elder farmers are 2.9% less likely to use smartphone and farmers who exhibit higher income levels are more likely to use smartphones. Also, an instrumental variable, social media, was used to address the endogeneity problem of farmers' smartphone use decision. The estimated coefficient of the instrumental variable reveals that social media can significantly increase the probability of smartphone use.

The results of the Translog ODF without correction for selection bias show that environmental efficiency on average is 0.901, suggesting that environmental inefficiency of Chinese maize producers is relatively low. The average EE score for smartphone users is 0.917, for nonusers is 0.869, implying that smartphone users can increase environmental efficiency by 5.17%.

The results of the Translog ODF with selection bias correction reveal that the coefficient for the selectivity variable $\rho$ is statistically different from zero for nonusers, however not statistically significant for smartphone users. The presence of selection bias for nonusers also indicates that the estimates from the model that does not correct for selectivity bias yield biased frontier estimates, which consequently affect the EE scores for nonusers. After selection bias correction, EE ranges from 0.767 to 0.917 for smartphone users and from 0.489 to 0.858 for nonusers, suggesting that smartphone users can increase environmental efficiency by 6.43%.

| **Discussion and Conclusion** | ***100 – 250 words*** |
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This study analyzed the role of smartphone use on enhancing environmental technical efficiency, using a cross-sectional data covering 449 farmers from three main maize-producing provinces in China. We utilized a Translog output distance function (ODF) with carbon footprint (CF) as bad output using the Stochastic Frontier (SF) model to calculate environmental efficiency. We also used the combination of Greene’s (2010) sample selection SF model and Dakpo’s (2021) full information maximum likelihood estimation (FIMLE) to account for potential selectivity bias associated with unobserved attributes. These approaches allowed for the estimation of unbiased and consistent effect of smartphone use on environmental efficiency of maize production in China.

The empirical results reveal that smartphone use tend to enhance environmental efficiency (EE) of maize production in China. In particular, for both without and with sample selection SF model estimations, the results show that smartphone users are environmentally more efficient than nonusers. Moreover, relative lower EE scores for smartphone nonusers and unchanged EE scores for smartphone users are revealed after the correction for selection bias, suggesting that there is selectivity bias for nonusers but no selectivity bias for users based on our available data.

Our results also suggest that in non-randomized studies, it is important to account for selection bias because the significant result of $\rho$ parameter for nonusers, when examining the differences of environmental efficiency. From a policy perspective, this implies that the adoption of Information Technologies, such as smartphone use, can improve technical and environmental efficiency, and further contribute to sustainable agricultural development of maize production in China.