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Research paper

Impact of agricultural extension service on adoption of chemical fertilizer: Implications for rice productivity and development in Ghana

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ABSTRACT

Given the increasing tension between food production and food demand in sub-Saharan Africa, as well as the poor development of the rice sector in Africa, the present paper examines the impact of agricultural extension on adoption of chemical fertilizers and their impact on rice productivity in Ghana. A parametric approach was employed to account for selectivity and endogeneity effects, which most impact studies fail to address. The empirical results reveal that agricultural extension service is endogenous in the chemical fertilizer adoption specification. Our findings show that access to extension services significantly promotes adoption of chemical fertilizer. Access to extension services and adoption of chemical fertilizer exert positive influences on rice productivity. Promoting farmer participation in irrigation schemes and row-planting technologies, facilitating easy access to education and credit facilities, sensitization of female farmers and leasing of farmlands are policy alternatives needed to facilitate adoption of chemical fertilizer and access to extension services, with the goal of enhancing rice productivity and the livelihoods of rice farmers in sub-Saharan Africa. Governments and various institutions in Africa should train more extension officers, given the significant impact they have on agricultural technology adoption and productivity. Future studies on adoption of agricultural technologies and access to extension services in developing countries should adopt empirical approaches that account for endogeneity and selectivity effect in order to arrive at the precise magnitude and extent of impacts from productive agricultural technologies and interventions.

1. Introduction

In Ghana, about 60% of the population are rural dwellers who depend either directly or indirectly on agriculture for their livelihood and survival [28]. This indicates that agriculture plays a critical role in promoting economic growth, food security, poverty reduction, livelihoods and rural development [27]. Contemporarily, there is high demand for food commodities due to population growth and urbanisation. Traditional subsistence agriculture cannot sustain this high food demand and population pressure. Therefore, there is a gradual paradigm shift occurring from traditional subsistence agriculture to market-oriented production [22]. In addition, the fertility of agricultural lands has been declining over the years due to continuous cropping on the same pieces of land. This is arising from the limited land available for crop production, particularly rice. Food production in Africa, especially in Ghana, is predominately undertaken by smallholder farmers who usually cultivate less than two hectares. Available statistics show that rice producers in Ghana can only supply 300,000mt, while the demand is estimated to be 960,000mt. This shows that the local supply has been able to meet only 31.25% of the local demand [28]. The deficit in food supply is sufficed by imports. However, the reliance on food imports to meet the expected food supply by the year 2020 may not be economically sustainable. This calls for an urgent need to increase domestic food production by paying critical attention to a green revolution in Africa [11].

Application of chemical fertilizers has been a key of green revolution around the world [1,13]. Higher rates of soil fertility decline and consistent lower crop yields necessitate the increased use of inorganic fertilizer in Africa. However, evidence shows that adop-

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tion of chemical fertilizer is low in Africa [15,16], particularly among rice producers in Ghana. One of the avenues for increasing the adoption of chemical fertilizer in the country is through the efficient agricultural extension service. Christoplos [5] conceptualised an efficient agricultural extension service as comprising all the different activities that provide the information and advisory services that are required, and demanded, by farmers and other actors in the agrifood systems and rural development. Agricultural extension strengthens a farmer's capacity to innovate by providing access to knowledge and information. Farmers also advocate that the development of agriculture depends largely on access to new technologies and information [28]. However, it is evident that farmers' access to agricultural extension in the country is low [22]. This raises the following pertinent research issues: What factors influence farmers' access to agricultural extension service? What is the impact of agricultural extension service on adoption of chemical fertilizer and rice yield? What impact does adoption of chemical fertilizer have on rice productivity?

A number of empirical studies have been conducted on the adoption of chemical fertilizer in Africa [1,13]. However, few studies exist on the impact of agricultural extension service on the adoption of chemical fertilizer and the resulting impact on rice productivity. Although some authors included extension as an explanatory variable in the adoption model specification [6,15,18,31], the effects of extension in these studies vary from one to another, with no consensus being seen on the real effect of extension on the adoption of soil improvement technologies. None of these studies accounted for the potential endogeneity of a farmer's access to agricultural extension service in their adoption models and hence the resulting endogeneity bias. This paper therefore contributes to the existing empirical literature on the adoption of soil improvement technologies by analysing the impact of agricultural extension service on adoption of chemical fertilizer, taking into account endogeneity and selection biases. Selection bias occurs because adoption of chemical fertilizer and access to extension services by farmers in Ghana are not randomly assigned [2,12]. Endogeneity problem arises in empirical estimations when the set of exogenous variables been examined in the model tend to correlate with the error term [2,23]. Specifically, the Probit instrumental variable approach is employed to determine simultaneously the impact of extension service on adoption of chemical fertilizer, as well as the determinants of farmer's access to agricultural extension service. The parametric approach employed addresses the potential endogeneity of farmer's access to agricultural extension service in the chemical fertilizer adoption specification. In addition, propensity score matching (PSM) was used to estimate the average treatment effect on the treated as well as addressing selection bias issue.

The rest of the article is organised as follows. Section 2 explains the methodology employed in addressing the key research question. Section 3 presents the key findings of the study. The last section outlines the conclusion and policy recommendations based on the key findings.

2. Methodology

2.1. Conceptual framework and empirical strategy

Farmers had not previously applied chemical fertilizers because the lands they cultivated were fertile. However, the current fertility level of most farming lands in the northern part of Ghana has been declining dramatically due to continuous cropping and soil degradation. The Ministry of Food and Agriculture is promoting the adoption of chemical fertilizers, based on a potential increase in productivity. Hence, we assumed that a farmer chooses to adopt chemical fertilizer application, based on the expected returns or net benefit, given the available socioeconomic, institutional and technological characteristics. Rationally, the farmer will choose an option that provides maximum net benefit. In this study, we determine the impact of extension service on chemical fertilizer adoption by modelling simultaneously factors influencing access to extension service and adoption of chemical fertilizer.

We represent the i^{th} farmer's net benefit from adopting chemical fertilizer as Y_{if}^{*}. The farmer is likely to adopt chemical fertilizer if the net benefit derived from chemical fertilizer application is higher than no chemical fertilizer application (Y_{inf}^{*}). Thus, $Y_{if}^{*} > Y_{inf}^{*}$. It is important to note that the benefits arising from adopting chemical fertilizer are unknown to the researcher, and that what is known are the characteristics and attributes of the farmer's choice. That is, Y_{if}^{*} is unobservable, but it can be expressed as a function of observable elements in a latent variable related to a set of socioeconomic, institutional and technological characteristics, and is expressed as:

$$Y_{if}^{*} = \delta X_{ij} + u_i,\ Y_{if} = 1[Y_{if}^{*} > 0] \tag{1}$$

where Y_{if} is a binary indicator that equals to 1 for farmer i, in case of adoption of chemical fertilizer and 0 otherwise, δ is a vector of parameters to be estimated, X_{ij} is a vector of socioeconomic, institutional and technological characteristics. u_i is an error term assumed to be normally distributed. The probability of adopting chemical fertilizer can be expressed as:

$$Pr(Y_{if} = 1) = Pr(Y_{if}^{*} > 0) = Pr(u_i > -\delta X_{ij}) = 1 - \Omega(-\delta X_{ij}) \tag{2}$$

where Ω is the cumulative distribution function for u_i. A standard Probit model can normally be employed to estimate the parameters in Eq. (1). However, access to extension service is treated as an endogenous variable in our adoption specification and so we express it as:

$$Y_{if}^{*} = \delta_0 + \delta_1 X_{ij} + \delta_2 Extension_i + \varepsilon_i \tag{3}$$

where X_{ij} represents a vector of socioeconomic, institutional and technological characteristics that affect chemical fertilizer adoption, $Extension_i$ is a binary variable, 1 if the farmer has access to extension service and 0 otherwise, and ε_i is the error term capturing unobservable effects. Adoption of chemical fertilizer and access to extension service are determined simultaneously. A possible reason why access to agricultural extension service is potentially endogenous in Eq. (3) is that unobservable characteristics, such as management skills, may influence both chemical fertilizer adoption and access to extension service. The determinants of a farmer's access to extension services are specified as:

$$Extension_i = \phi_0 + \phi_1 X_{ij} + \xi_i \tag{4}$$

where ϕ_0 and ϕ_1 are parameters to be estimated and ξ_i is an error term. A two-stage instrumental variable (IV) approach is employed to estimate simultaneously Eqs. (3) and (4). The Probit estimates of δ_2 are consistent with the correct asymptotic variance matrix indicated by Smith and Blundell [25]. A Wald test on the vector δ_2 is performed to test for endogeneity of access to agricultural extension service. To ensure identification in the estimation of the Probit model, some of the variables included in the first stage estimation of access to extension service are excluded in the adoption of chemical fertilizer specification.

In addition to determining simultaneously the determinants of adoption of chemical fertilizer and access to agricultural extension service, it is relevant to determine whether there is a significant difference between fertilizer use by recipients and non-recipients of agricultural extension services. Conceptually, a recipient is defined as a farmer who receives agricultural extension services, and otherwise for a non-recipient. Using a normal standard t-test to make comparison may not give the true picture due to confounding and

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