International Journal of Food and Agricultural Economics
ISSN 2147-8988, E-ISSN: 2149-3766
Vol. 11, No. 3, 2023, pp. 149-163

ADOPTION DETERMINANTS AND PRODUCTIVITY EFFECT OF IMPROVED MAIZE TECHNOLOGY IN TOLON DISTRICT OF NORTHERN GHANA

Benjamin Tetteh Anang
University for Development Studies, Department of Agricultural and Food Economics, Tamale, Ghana, Email: benjamin.anang @uds.edu.gh, ORCID: 0000-0003-0093-2660

Rebecca Owusu
University of Cape Coast, Department of Agricultural Economics and Extension, Ghana, Email: rebecca.owusu @ucc.edu.gh, 0000-0003-0683-0278

Abstract

Adoption of improved agricultural technologies is crucial to improve land productivity, food security and economic development in low-income countries. In this paper, we examined the determinants of improved maize variety (IMV) adoption and the impact of adoption on land productivity of resource-constrained smallholder maize farmers in a semi-arid region of Ghana. Primary data on 340 respondents were gathered and modelled using an endogenous switching regression econometric model to evaluate the impact and determinants of maize technology adoption among the sampled farmers. From the results, adoption of IMV significantly improved land productivity by 10.7 – 14.1 percent. Furthermore, quantity of labour deployed by the household was found to be a key determinant of both adoption and land productivity, while factors which enhance soil fertility status positively influenced improved variety adoption. The authors make practical policy recommendations to enhance adoption and land productivity to improve food security and income of smallholder farm households.
Keywords: *Adoption, improved maize technology, land productivity, Ghana*
JEL Codes: *D24, Q12, Q15*

1. Introduction

It is widely acknowledged that agriculture contributes immensely to the socioeconomic development of many developing countries, such as Ghana. For instance, the agricultural sector accounted for about 20% of the country's gross domestic product in 2019 ((Nyamekye et al., 2021) and provides raw materials to feed local industries. The sector also has forward and backward linkages with the manufacturing and service sectors, thus promoting the growth of the economy. The realization of the country's agro-based industrialization agenda is also highly dependent on the agricultural sector. The sector also generates employment for about 75% of the rural population and therefore plays a critical role in income generation and socioeconomic development (MoFA, 2017; Yeboah and Flynn, 2021).

Notwithstanding the critical role that agriculture plays in many developing countries, the sector is dominated by smallholder farmers operating at subsistence level and using rudimentary tools. For instance, the agricultural sector in Ghana is subsistence-based and dominated by small-scale producers domiciled in rural areas of the country. Smallholder farmers cultivate less than 5 hectares of land (Kamara et al., 2019), with majority producing less than 2 hectares. Ghana's agricultural sector is also bedeviled with considerable challenges ranging from low technology adoption, unavailability of production resources and poor service delivery which affect farm yield and the development of a sustainable agricultural sector (Asante & Amuakwa-Mensah, 2015; Abdul-Mumin & Abdulai, 2022).

Modernizing the agricultural sector is therefore important to ensure socio-economic development and sustainability (Poku, 2018). Empirical studies show that improvement in productivity of the agricultural sector increases income level, lessens poverty and food insecurity and also contributes to sustainable socioeconomic development (Anang, 2019; Anang et al., 2020a; Damba et al., 2020; Owusu, 2020; Donkoh, 2011). The potential of increasing wellbeing in Sub-Sahara Africa and reducing poverty through boosting agricultural productivity within the value chain has been emphasized by Walker & Alwang (2015).

In Ghana, several policies have been introduced to increase productivity in the agricultural sector. An example of such policies includes Ghana Share Growth and Development Agenda (GSGDA) from 2010-2013. The policy aimed at boosting the cultivation of the country's major stable crops, improve farmers' access to fertilizer, improved seeds, credit and water for irrigation. Another example of agricultural sector policies is the Planting for Food and Jobs (PFJ) programme that aims at improving food security through a policy that seeks to ease access to inputs (fertilizer and improved seeds) to boost productivity (MoFA, 2017). Initially, the PFJ programme targeted only cereals and vegetables, but later expanded to include legumes and root crops (Karl 2017). Since its inception, the PFJ programme has provided several benefits to the programme participants such as 1) improving farmers' access to extension services and farm input subsidy particularly improved seeds and fertilizer, 2) provision of marketing and processing infrastructure, and 3) enhanced market access through provision of improved market information systems. One of the key benefits of the PFJ programme in Ghana is the provision of subsidized improved seeds aimed at improving agricultural productivity.

The development of a viable seed system demands key investments to promote breeding programmes as well as providing support to seed growers, companies and agro-input dealers. The seed system in Ghana is privatized but less than 5% of producers have access to improved seeds from approved sources (Market Growth, 2021). For this reason, the Ministry of Food and Agriculture (MoFA) through research institutions, for example, the Council for Scientific and Industrial Research (CSIR), Savannah Agriculture Research Institute (SARI) and the Universities, coordinates to release improved seeds for farmers in Ghana.

Over the years several studies have examined the nexus between farmers' technology adoption and improvements in productivity, food security and poverty reduction (Anang, 2019; Danso-Abbeam et al., 2017; Dokyi et al., 2021; Salifu et al., 2015). Previous studies (Anang, 2019; Bruce et al., 2014; Donkoh and Azumah, 2019; Donkor et al., 2014) show that adoption of improved technology has the likelihood of reducing food insecurity, increase income levels and farm productivity. Scientific research shows that adoption of improved seeds technology improved food security and nutrition, yield level and also livelihood of smallholder households (Adu et al., 2018; Spielman & Smale, 2017). Improved technologies such as new seed varieties are crucial for smallholder farmers' productivity in developing countries. This seeds are drought-friendly, resistant to pest and diseases, respond well to fertilizer and high fruiting (Simtowe et al., 2019a). This makes improved seeds better off to local seeds in adapting to harsh conditions (Anang, 2019).

In spite of efforts aimed at improving the seed sector in Ghana and technology adoption, research shows that farmers' level of adoption is low. This study therefore examines factors affecting adoption of improved maize technologies in Ghana's Tolon district and the effect of adoption on land productivity. Maize is considered because it is a valuable staple crop in Africa, for which significant investments have been made to enhance its productivity through promotion and adoption of improved seeds (Walker & Alwang, 2015). Some countries in

Africa such as Mozambique succeeded in developing commercial seed centers (World Bank, 2016). Others have also liberalized seed sectors to help smallholder farmers improve their yield. Ghana has also followed suit and introduced a law on seeds, passed in 2010, termed the Plants and Fertilizer Act (GoG, 2010). The act seeks to provide the needed support to donors and regulate production of seeds and marketing to ensure that smallholder farmers have access to improved seeds to improve productivity (Poku, 2018). Literature indicates that improved maize varieties have the tendency to increase yield more than the local variety (Anang, 2019; Danso-Abbeam et al., 2017; Dokyi et al., 2021; Poku, 2018; Simtowe et al., 2019b; Wiredu et al., 2010).

2. Conceptual Framework

Figure 1 shows the linkages between farmers' technology adoption, productivity and food security. Underpinning technology adoption are several institutional, farm and farmer characteristics. The institutional factors include agricultural extension, credit, input subsidy, crop insurance, mechanization services, among others. These factors serve as precursors to technology adoption as they enhance the adoption and operationalization of a given technology. For instance, through extension education, farmers gain insight into new technologies, their benefits and how to use the technology to enhance farm operations. Access to credit is critical to finance the cost of adoption, hence a key determinant of technology adoption. Input subsidy is another important determinant of adoption. Farmers' adoption costs are lower thanks to access to subsidies, which encourages the use of innovative technologies. A reduction in the cost of an input is an incentive for farmers to use that input in production, all things being equal.

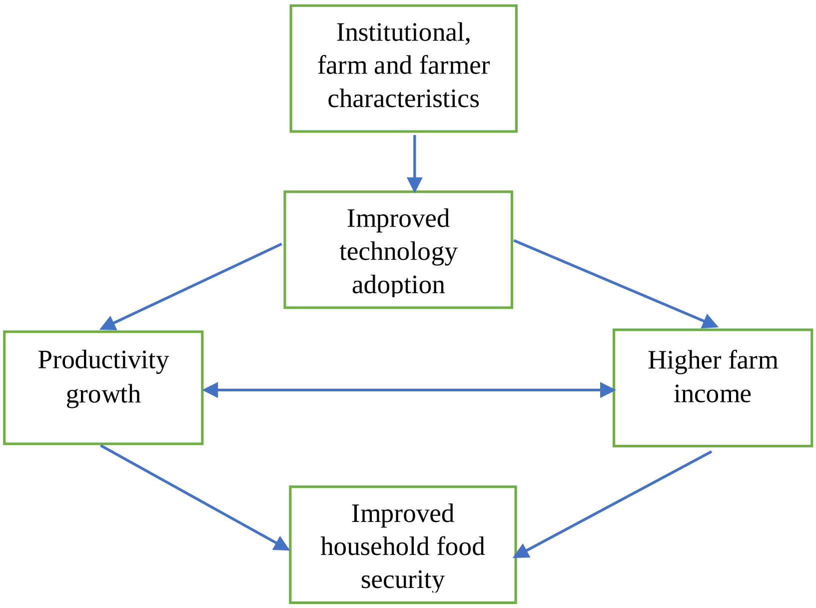

Figure 1. Conceptual Framework of Technology Adoption, Productivity and Food Security

In this paper, adoption means the choice of a farmer regarding a particular bundle of technology and its usage on the farm. An adopter therefore is someone who has chosen to cultivate improved maize variety (IMV) on his farm. Non-adopters by definition are those farmers who stick to traditional varieties. Improved varieties have the advantage of being high-yielding and thus resulting in more output per unit area, all things being equal. When the required conditions are met, such as right fertilization and water regimes, weeding and chemical applications rates, etc., improved varieties turn to provide higher yield compared to traditional varieties. On the other hand, traditional seeds are well adapted to the local environmental conditions and tend to do well with limited external inputs such as chemical fertilizer. Thus, with the right mix of inputs, improved varieties are expected to provide yield levels exceeding that of traditional varieties.

The productivity and income effects of improved variety adoption portray a reverse causality. In other words, productivity growth and increase in income both influence each other. For instance, productivity growth is expected to lead to higher farm income. In the same way, higher farm income is expected to lead to productivity growth through its influence on resource acquisition and ability to afford improved technology. The study's main emphasis is to evaluate the productivity gains that emanate from adopting improved maize technology.

The direct consequence of higher farm income and growth in productivity is improvement in household food security status. Improving the productivity of smallholder farmers is so critical that it has gained much attention among researchers and policymakers. Increasing agricultural productivity is essential to reduce hunger and poverty among rural agrarian households. Improving total factor productivity through the efficient use of farmers' scarce production resources is therefore critical in the quest to eradicate rural poverty, enhance rural incomes and improve household food security.

3. Econometric Approach

The problem under study was modelled using an endogenous switching regression (ESR) model. ESR is one of the traditional approaches for conducting impact evaluation studies. ESR helps to deal with sample selection bias or endogeneity problems associated with impact assessment studies. There is sample selection bias when the treatment variable is not randomly assigned resulting in systematic difference between individuals in the treatment group and those outside the treatment group. Endogeneity describes a situation in regression analysis when there is a correlation between an explanatory variable and the error term. This may arise when there is omission of some explanatory variables in the model specification. Endogeneity occurs when the explanatory variable is influenced by the dependent variable or both are jointly influenced by an unmeasured (omitted) variable. Endogeneity is widely regarded as an aspect of selection bias, and both lead to parameter estimates that are biased, hence the need to address it.

ESR is a two-step analysis where in the initial stage a probit model is employed to evaluate the factors affecting of adoption (the treatment) while in the next stage, a selectivity-corrected model is applied to assess the effect of adoption (the treatment) on land productivity (the outcome of interest). In this paper, we consider producers' choice to adopt IMV. In adoption, producers' choice to adopt IMV is considered a dichotomous choice and is based on the assumption that farm households seek to maximize the net benefits from adopting or not adopting a particular variety or technology (Heckman, 1979). The benefits derived from adopting IMV is given by A_i, which is latent or unobserved but can be modelled using observed farmer, farm and institutional characteristics (X_i). The adoption decision of a farmer may be represented using the following expression:

$$A_i^* = \alpha X_i + \varepsilon_i\ ,\ A_i = 1\ \text{ if }\ A_i^* > 0, \qquad A_i = 0, \text{otherwise} \tag{1}$$

where A_i represents the dichotomous adoption decision which is observable such that $A_i = 1$, if the individual adopts and $A_i = 0$ if the individual failed to adopt; α represents a vector of parameters and X_i denotes the farm-level and household characteristics hypothesized to determine adoption. ε_i represents a random error term and is uncorrelated with X_i.

The likelihood of an individual adopting IMV is shown as:

$$Pr(A_i = 1) = Pr(A_i^* > 0) = Pr\ (\varepsilon_i > -\alpha X_i = 1 - G(-\alpha X_i) \tag{2}$$

where G denotes the cumulative distribution function of ε_i. This model employs the probit link function and estimates a probit model for the dichotomous adoption decision.

The second-stage analysis encompasses the assessment of the effect of adoption on the outcome variable, i.e., land productivity. This involves the estimation of the following equation:

$$Y_i = \gamma Z_i + \delta A_i + \mu_i \tag{3}$$

where Y_i denotes land productivity, A_i is as previously defined, Z_i is a vector of explanatory variables influencing productivity, γ is a vector of unknown parameters, and μ_i represents the random error term which is not correlated with both Y_i and Z_i. As already stated, to account for selectivity bias, a two-regime regression model may be specified using a simultaneous equation model with endogenous switching, represented as:

Regime 1: $Y_{i1} = \gamma_1 Z_i + \mu_{i1}$ if $A_i = 1$ (4a)

Regime 2: $Y_{i0} = \gamma_0 Z_i + \mu_{i0}$ if $A_i = 0$ (4b)

where Y_{i1} and Y_{i0} denote land productivity for adopters and non-adopters, respectively, while Z_i denotes a vector of independent variables determining land productivity.

Due to farmer self-selection into the adopter and non-adopter groups, the covariance between ε_i in equation 1 and μ_{i1} and μ_{i0} in equations 4a and 4b may not be equal to zero, i.e., $corr(\mu_{ij}, \varepsilon_i) = \rho$. The selectivity corrected model of land productivity for adopters of IMV is given as follows:

$$E(Y_{i1}|A_i = 1) = \gamma_{1i} Z_i + \sigma_{1\varepsilon} \aleph_{1i} \tag{5a}$$

The expected value of the outcome variable for a farmer who chooses not to adopt (or the counterfactual case) is represented as:

$$E(Y_{i0}|A_i = 1) = \gamma_{0i} Z_i + \sigma_{0\varepsilon} \aleph_{0i} \tag{5b}$$

where $\aleph_{1i}$ and $\aleph_{0i}$ signify the inverse Mills' ratios or the selectivity terms. From equations 5a and 5b, we can obtain the average treatment effect on the treated (ATT) which is the difference between the expected outcomes of the two equations (equations 5a and 5b) as expressed by Di Falco et al. (2011):

$$\text{ATT} = E(Y_{i1}|A_i = 1) - E(Y_{i0}|A_i = 1) = (\gamma_{1i} - \gamma_{0i}) Z_i + \aleph_{1i}(\sigma_{1_\varepsilon} - \sigma_{0_\varepsilon}) \tag{6}$$

ESR may be estimated without the inclusion of instruments (Lokshin and Sajaia, 2004), but Di Falco et al. (2011) recommends the inclusion of at least one instrument to improve identification of the outcome variable. In this study, farm size was added to the adoption equation but excluded from the productivity equation to improve identification of the outcome variable. The use of farm size as an instrument was based on the fact that the production inputs and maize output were transformed into factor intensities and output per land area respectively, in line with Donkor and Owusu (2019).

4. Study Area and Data

Tolon district is found in the Northern Region of Ghana. The district is a major main food-producing area in northern Ghana. It is located in the Guinea Savanna and experiences a unimodal rainfall regime, starting in late May and ending in October which is preceded by a dry season during which bushfires are rampant, resulting in loss of soil nutrients. Low soil fertility due to continuous cropping, bush burning and minimal use of chemical fertilizer characterize the soils in the area. Manure is used by some farm households but in limited quantities. The district is home to key research institutions such as the Savanna Agricultural Research Institute (SARI) and the Animal Research Institute (ARI), which are involved in agricultural research in the savanna ecological area of the country. These two institutions, together with the University for Development Studies, which is also located in the district, have been instrumental in developing and disseminating improved crop varieties and animal breeds to enhance the productivity of farmers. The district is also endowed with irrigation facilities for crop production particularly in the dry season. Crops grown in the district include maize, rice, soybean, groundnut, cowpea, pepper, among others.

A multistage sampling technique was used to select communities and households for the study. First, Tolon district was purposively chosen among the districts in Northern region as a result of its status as a major food-producing area which is also endowed with irrigation facilities and the presence of research institutes. Hence, farmers in the area are expected to have exposure to and knowledge of improved agricultural technologies. Exposure to innovations and modern technologies plays a crucial role in farmers' adoption decisions. Next, eleven (11) communities within the district were chosen using simple random sampling. Subsequently, 30-35 farmers were sampled at random from each community to provide a total sample size of 340 farmers. Data were collected between February and March 2019 and covered activities for the 2018/2019 farming season. The data collection was carried out by trained enumerators using a pre-tested questionnaire. Participation in the interviews was voluntary in line with ethical considerations. The purpose of the research was first explained to the respondents who in turn gave their consent to participate in the interviews and volunteered information to the enumerators. The statistical analysis was performed using the econometric software Stata version 15.

Table 1 provides a description of the variables used included in the study. The respondents are mostly male farmers in their prime ages for agricultural production and cultivated about 1.6 hectares of maize. Per the land holding of the respondents, they can be described as smallholder farmers (Chamberlin (2007). As indicated by Seini and Nyanteng (2005), most Ghanaian farmers cultivate less than two hectares of land. Smallholder farmers typically produce for subsistence, and sell the surplus for cash. Maize is a major staple crop in Ghana and its cultivation for household consumption is a common practice, while farmers with larger farms produce for commercial purposes. Participation in off-farm work and access to credit and agricultural extension service were low among the respondents. The sampled farmers had low level of formal education as shown by the years of formal education. A little over half of the respondents self-reported their farms to be high in fertility while 42 percent adopted improved maize varieties. Averagely, the respondents had 2 cattle per household. The respondents produced 872 kg of maize per hectare using 427 kg of chemical fertilizer.

Table 1 Characteristics of the Sample

Variable description	Mean	Std. Dev.	Min	Max
Land productivity (output per hectare, kg/ha)	872.6	349.7	222.4	1977
Access to credit: 1 = access; 0 otherwise	0.397	0.490	0	1
Off-farm work: 1 = yes; 0 otherwise	0.294	0.456	0	1
Farmer group member: 1 = yes; 0 otherwise	0.465	0.499	0	1
Age in years	38.40	11.80	18	76
Education in years	2.315	4.287	0	16
Access to extension: 1 = access; 0 otherwise	0.291	0.455	0	1
Sex: 1 = male; 0 otherwise	0.935	0.246	0	1
Herd size (number of cattle)	2.356	4.762	0	23
Labour in man-days	77.14	44.85	19	260
Seed quantity in kilogramme	21.72	14.71	2	100
Fertilizer quantity in kilogramme	427.4	327.1	0	2250
Capital in Ghana cedis	68.23	45.49	0	395
Soil fertility dummy: 1 = fertile; 0 otherwise	0.541	0.499	0	1
Farm size in hectares	1.554	1.147	0.405	8.1
Crop variety: 1 = improved; 0 otherwise	0.424	0.495	0	1

5. Results and discussion

5.1 Sample Description According to Adoption Status

The characteristics of the sampled farmers according to adoption status is presented in Table 2. Adopters of IMV had higher land productivity which is consistent with a priori expectation. Improved varieties usually give higher yield than traditional varieties, but they require higher application of other inputs such as chemical fertilizer. Farmers who plant traditional varieties do so because these varieties require minimum external inputs such as chemical fertilizers and are usually well adapted to the local environmental conditions. However, in terms of yield, traditional varieties perform below the improved varieties.

Adopters of IMV were older and more educated than non-adopters. Education enhances technology adoption as shown by the extant literature. Adopters of IMV had higher participation in agricultural extension compared to non-adopters. Thus, access to extension correlates with technology adoption which agrees with the extant literature. Adopters also used more of the factor inputs used in maize production such as labour and fertilizer which are important inputs in maize cultivation. Bridging the technology adoption gap therefore requires a thorough understanding of the inhibiting factors such as resource endowment of farm households and access to services.

Table 2 Characteristics of the sample according to adoption status

Variable	Adopters		Non-adopters		Mean difference
	Mean	Std Dev	Mean	Std Dev	
Land productivity	943.4	378.2	820.5	318.2	122.9***
Access to credit	0.389	0.489	0.403	0.492	-0.014
Off-farm work	0.333	0.473	0.265	0.443	0.068
Farmer group membership	0.444	0.499	0.480	0.501	-0.035
Age	39.65	10.70	37.47	12.50	2.178*
Education	2.910	4.812	1.878	3.809	1.032**
Access to extension	0.403	0.492	0.209	0.408	0.194***
Sex	0.903	0.297	0.959	0.198	-0.056**
Herd size	2.188	4.246	2.480	5.115	-0.292
Labour in man-days	84.26	46.53	71.91	42.94	12.36***
Seed quantity	20.91	15.54	22.31	14.07	-1.395
Fertilizer quantity	463.7	391.5	400.8	268.1	62.95*
Capital	62.70	39.89	72.29	48.90	-9.599*
Fertility dummy	0.542	0.500	0.541	0.500	0.001
Farm size	1.593	1.311	1.525	1.012	0.069

5.2 Determinants of Improved Variety Adoption

The factors affecting of IMV adoption are presented in Table 3. Adoption of IMVs increased with farmers' years of formal education. Dokyi et al. (2021) and Danso-Abbeam et al. (2017) obtained similar results in their studies in northern Ghana. Education influences adoption decisions of farmers according to the extant literature. Education enhances the knowledge and skills of producers and exposes the farmer to new ideas and techniques that enhance productivity. Farmer with the ability to read and write are able to seek and acquire advice on their farming activities to enhance farm performance.

In addition, IMV adoption increased with access to agricultural extension which is in sync with the results of Dokyi et al. (2021) and Anang et al. (2020b) in northern Ghana. Extension agents play a key role in facilitating technology adoption. By means of extension advice, producers gain knowledge of improved practices and their benefits, thus promoting adoption. Extension agents serve as conduits between producers and research stations and facilitate adoption by explaining the benefits of modern technologies to farmers and showing them how to apply these technologies to improve their level of production and productivity.

Contrary to expectations, adoption of IMVs decreased with farmer group membership at 5% significant level. The result is contrary to expectation but aligns with the assertion of other authors that farmer groups sometimes become less effective due to free-riding behaviour of some members (Mwangi and Kariuki, 2015), politicization of the groups and deviation from their main functions (Anang et al., 2022). The results of Ahmed and Anang (2019) further buttress the findings of this study. In their study in the Tolon district, the authors showed that producer groups in the district were ineffective in promoting technology adoption.

The findings further reveal that uptake of IMVs increased with farm size. The finding synchronizes with that of Dokyi et al. (2021) as well as Ogada et al. (2014) in their studies in northern Ghana and Kenya respectively. Farmers with larger acreages are expected to be more progressive and therefore more likely to be adopters on modern technology. Farmers with very small acreages may be part-time producers or less-endowed farmers and thus less likely to have the wherewithal to finance the cost of adopting new technologies.

Table 3 Factors Affecting Improved Variety Adoption

Variable	Coefficient	Std. Error
Age	0.008	0.007
Sex	-0.446	0.315
Education (years)	0.043**	0.017
Off-farm work	0.128	0.159
Access to credit	-0.010	0.168
Access to extension	0.603***	0.199
Farmer group membership	-0.387**	0.167
Herd size	0.003	0.018
Farm size (ha)	0.438***	0.101
Labour man-days	0.458**	0.186
Seed quantity	-0.744***	0.175
Fertilizer quantity	0.281*	0.162
Capital	-0.034	0.045
Fertility dummy	0.481**	0.189
Constant	-2.440**	1.217

Note: ***, ** and * refer to 1%, 5% and 10% significance level, respectively.

Adoption of IMVs increased with the household's man-days of labour used in production. The result is expected because maize cultivation is labour-intensive, and IMVs tend to require higher deployment of labour. Improved maize varieties typically require far more regimented management practices, and therefore requires timely and sufficient labour availability for the critical farm operations such as weed control, chemical application, among others.

Improved maize variety adoption also increased with quantity of fertilizer applied. Maize is a heavy-feeder and requires high doses of fertilizer to achieve optimal yield. Typically, improved varieties require higher fertilizer application rates compared to traditional varieties. Hence, all things being equal, farmers who adopt IMVs are expected to also apply chemical fertilizer, resulting in a positive association between fertilizer use and improved seed adoption.

The study further indicated that adoption of IMVs decreased with quantity of seed planted by the farmer and highly significant at 1% level. The result indicates that as the cost of seeds become prohibitive, farmers are likely to rely on traditional seeds that come at an extra cost. Hence, farmers who cannot afford the cost of improved seed have a lower likelihood to adopt IMVs. It is therefore important to make improved seeds affordable to enhance adoption.

Farmers' perceived fertility of their soils had an influence on their adoption decisions. Adoption was higher for producers who perceived that the soil on which they produced their crops was fertile, in line with expectation. Dokyi et al. (2021) also observed that uptake of modern seed maize technology was higher for farmers who perceived their soils to be fertile compared to producers who perceived their soils to be infertile or moderately fertile. Improved maize varieties require more fertile soils to produce optimum yield hence farmers are less likely to cultivate improved varieties on farms perceived to be poor in fertility.

5.3 Determinants of Land Productivity

The factors affecting of land productivity are shown in Table 4. Female adopters reported higher productivity compared to male adopters suggesting that female farmers in this study have the capacity to be more productive in production. Usually, female farmers face resource constraints in production because of the nature and traditional setting of rural farm households whereby resources are owned and controlled largely by men. Incentivizing women farmers with input subsidies are therefore necessary to empower female farmers to enhance their productive capacity.

Table 4 Determinants of Land Productivity

Variable	IMV adopters		IMV non-adopters	
	Coefficient	S. E.	Coefficient	S. E.
Age	0.0001	0.003	0.003	0.003
Sex	-0.212*	0.125	0.010	0.161
Education (years)	0.004	0.007	0.013	0.008
Farmer group membership	-0.179**	0.091	-0.177**	0.073
Off-farm work	0.009	0.063	0.141*	0.074
Access to credit	-0.031	0.077	-0.167**	0.073
Access to extension	-0.005	0.108	0.232**	0.093
Herd size	0.030***	0.009	0.009	0.007
Labour man-days	0.411***	0.092	0.198**	0.085
Seed quantity	-0.130	0.088	-0.086	0.064
Fertilizer quantity	0.099	0.096	0.063**	0.028
Capital	-0.016	0.017	0.020	0.022
Fertility dummy	-0.027	0.087	0.137*	0.081
Constant	4.981***	0.773	5.735***	0.481
Diagnostic statistics				
/lns1	-1.047***	0.109		
/lns2	-0.692***	0.067		
/r1	0.353	0.478		
/r2	1.755***	0.231		
sigma_1	0.351***	0.038		
sigma_2	0.501***	0.034		
rho_1	0.339	0.423		
rho_2	0.942***	0.026		
LR test of indep. eqns.: chi2(1)	26.02***			

Note: ***, ** and * refer to 1%, 5% and 10% significance level, respectively.

Farmer-based association membership was negatively associated with land productivity for both adopters and non-adopters, suggesting a negative influence of farmer groups on land productivity. The result is contrary to expectation but supports the assertion of other authors that farmer groups are sometimes ineffective due to free-riding behaviour, politicization and deviation from their core duties as a group.

Participation in off-farm work increased land productivity of non-adopters on IMVs at 10% level. The influence of off-farm work on productivity has been reported to be positive in some instances and negative in other instances. This is because off-farm work can result in labour-loss effect thus potentially decreasing farm performance or enhance liquidity of the farm household, thus potentially increasing farm performance. The result of this study suggests that off-farm work may be associated with improvement in liquidity of the farm household resulting in higher productivity.

Contrary to expectation, land productivity of non-adopters decreased with access to credit. Diversion of credit is a common problem in smallholder farming where poverty levels are high and needs are multifaceted. Hence, access to credit may not necessarily translate into the desired outcome due to credit diversion and other factors.

In line with expectation, access to extension enhanced the productivity of farmers, albeit for the non-adopting category only. Extension agents play a major role in promoting farm productivity of producers through extension education on good agronomic and management practices. There is therefore the need to augment the number of extension staff to improve the extension agent to farmer ratio as a means to enhance agricultural productivity among smallholder farm households. Lee et al. (2017) therefore called for more investment in public extension service.

Herd size improved land productivity at 1% significance level for adopters of IMVs. In smallholder agriculture, ownership of cattle plays a role in production, such as land preparation, carting of goods and provision of animal manure to fertilize the cropland. Herd ownership, used as proxy for wealth status, was found to increase the productivity of rice producers in northern Ghana (Anang, 2017). This implies that, all things being equal, the wealthier the farm households, the higher the level of farm productivity because wealthier farm households are better placed to afford the cost of productive inputs to improve farm yields.

A major outcome of this study is the influence of labour on land productivity. Land productivity increased with labour man-days for adopters and non-adopters alike, in line with *a priori* expectation. Smallholder agriculture is generally labour-intensive, with limited ability to hire-in labour. Maize production in particular is an intensive activity and requires high labour input especially at critical stages of production such as land preparation, planting, weed control and chemical application. Labour-constrained households are likely to experience labour shortages and therefore a challenge in carrying out such critical farm operations timeously. The study's finding agrees with Owusu (2020) who observed that labour plays a crucial role in increasing productivity.

Quantity of fertilizer applied had a positively significant influence on land productivity of non-adopters but a positive and non-significant influence on land productivity of adopters. Adopters may not have applied fertilizer to the threshold that is required to enhance productivity since IMVs typically require higher application of chemical fertilizer to produce optimal yield. The data showed that adopters cultivated on average 1.6 ha of maize and used 464 kg of chemical fertilizer. Non-adopters on the other hand cultivated 1.5 ha of maize and applied 401 kg of chemical fertilizer.

Farmers' self-reported soil fertility status influenced land productivity of non-adopters of IMVs at 10% significance level. Non-adopters who perceived their soils to be fertile were more productive than farmers who perceived their soils to have lower fertility. The perception of adopters on the other hand did not influence their level of productivity.

5.4 Treatment Effects Estimates of the Impact of Adoption on Land Productivity

The estimates of the impact of adoption on land productivity are indicated in Table 5. The dependent variable is in logged form hence the results are interpreted as percentages. From the results, adoption of IMV enhances land productivity by 10.7 – 14.1 percent for adopters of IMVs. On the other hand, adoption of IMV enhances land productivity of the average maize farmer in the study area by 7.7 – 11.6 percent. The results reinforce the critical role of modern varieties in enhancing crop productivity. In particular, this study's value is in the fact that it provides the percentage increase in productivity from the adoption of IMVs. Armed with this information, farmers can make decisions regarding the crop variety to adopt. The result of this study is buttressed by other findings. Anang (2019) showed that uptake of modern varieties enhanced land productivity of small-scale rice farmers in northern Ghana by 459.4 kg/ha.

Dokyi et al. (2021) also noted that uptake of IMVs enhanced farmers technical efficiency and land productivity by 16.1% and 33.8% respectively in Ghana's Tolon district.

Table 5 Impact of IMV Adoption on Land Productivity

Matching algorithm	ATT estimation		ATE estimation	
	Estimate	Std. Err.	Estimate	Std. Err.
IPWRA	0.107**	0.049	0.077*	0.047
RA	0.107**	0.049	0.077*	0.047
IPW	0.141***	0.053	0.116***	0.044

Note: ***, ** and * denote statistical significance at 1%, 5% and 10% respectively. Numbers in parentheses are standard errors. IPWRA is inverse-probability-weighted regression adjustment. RA is regression adjustment. IPW is inverse-probability-weighted.

6. Conclusion and Recommendations

Adoption of improved agricultural technologies like IMVs is crucial to improve land productivity, food security and economic development in many low-income countries such as Ghana. In this paper, an endogenous switching regression model augmented with a treatment effect model was employed to evaluate adoption determinants and impact of IMVs among a sample of farmers in Tolon district of Ghana. The results from the modelling revealed that adopters of IMVs had higher land productivity compared to those who adopted traditional varieties. The following key policy issues emerge from the study.

First, improving soil health is key to increasing adoption of improved varieties among small-scale farmers. Adoption is enhanced by perceived soil fertility level and quantity of fertilizer applied, both of which are related to soil health. Hence, efforts to promote soil health in the study area will go a long way to promote adoption of improved varieties. Measures to enhance the productivity of small-scale maize farmers should prioritize the dissemination of improved maize varieties to farmers, and complement this with adequate supply of chemical fertilizer and training on soil fertility management.

Second, developing the human capital of farmers through education and access to extension services is critical to promote adoption of improved varieties. From the study's findings, access to agricultural extension and years of education both had a positive influence on adoption, implying that improving the human capital through education alongside access to agricultural information and training promote adoption. Hence, attention should be given to increasing smallholders' access to extension services as well as promoting access to education especially in rural areas to enhance numeracy among farm households. In low-income countries like Ghana, farmers' awareness and level of knowledge of improved varieties depend largely on extension advisory services, hence the agricultural extension departments at the district level should organize on-farm trials for farmers to raise their level of awareness and uptake of improved maize seeds. The agricultural extension department should also intensify public education using radio, mobile phones, farmers' fora and community durbars to enhance and reinforce farmers' knowledge of modern agricultural technologies. Besides increasing access to extension, priority should also be given to increasing access to education in rural communities since education is critical to the uptake of farm technologies. Education improves the human capital of the farmer to become well informed and better placed to understand modern technologies as well as seek relevant information to improve production. The provision of formal education to the youth in rural farming communities should be pursued to encourage more young people to take up farming as a business. Older farmers could be taught numeracy using informal/non-formal educational approaches to enhance their decision-making. These measures when taken in tandem are expected to increase adoption of improved maize varieties which has been shown to exert a positive effect on land productivity of smallholder farmers.

References

Abdul-Mumin, Y., & Abdulai, A. (2022). Social networks, adoption of improved variety and household welfare: evidence from Ghana. European Review of Agricultural Economics, 49(1), 1-32.

Adu, M. O., Yawson, D. O., Armah, F. A., Abano, E., & Quansah, R. (2018). Systematic review of the effects of agricultural interventions on food security in northern Ghana. 1–17.

Alhassan, A., Salifu, H., & Adebanji, A. O. (2016). Discriminant analysis of farmers' adoption of improved maize varieties in Wa Municipality, Upper West Region of Ghana. SpringerPlus (2016) 5, 1514. https://doi.org/DOI 10.1186/s40064-016-3196-z.

Anang, B. T. (2017). Effect of non-farm work on agricultural productivity: Empirical evidence from northern Ghana. WIDER Working Paper 2017/38.

Anang, B. T. (2019). Are adopters of improved rice varieties more productive than non-adopters? Empirical evidence from northern Ghana. Ghana Journal of Development Studies, 16 (1), 92-107.

Anang, B. T., Alhassan, H., & Danso-Abbeam, G. (2020a). Estimating technology adoption and technical efficiency in smallholder maize production: A double bootstrap DEA approach. Cogent Food & Agriculture, 6(1), 1–16. https://doi.org/10.1080/23311932.2020.1833421.

Anang, B. T., Bäckman, S., & Sipiläinen, T. (2020b). Adoption and income effects of agricultural extension in northern Ghana. Scientific African, 7 (2020) e00219. https://doi.org/10.1016/j.sciaf.2019.e00219.

Anang, B. T., Dokyi, E. O., Asante, B. O., Donkoh, S. A. (2022). Technical efficiency of resource-poor maize farmers in northern Ghana. Open Agriculture 2022; 7, 69–78. https://doi.org/10.1515/opag-2022-0075.

Antwi-Agyei, P., Dougill, A. J., Stringer, L. C., & Ardey, S. N. (2017). Adaptation opportunities and maladaptive outcomes in climate vulnerability hotspots of northern Ghana. Climate Risk Management, 19, 83-93. https://doi.org/10.1016/j.crm.2017.11.003

Asante, F. A., & Amuakwa-Mensah, F. (2015). Climate change and variability in Ghana: Stocktaking. Climate, 3(1), 78–99. https://doi.org/10.3390/cli3010078.

Bellon, M. R., Hundie, B., Azzarri, C., & Caracciolo, F. (2020). To diversify or not to diversify, that is the question. Pursuing agricultural development for smallholder farmers in marginal areas of Ghana. World Development, 125, 104682. https://doi.org/10.1016/j.worlddev.2019.104682.

Bruce, A. K., Donkoh, S. A., & Ayamga, M. (2014). Improved rice variety adoption and its effects on farmers' output. Journal of Development and Agricultural Economics, 6(6), 242-248. https://doi.org/10.5897/JDAE2013.0544.

Chamberlin, J. (2007) Defining smallholder agriculture in Ghana: Who are smallholders, what do they do and how are they linked with markets? GSSP Background Paper 6. Washington, DC: IFPRI.

Damba, O. T., Gershon, I., Ansah, K., Donkoh, S. A., Alhassan, A., Mullins, G. R., Yussif, K., Taylor, M. S., & Tetteh, B. K. D. (2020). Effects of technology dissemination approaches on agricultural technology uptake and utilization in Northern Ghana. Technology in Society, 62, 101294. https://doi.org/10.1016/j.techsoc.2020.101294

Danso-Abbeam, G., Bosiako, J. A., Ehiakpor, D. S., & Mabe, F. N. (2017). Adoption of improved maize variety among farm households in the northern region of Ghana. Cogent Economics & Finance, 5(1). https://doi.org/1416896.

Dokyi, E., Anang, B. T., & Owusu, V. (2021). Impacts of Improved Seed Maize Technology Adoption on Productivity and Technical Efficiency in Northern Ghana. Open Economics, 4, 118–132.

Donkoh S.A., Azumah S.B., A. J. A. (2019). Adoption of improved agricultural technologies among rice farmers in Ghana: a multivariate probit approach, Ghana Journal of Development Studies, 16 (1), 46–67. https://www.ajol.info/index.php/gjds/article/%0Aview/186964

Donkoh, S. (2011). Technology Adoption and Efficiency in Ghanaian Agriculture: A Microeconomic Study: USA LAMBERT Academic Publishing.

Donkor, E., & Owusu, V. (2019). Mineral fertiliser adoption and land productivity: Implications for securing stable rice production in northern Ghana. Land, 8(4), 59.

Donkor, E., Owusu, V., & Owusu-Sekyere, E. (2014). Assessing the determinants of adoption of improved cassava varieties among farmers in the Ashanti Region of Ghana. Africa Development and Resources Research Institute Journal, 5(2), 121-133.

GoG. (2010). Plants and Fertiliser Act, 2010 (Act 803). Accra: Ministry of Food and Agriculture, Government of Ghana (GoG).

Horna, D., & Nagarajan, L. (2010). Seed sector development in Ghana: case of rice and maize. Final report submitted to Ghana Strategy Support Program. International Food Policy Research Institute, Accra, Ghana. https://doi.org/DOI: http//dx.doi.org/10.1016/j.njas.2017.07.004.

Kamara, A., Conteh, A., Rhodes, E. R., & Cooke, R. A. (2019). The relevance of smallholder farming to African agricultural growth and development. African Journal of Food, Agriculture, Nutrition and Development, 19(1), 14043-14065. https://doi.org/10.18697/ajfand.84.BLFB1010.

Lee, H. (2020). The Current Status and Constraints of Drought-Tolerant Maize Adoption in Uganda. The Open Agriculture Journal, 14(1), 98-107.

MoFA (Ministry of Food and Agriculture) (2017). Planting for Food and Jobs, strategic plan for implementation (2017-2020). Republic of Ghana.

Mwangi M, Kariuki S. (2015). Factors determining adoption of new agricultural technology by smallholder farmers in developing countries. Journal of Economics and Sustainable Development, 6(5), 208–16.

Nyamekye, A., Tian, Z. and Cheng, F. (2021) Analysis on the Contribution of Agricultural Sector on the Economic Development of Ghana. Open Journal of Business and Management, 9, 1297-1311. doi: 10.4236/ojbm.2021.93070.

Ofosu, G., Dittmann, A., Sarpong, D., & Botchie, D. (2020). Socio-economic and environmental implications of Artisanal and Small-scale Mining (ASM) on agriculture and livelihoods. Environmental Science and Policy, 106 (April 2019), 210–220. https://doi.org/10.1016/j.envsci.2020.02.005.

Ogada, M. J, Mwabu, G., & Muchai, D. (2014). Farm technology adoption in Kenya: a simultaneous estimation of inorganic fertilizer and improved maize variety adoption decisions. Agricultural and Food Economics, 2(1):12. doi:10.1186/s40100-014-0012-3.

Owusu, R. (2020). Efficiency differential in rice production technologies in Ghana: a comparison between stochastic and bias-corrected metafrontier approaches. International Journal of Food and Agricultural Economics, 8(1), 97-110.

Poku, A. (2018). Why do maize farmers in Ghana have a limited choice of improved seed varieties? An assessment of the governance challenges in seed supply. Food security, 10(1), 27-46.

Ragasa, C., Dankyi, A., Acheampong, P., Wiredu, A. N., Chapo-to, A., Asamoah, M., & Tripp, R. (2013). Patterns of adoption of improved maize technologies in Ghana. GSSP working paper no. 35. International Food Policy Research Institute, Washington.

Salifu, H., Alhassan, A., & Salifu, K. (2015). Determinants of farmers adoption of Improved maize varieties in the Wa Municipality. American International Journal of Contemporary Research, 5(4), 27-35.

Seini, A. W. & Nyanteng, K. V. (2005). Smallholders and structural adjustment in Ghana. In: Djurfeldt, G., Holmen, H., Jirström, M. & Larsson, R. (eds.), The African food crises: Lessons from the Asian Green Revolution. UK: Biddles Ltd, King's Lynn.

Simtowe, F., Amondo, E., Marenya, P., Sonder, K., & Erenstein, O. (2019a). Impacts of drought-tolerant maize varieties on productivity, risk, and resource use: Evidence from Uganda. Land Use Policy, 88, 104091.

Spielman, D. J., & Smale, M. (2017). Policy options to accelerate variety change among smallholder farmers in South Asia and Africa South of the Sahara. IFPRI Discussion Paper 1666. Washington, D.C.

Walker, T., & Alwang, J. (2015). Crop Improvement, Adoption and Impact of Improved Varieties in Food Crops in Sub-Saharan Africa. Rome: CGIAR and CABI.

Wiredu, A. N., Gyasi, K. O., Abdoulaye, T., Sanogo, D., & Langyintuo, A. (2010). Characterization of maize producing households in the Northern Region of Ghana. CIMMYT.

World Bank (2016). Enabling the business of agriculture 2016: Comparing regulatory good practices. Washington: World Bank Group.

Yeboah, T., & Flynn, J. (2021). Rural Youth Employment in Africa: An Evidence Review. Boosting Decent Employment for African Youth. Evidence Synthesis Paper Series, 10/2021. https://includeplatform.net/wp-content/uploads/2021/05/Rural-youth-employment-in-Africa-evidence-review.pdf.