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Welfare impacts of adoption of improved soybean varieties in Northern Ghana

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ABSTRACT

Soybean is an integral part of Ghana's smallholder cropping systems and show significant promise for combating declining soil fertility, improving household food security and welfare. Many yield-enhancing and improved soybean varieties (ISVs) have been bred and distributed in Ghana. However, little is known about the predictors of ISVs' adoption and the magnitude of their effects on productivity and household welfare. This paper explores the welfare effects of adopting ISVs using data collected from 330 soybean farmers in Northern and Savannah regions of Ghana. The results indicated that about 47% of the sampled farming households have adopted the ISVs. Adoption of ISVs was influenced by factors such as farm size, engagement in non-farm economic activities, membership of farmer group and household asset. Using both Instrumental Variable two-stage least square (IV-2sls) and Generalized Method of Moments (GMM) estimators to correct for both observed and unobserved differences in household characteristics, the adoption of ISVs led to significant gains in productivity/yields and food consumption expenditure per capita (welfare indicators). Overall, the findings suggest that ISVs need to be scaled up in order to have a strong influence on the welfare of smallholder farmers in Ghana.

Keywords: Adoption; soybean; IV-2SLS, welfare, Ghana

INTRODUCTION

Agriculture provides a living for the majority of households in developing countries. Despite this, agricultural production is low, and the food system has yet to undergo a significant transformation (Anderson *et al.*, 2019). In a number of previous and contemporary development programs, increasing agricultural output has been advocated as a measure of improving farmers' well-being (Fugile *et al.*, 2012, Martey *et al.,* 2019). Some of these interventions include increased fertilizer supply, improved seed varieties, and enhancing farmers' managerial and technical skills. As a result, improving agricultural productivity is a top priority for Ghana's government in order to increase food security, public health, and welfare.

In Ghana, improvements in conventional and staple crop varieties, land, soil, and water management practices, and input and fertilizer application through subsidy packages have been the most common forms of agricultural technology (Tamimie and Goldsmith, 2019). As the patterns of climate change is expected to worsened, it directly affects production of crops that smallholder Ghanaian farmers, particularly those in the northern part of the country are currently cultivating, which translates into loss of welfare. One of the significant food and cash crop cultivated by farmers in northern Ghana, which is susceptible to climate variability is soybean. A growing number of Ghanaian farmers recognize the economic relevance of soybeans (Asodina *et al.,* 2021), despite the fact that the crop is still relatively new to the country. Such economic significance could be derived from both market and non-market factors (Biam *et al.,* 2013, Dogbe *et al.,* 2013). One of the crop's non-market features is its ability to fix atmospheric nitrogen through Biological Nitrogen Fixation (BNF) (Chianu *et al.,* 2009, Mohammed *et al.,* 2016). Because of the nutrient inadequacy of cultivated soils in Northern Ghana, the BNF characteristic plays an important role in reducing the cost of production inputs, particularly fertilizer. A smart agriculture strategy that conserves soil fertility and increases the production of other basic food crops including rice, maize, sorghum and millet for rural livelihood sustenance may be found in soybean production. In order to promote the cultivation of soybean in Ghana, many international organizations have implemented breeding programs to enhance the varietal attributes of the crop. For example, International Institute of Tropical Agriculture (IITA) and National Agricultural Research Systems (NARS) of Ghana collaborated to conduct extensive soybean trials in the 1980s. As a result of this, certain cultivars have been commercially available since 1985 (MoFA, 2019). Since soybean is a relatively new crop with a growing worldwide demand as nutritious food, animal feed and edible oil, governments and development organizations and funders see the potential for soybean to produce new income for smallholder farmers, and consequently improved their welfare.

Many initiatives to scale up better soybean varieties have been made, but there is paucity of scientific evidence of their adoption and impact on farmers' welfare. Despite the substantial body of literature on the topic of crop variety adoption and its effects, the majority of these studies (e.g., Danso-Abbeam *et al.,* 2022b, Bello *et al.,* 2021, Sinyolo 2020, Khonje *et al.,* 2018) have focused on other crops (rice, maize, wheat, pigeon peas, sweetpatatoes, and groundnuts) in other African countries like Nigeria, Uganda and Kenya, among others. There is insufficient studies on the impact of ISVs variety adoption on welfare, particularly in Ghana. Moreover, even though there have been a plethora of research on the effects of using improved crop cultivars in various SSA countries, we have no way of knowing how relevant they are to the situation in Ghana. This is due to variations in available resources, social and economic standing of farmers across nations, regions, and even within communities in the same country. Consequently, the purpose of this study is to examine the welfare impacts of adopting enhanced soybean varieties in Northern Ghana. Households' welfare was proxy by soybean yield/productivity in kilograms per hectare and food consumption expenditure per capita. In the fields of food security, nutrition, health, and poverty, expenditure on food items is central to some of the most popular welfare indices (Zezza *et al.,* 2017). In low-income nations, it accounts for over half of household budgets (USDA, 2011). The study also employed rigorous econometric technique that has the potential to address some of the impact evaluation assessment in an observational data such as self-selection bias and endogeneity. Thus, an instrumental variable approach, precisely, IV-2SLS as a primary estimator and GMM as a robustness check of the estimates. This study also has a number of benefits for both soybean industry development and empirical literature. The importance of farm-specific, socioeconomic, and institutional factors in promoting the uptake of soybean improved varieties is brought to light. Findings from this study will be useful to international development agencies as well as policymakers in creating strategies to enhance the uptake of improved soybean varieties among smallholder farmers in order to improve their welfare. This is important because of the many domestic and industrial uses of soybean, as well as Ghana government's main agriculture policy, 'Planting for Food and Jobs (PFJ). Lastly, the findings of this study will help fill a gap in the research on the adoption of improved soybean varieties in Sub-Saharan Africa and Ghana in particular.

METHODOLOGY

Study area, sampling and data collection techniques

This study collected primary data from 330 soybean farmers in Savannah and Northern regions of Ghana in 2020. The Northern region has 16 districts, whereas the Savannah region has seven districts. The data was collected in 12 communities across four districts (Saraga, Cheriponi, Saboba, and Gushiegu). The districts have the highest soybean production in the country. The climate of the regions, however, is rather dry, with a single rainy season that lasts from May to October. The main crops grown in the regions include yam, maize, millet, guinea corn, rice, groundnuts, beans, soybeans, cowpea, and cotton (SRID, MoFA 2021). A structured questionnaire was used to obtain primary data. According to a list of communities compiled by the Ministry of Food and Agriculture (MoFA), the districts have approximately 3,100 farmers producing soybeans. In order to choose respondents for the study, a multistage sampling process was used. The study purposefully selected four districts for the investigation in the initial stage. The second stage involved the deliberate selection of 12 communities based on their role in soybean production. In the last stage, the study used a simple random sample technique to choose roughly 30 farmers (comprising of both adopters and non-adopters of ISV) from each community, leading a total sample of 330 farmers cultivating soybeans. There were 155 adopters of ISVs and 175 non-adopters of ISVs, representing 47 and 53%, respectively.

Empirical strategy and model specification

In this study, ISV and other demographic, farm-specific, and institutional factors are used to model household welfare. The baseline model can be expressed as:

$$Y_i = \beta_0 + \beta_i X_i + \chi_i A_i + \varepsilon_i \qquad (1)$$

where Y_i denote household welfare indicator, X_i denote a set household demographic, farm-specific and institutional factors, and A_i is the binary indicator for adoption of ISVs (1 for adoption, 0 otherwise) and β_i and χ_i are the point estimates for the other variables and the adoption variable, respectively. Following empirical literature relating to the determinants of household welfare, X_i contains variables such as age of the respondent, household size, educational attainment, farm size, and access to agricultural credit facilities, among others.

The primary objective of this study is to estimate δ_i (the coefficient of Z_i), as accurately as possible, which is an indication of how adoption of ISVs impacts household welfare. The assumption that adoption of ISVs is determined exogenously, as in equation [1], may lead to inaccurate and inconsistent estimations of welfare. This is due to the fact that households voluntarily choose to cultivate ISVs (i.e. self-select themselves into treatment), making treatment not randomly assigned. This is referred to as self-selection bias. Self-selection bias may emanate from the adopters of ISVs having different set of observed features as compared to non-adopters. Another reason for self-selection bias is that households may choose to adopt or not depending on their availability of productive resources. Self-selection bias creates an econometric issue when attempting to use observational data to estimate the effect of farm technology adoption on a particular outcome variable (Shiferaw *et al.,* 2014). Moreover, household adoption decisions are also likely to be influenced by unobserved characteristics (e.g., managerial skills and motivation) that may correlate with the welfare variable when the treatment (adoption of ISVs) is not randomly assigned. The fact that adoption of ISVs is not randomly assigned across the farming households and may be influenced by unobserved characteristics implies that direct estimation of equation [1] may lead to biased and inconsistent estimate of the coefficient of Z_i. That is, adoption is potentially endogenous to the outcome variables. The endogenous nature of the treatment variable (adoption status) also suggests that estimating equation [1] with ordinary least square (OLS) estimator will render the estimate biased and inconsistent.

In order to address the problem of self-selection bias and endogeneity, the study employs an instrumental variable (IV) approach, specifically the IV two-stage least square (IV-2SLS) estimator. The IV-2SLS is a technique that uses two estimating steps, as the name implies. An endogenous variable in the outcome (welfare) equation [Eq. 1] is regressed on all exogenous variables, including instruments used to identify the equation, in the first stage. These instruments are variables that significantly explain the changes in adoption but redundant in determining the changes in the outcome variable (welfare). The instruments used here are membership of farmer group and distance from homestead to farm. Many possible variables could serve as instruments, according to Wooldridge (2010), hence there is no single best choice for an instrumental variable. Thus, there is no 'rule of thumb' that point to specific variables as instruments. However, by intuition, these instruments are attractive for the following reasons: (1) farmer group serve as a conduit for information dissemination on innovations as farmers share information among themselves during group meetings; (2) the closer a farmer's farm is from the homestead, the higher the likelihood of paying great attention, hence, the higher the probability of adoption. More importantly, the instruments were tested via the use of falsification test suggested by Di Falco (2011) and were found to be valid[1]. The preliminary results indicated that the two variables used as instruments were significant in the treatment equation ($Chi^2 = 18.61, p = 0.000$) but not significant in the outcome equations: yield ($F = 0.470, p = 0.626$) and food consumption expenditure per capita ($F = 0.690, p = 0.501$).

The endogenous variable (A_i) can be expressed in terms of exogenous variables and instruments in a regression equation:

$$A_i = \delta_0 + \delta_i X_i + \pi_i Z_i + \mu_i \quad (2)$$

Z_i indicates the vector of the instruments, π_i denotes the point estimate and μ_i is the error term. The IV-2SLS begins with an estimation of Equation [2]. The predicted values from the first step were fed into an IV estimator, which was used to execute Equation [1] using the expected values. The two stages of the IV-2SLS was estimated simultaneously using STATA. For consistent and robustness of the estimates, the IV-2SLS estimator was complemented with the GMM.

RESULTS AND DISCUSSIONS

Definitions of variables and summary statistics

The study followed many pieces of literature (e.g,, Ali and Awade 2019, Tufa *et al.,* 2019, Martey *et al.,* 2020, Sinyolo 2020, Adams *et al.,* 2021, Bello *et al.*, 2021,) on agrarain adoption and impact evaluation to select variables hypothesized to influence farmers' decision on adoption of improved varieties of soybean. Table 1 provides the selected indicator of welfare and summary statistics of the selected variables. The yearly food consumption expenditure, which is the sum of a household's expenses over the previous year, was used to determine the per capita food consumption expenditure. Cost of food (sum of consumption of home-produced foods, purchased food andgifts food) were aggregated monthly to get the annual consumption spending. Adjusted for adult equivalents, the per capita food consumption expenditure is the amount of money spent on food each person consumes, leading to food consumption expenditure per capita used in the study. Soybean productivity/yield was measured as quantity of soybean cultivated in kilograms per hectare (kg/ha). Table 1 indicates that only 47% of the sampled farmers adopted the ISVs in the previous farming season. This indicates that there has been a low level of ISVs' adoption. Adoption in Sub-Saharan Africa often moves at a leisurely pace, therefore it may take some time to see a significant shift in adoption levels of improved crop varieities. This result can be compared with those obtained by Martey *et al.* (2020) who reported an improved maize adoption rate of 52% in Ghana, and Danso-Abbeam *et al.* (2022a) who observed about 46% adoption rate of dual-purpose sweetpotato varieties in rural Rwanda. According to the findings, ISV adopters had greater levels of productivity and food consumption expenditure per capita than non-adopters. However, no statistically significant differences exist between the values of adopters and non-adopters.

The mean age of soybean farmers is roughly 45 years, with a statistical difference between those who have adopted ISVs (about 44 years) and those who have not (46 years). On the average, around 26% of soybean farmers in the study area had formal education and about 85% are living with their spouses as married couples. It is also worth noting that on average, adopters of improved verities of soybean have a larger household size (roughly 9) than those who did not adopt the improved varieties (about 8). The proportion of adopters engaged in non-farm economic activities is significantly higher than non-adopters, while 38% of the sampled farmers accessed agricultural credit. Adopters had significantly more extension contacts (2.23) than non-adopters (2.06), and significantly most adopters are members of farmer groups than non-adopters, according to the descriptive statistics. On average, the distance between farmers' residences and their farm plots is about 2.4 kilometers, whereas the distance between their homes and the market is roughly 6 kilometers. Household asset index was calculated as a composite measure of some selected household assets such as productive assets (sickle, axe, hoe, plough, tractor, irrigation facilities, etc.) and non-productive assets (bicycle, motorbike, tricycles, television, radio, refrigerator, cell phones, etc.). All the selected variables are coded into binary and through the use of principal component analysis (PCA), a single continuous index was generated. The average asset index was 1.44, and adopters of ISVs have significantly higher value of asset index than the non-adopters.

Table 1: Description and summary statistics of household characteristics

Variables	*Pooled*	*Adopters*	*Non-adopters*	*t-value*
Treatment variable				
Adoption of improved soybean verities	0.469	-	-	-
Outcome variables				
Food consumption expenditure per capita (GH¢)	1,720.92	1,727.52	1,713.33	0.105
Productivity/yield (kg/ha)	1,476.72	1,481.42	1,471.41	0.152
Explanatory variables				
Gender (Male = 1, 0 otherwise)	0.686	0.725	0.652	1.45
Age (in years)	45.09	43.62	46.38	1.78[c]
Marital status (Married =1, 0 otherwise)	0.856	0.856	0.862	0.311
Formal education (Formal education = 1, 0 otherwise)	0.255	0.269	0.243	0.541
Household size (count)	8.049	8.618	7.547	1.836[c]
Farm size (hectares)	2.133	2.094	2.169	0.328
Non-farm activities (Yes = 1, 0 otherwise)	0.411	0.463	0.365	1.837[c]
Credit access (Yes = 1, 0 otherwise)	0.384	0.413	0.359	1.01
Extension contacts (Number of contacts)	2.065	2.231	1.917	1.763[c]
Farmer group (Yes = 1, 0 otherwise)	0.534	0.638	0.442	3.672[a]
Distance from homestead to farm (Km)	2.395	2.034	2.714	1.982[c]
Distance from homestead to market (Km)	6.004	6.135	5.887	0.216
Regional dummy (Northern = 1, otherwise 0)	0.539	0.538	0.541	0.073
Household asset index (continuous)	1.445	1.694	1.227	5.726[c]

a, b and c denote significant levels at p<0.01, p<0.05 and p<0.1, respectively.

Predictors of improved soybean varieties adoption

Using a probit regression model, the factors that influence the adoption of ISVs were identified. Based on previous studies, this model incorporates household and agricultural variables as factors in the adoption of new technologies, as indicated earlier. Table 2 shows the estimated probit model of the predictors of adoption of ISVs by soybean farmers. The likelihood ratio (*Wald Chi*^{2} *(14) = 117.59; p = 0.000*) indicates that the probit model is statistically significant at the 1% level of significance. The study determined marginal effects, which were then used to explain the results because coefficients of parameters don't provide any relevant interpretations of magnitudes in probability models. Covariates' influence on the selection variable (adoption of improved varieties) can be seen by the sign of the marginal effect values and the magnitude of the probability of effects.

The results in Table 2 indicate that farm size under soybean cultivation, engagement in non-farm economic activities, membership of farmer groups, distance from farmers’ home to farm plots, and household asset index were significant predictors of soybean varieties’ adoption. Farmers' adoption decisions can be influenced by the availability of land to cultivate an ISV. To put it another way, farmers can only assign more land to improved varieties if they have enough space, and those with more acreage have a comparative advantage in adopting modern agrarian technologies. The results indicate that one more acreage of land leads to about 1.5% likelihood of adopting improved varieties of soybean. The positive and significant influence of land size on farm technology adoption has been found by many studies such as Manda *et al.* (2017) and Tufa *et al.* 2019, among others. Even more importantly, farmers may expect to earn more profit as their farm size expands since they will be able to produce more grains and thus have more funds to purchase input materials like improved varieties (Wongna *et al.*, 2021).

Table 2: Predictors of adoption of improved varieties of soybean

Predictors	***Coefficient***	***Std. err.***	***Marginal effects***	
Gender	0.1976	0.1749	0.0781	0.0686
Age	-0.0490	0.0356	-0.0195	0.0141
Age square	0.0003	0.0003	0.0001	0.0001
Marital status	-0.0887	0.2192	-0.0353	0.0874
Formal education	-0.0899	0.1758	-0.0357	0.0699
Household size	0.0262	0.0177	0.0104	0.0071
Farm size	0.0157[b]	0.0015	0.0622[a]	0.0046
Non-farm activities	0.3171[b]	0.1552	0.1258[b]	0.0611
Credit access	0.0687	0.1517	0.0273	0.0604
Extension contacts	0.0019	0.0499	0.0008	0.0198
Farmer group	0.5013[a]	0.1653	0.1970[a]	0.0635
Distance from home to farm	-0.0574[b]	0.0271	-0.0228[b]	0.0108
Distance from market	0.0002	0.0073	0.0001	0.0029
Regional dummy	-0.0854	0.1819	-0.0340	0.0723
Household asset index	0.5517[a]	0.1218	0.2193[a]	0.0486
Constant	0.2918	0.7765		
Wald Ch^2 *(14)*	117.59			
Prob < Ch^2	0.000			

a, b, and c denote significant levels at p<0.01, p<0.05 and p<0.1, respectively.

Non-farm activities such as salaried employment, petty commerce, and other vocations such as carpentry, and masonry, among others serve as income diversification measures to manage risks and respond to opportunities to enhance productive activities (Ellis 2010). The results of the study indicate that farming households' engagement in non-farm economic activities leads to about 12.6% chances of adopting an ISV. Furthermore, participation in non-farm economic activities has been widely accepted as a means of reducing smallholder farmers' financial limitations and increasing productivity by increasing the intensity of agricultural technology adoption (Dagunga *et al.*, 2018). Farmers' membership in a farmers' association influences their adoption of ISVs, and this effect is statistically significant. The marginal effects suggest that farmers who belong to a farmer association have a 19.7% greater chance of adopting new soybean varieties. This could be due to the many advantages of being part of a farmer's organization, such as sharing resources, getting access to markets that pay higher prices, and building deeper social ties. This finding adds weight to those made by Adams *et al.* (2021), who found that membership in farmer organizations was associated with greater adoption of improved maize varieties in Ghana.

For the adoption of new technologies, the distance traveled by farmers is critical. Farmers who live a long distance from their fields are less likely to adopt ISVs, according to the results of the study. Thus, due to the remote location of fields, farmers are required to travel considerable distances to their fields, and this diminishes their probability of adoption by about 2.3%. The study's outcome is in conformity with the results of Workineh *et al.* (2020) who found distance as a decreasing function of probability of adoption of farm innovations such as wheat varieties. Many pieces of literature (e.g., Dubbert *et al.,* 2021, Danso-Abbeam *et al.*, 2022a) have documented the influence of household asset ownership on farm technology adoption. The results indicated that a percentage increase in household asset ownership increases that likelihood of ISVs adoption by approximately 22%.

Welfare effects of the improved soybean varieties' adoption

Two estimators were employed to estimate the effects of improved soybean adoption on two welfare indicators (per capita food consumption expenditure and soybean farm productivity). The IV-2SLS and GMM were used to compare the robustness of the estimates. The study conducted diagnostic tests to validate the two estimators' accuracy in predicting the magnitudes and directions of the impacts. These include: 1) the endogeneity of the ISVs adoption as a treatment variable, 2) the weak instrument test to check the quality of the selected instruments, and 3) the over-identification of the adoption equation. On each of the welfare indicators, the three diagnostic tests were carried out using the two estimators. Table 3 summarizes the model estimation findings. The adoption of ISVs is the major variable of interest in this study.

As shown in the last rows of Table 3, the diagnostic test rejects the null hypothesis that ISV adoption is exogenous. As a result, the ISVs, which is the treatment variable, is endogenous, as evidenced by significant *p-values* of the Durbin and Wu-Hausman tests in the IV-2SLS equations and the GMM C statistic in the GMM equations. The diagnostic test results further support the use of group membership and distance from homestead to farm as quality indicators for determining the ISV selection equation. This is because the F-statistic values for the two outcome specifications are relatively large (> 10) and significant. A high and significant F-statistic value is essential to prove the IV procedure's dependability, particularly when only one endogenous regressor is used (Andrews *et al.,* 2007). A similar test was conducted to determine whether the selected instruments are valid in the sense that they are not associated with the error term and variables not used as instruments are correctly omitted from model estimation using Sargan and Basman tests for IV-2SLS and Hansen's J for GMM. Since the related *p-values* for all of the model parameters are not significant, the results of the over-identification tests confirmed this hypothesis. As a result, the models can be considered to be well specified.

After accounting for variations in unobservable traits between adopters and non-adopters, the results in Table 3 are consistent across the two models. Adoption of ISVs results in significant increases in food consumption expenditure per capita and quantity of soybeans harvested per ha in both the IV-2SLS and GMM estimators. Precisely, adoption of ISVs boosts yield by around 69% and raises food consumption expenditure per capita by 130 to 134%. The productivity enhancement of ISVs confirmed some of the earlier results obtained by Tufa *et al.* (2019), who observed a 61% increase in yield as a result of smallholder farmers in Malawi adopting ISVs. Similarly, Kamara *et al.* (2022) observed a 26% increase in yield with the use of ISVs by smallholders in Nigeria.

Table 3: Welfare Indicators model using IV-2SLS and GMM

	Food expenditure per capita				*Productivity/yield (kg/ha)*			
	IV-2SLS		*GMM*		*IV-2SLS*		*GMM*	
Variables	*Coeff*	*SE*	*Coeff*	*SE*	*Coeff*	*SE*	*Coeff*	*SE*
Improve varieties of soybean	1.2975[a]	0.4144	1.3399[a]	0.4151	0.6857[c]	0.4044	0.6886[c]	0.415
Gender	0.0573	0.2081	0.0412	0.2407	-0.1724	0.1145	0.1738	0.1109
Age	0.0701[c]	0.0396	-0.0005	0.0004	-0.0659[a]	0.0221	-0.0657[a]	0.0234
Age square	-0.0005	0.0004	0.0636	0.0434	0.0006[a]	0.0002	0.0006[a]	0.0002
Marital status	0.1991	0.2556	0.2047	0.2954	0.085	0.1415	0.0821	0.1547
Formal education	0.0054	0.2157	0.0292	0.2155	0.3687[a]	0.1179	0.3679[a]	0.1269
Household size	-0.0639[b]	0.0251	0.0348[b]	0.0157	0.0243[c]	0.0133	0.0243[c]	0.0141
Farm size	0.0359[b]	0.0144	0.0641[b]	0.0256	-0.0202[a]	0.0077	-0.0201[b]	0.0082
Off-farm activities	-0.1689	0.2023	-0.2067	0.2115	-0.0925	0.1101	-0.0924	0.1119
Access to credit	-0.2530	0.1731	-0.0556	0.0693	0.0782	0.1073	0.0774	0.1108
Extension contacts	0.0531[a]	0.0131	0.0610[a]	0.0113	-0.0125	0.034	-0.0125	0.0299
Distance to market	-0.0062[a]	0.0008	-0.0624[a]	0.0207	-0.0112[b]	0.0046	-0.0112[b]	0.0036
Regional dummy	0.6324[a]	0.1979	0.2446[a]	0.0424	-0.5151[a]	0.1096	-0.5159[a]	0.1108
Household asset index	0.1464	0.1486	0.1851	0.1745	0.0179	0.027	0.0178	0.0216
Constant	2.0862	0.9454	2.2591	1.1417				
Tests of endogeneity								
Durbin (score) chi2(1)	15.275[a]	0.000*			3.012[c]	0.083*		
Wu-Hausman	15.241[a]	0.000*			2.897[c]	0.089*		
GMM C Statistic Chi^2			16.185[a]	0.000*			3.09[c]	0.079*
Test of instruments								
F-statistic	11.117[c]	0.0814*	11.198[c]	0.094*	12.964[c]	0.071*	10.065[c]	0.081*
Test of over-identification								
Sargan (score) chi2(1)	2.278	0.131*			0.877	0.349*		
Basmann Chi2(1)	2.187	0.139*			0.841	0.359*		
Hansen's J Chi			2.514	0.113*			0.278	0.868*

*a, b and c denote significant levels at p<0.01, p<0.05 and p<0.1, respectively. * are the p-values.*

Different signs and magnitudes were estimated for the other explanatory factors anticipated to influence productivity and food consumption expenditure per capita. According to the table, whereas age has a significant and negative influence on productivity, it has a significant and positive effect on food consumption expenditure per capita. The fact that younger farmers employ more farm innovations to increase productivity than older farmers could explain the detrimental effects of aging on productivity. This is shown in the soybean adoption estimates in Table 2, where age is inversely connected with ISV adoption, albeit not significant. The positive influence of age on food consumption expenditure per capita may be due to wealth accumulation over a long period of time by older farmers. The findings also support the notion that older farmers are less productive than younger farmers (Dubbert 2019).

Formal education has a positive and significant effect on productivity. This finding lends credence to the notion that better-educated farmers have easier access to information and are more likely to employ appropriate farm management methods, hence increasing output. However, household size has a decreasing effect on food consumption expenditure per capita and an increasing effect on productivity. When there are more people in the home, limited resources are shared among them, reducing the consumption expenditure per member. However, more members may serve as an active labor force, lowering the number of workers that may be hired for farming activities and freeing up financial resources for the acquisition of additional inputs such as improved seeds.

The study also shows the importance of farm size in increasing food consumption expenditure per capita. Thus, a 1% increase in the area of the farmers' soybean plot results in a marginal increase in food consumption spending per capita by 3.6 – 6.4%. Farm size, on the other hand, has a negative and significant influence on soybean productivity, implying that farmers with big farm sizes are less productive than those with small farm sizes. This could be due to internal diseconomies of scale, where farmers are unable to manage their resources efficiently as farm plots get larger. Many pieces of empirical evidence have found an inverse correlation between plot size and yield (Casaburi *et al.*, 2016). Extension contacts has a positive and significant influence on food consumption expenditure per capita, implying that farmers who have regular contact with extension officers are better off in terms of welfare than farmers who have less contacts with extension officers. As a result, a percentage increase in the frequency of extension contacts has resulted in an increase in household consumption expenditure per capita of around 5.3 - 6.1%. Farmers that have frequent interaction with extension services are more aware of new technologies and their application, have easy access to information on weather variability, and can easily access input and output market. These boost household welfare by increasing the sustainable supply of food for home consumption and surpluses to the market. Long distances to market centers lower food consumption expenditure per capita and productivity by 0.6 to 6.2%, depending on the estimation approach. Market centers are typically located in district or regional cities in most regions of Africa, including Ghana, and are often located distant from the villages where crop farms are located. The high cost of transportation, along with bad roads, is a barrier to food product marketing, reducing farmers' willingness to maintain production in coming years. Regardless, this has an influence on productivity and, as a result, lowers food consumption expenditure per capita. Finally, the findings show that farmers in the northern region are less well-off in terms of welfare indicators than those in the upper east.

CONCLUSIONS AND POLICY RECOMMENDATION

Using survey data from 330 farming households in Northern Ghana and IV estimators, this study identified some critical determinants of ISV adoption and evaluated the impact of ISV adoption on two major welfare indicators: food consumption expenditure per capita and yield. According to the study's findings, farm size, participation in non-farm economic activities, membership in farmer associations, and household asset are important drivers of ISV adoption in the study area. Agricultural policy should prioritize non-agricultural employment opportunities for farmers, particularly during off-season months, to allow them to transit to other occupations. Non-farm work can enable farmers generate more capital to purchase farm inputs like ISVs, hence increasing adoption. Furthermore, improving farmer group dynamics at the farm and community levels can be an important conduit for boosting the adoption of improved crop varieties such as ISVs. Another significant policy recommendation is to encourage farmers to invest in productive assets. This might be accomplished by supporting community financial schemes such as village saving and lending mechanisms, which will enable farmers to amass financial capital as well as have access to credit to reduce their liquidity constraints during the farming season.

After controlling for observed and unobserved changes in household characteristics, the study's findings revealed that adopting ISVs leads to considerable gains in yield and food consumption expenditure per capita of soybean growers. Scaling up has become increasingly important as the current adoption rate of ISVs is roughly 47%, which has a direct influence on household welfare. Policies at the farm level that exposed farmers to the improved soybean varieties are crucial in this regard.

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