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EFFECT OF ADOPTION OF IMPROVED AGRICULTURAL TECHNOLOGIES ON THE PRODUCTIVITY OF YAM FARMERS IN GHANA

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Abstract
This study examined the effect of adoption of improved agricultural technologies (IATs) on the productivity of yam farmers in Ghana. The study applied mixed methodological approach in both data collection and analysis. Econometric and qualitative tools such as Two Stage Least Square IV regression model was used to analyse the effect of adoption of IATs on the productivity of yam famers. The focus group discussion transcripts were subjected to thematic analysis to understand the themes that run across the data. These were used to complement the quantitative data. The results show that the adoption of IATs has a positive and significant effect on the productivity of yam farmers in the study area. The study recommends that yam be included in the list of root and tuber crops in the priority crops of the government of Ghana, since it has the potential of enhancing the food security and livelihood of the rural poor, and increase the foreign exchange earnings of Ghana, being the foremost exporter of yam.

Keywords: Education, income, farm size, sex, hired labour, ownership of asset, adoption, and IAT

Introduction

Yam is very significant to the food economy of the people of Ghana, where root and tuber crop-based foods are dominant over cereals. The role of this tuber crop as source of cash income for the yam producing households was highlighted by Nteranya (2015). The crop has also made Ghana a front-liner in yam export (Ikeorgu, 2009; Asante *et al.,* 2014). Considering her potentials in yam production, Ghana should have been self-sufficient in yam production when compared with the demand arising from her teeming population as observed by the Food and Agriculture Organisation (Ajoni *et al.,* 2017). The rapid growth of the population of the country, which was put at 2.19% as at 2018 (Plecher, 2018), has also led to a decline in per capita production of starchy staples, just as in most developing countries, resulting in huge spending of foreign exchange on food imports to the detriment of the national development plan (FAO, 1996). This development, therefore, makes it difficult to match demand with supply; instead, most of the yams produced in Ghana are consumed locally with little left for next season's planting. Ghana's present productivity status in yam production is largely influenced by area expansion (FAOSTAT, 2013), and the advent of urbanization poses a huge challenge as most arable lands meant for cropping are speedily being converted to residential areas. The implication of this development is that farmers can no longer rely on area expansion to increase productivity, and the only sustainable alternative is the use of improved agricultural technologies for increased yields (Ofori-Kuragu, 2016).

Yams, like other root and tuber crops, do not usually produce viable botanic seeds and therefore are propagated through seed tubers. Also, these vegetative planting materials have low multiplication ratio (1:10), unlike maize that has multiplication ratio of 1:300. Therefore, the greatest constraint to increased yam production is scarcity or high cost of seed yams (Agyei-Holmes *et al.,* 2011; Ikeorgu, 2009; Okoli *et al.*, 1982). This problem has persisted till date even with the development of the minisett technique by the National Root Crop Research Institute (NRCRI), Umudike and International Institute of Tropical Agriculture (IITA), all in Nigeria since 1982 (Ironkwe, 2007). The development and dissemination of the minisett technology, therefore, should have completely solved the problem of seed yam shortage but this problem continually persists.

It has also been observed that the decline in yam productivity is also as a result of farmers not using the required production inputs, such as recommended quality and quantity of yam seeds. Moreover, due to the shortage of arable land, as a result of the land tenure system in Ghana and the negative impact of urbanization, which is gradually reducing the land space for arable cropping, smallholder yam farmers are forced to intensify their land use to keep up with demands to feed their households and for market. This wears out the fertility of the soil over time and so hampers farmers' productivity. It highlights the need to explore better means of enhancing farmers' productivity. Literature on the effect of improved technology adoption on the productivity of yam production in Ghana is limited. Most of these literatures rather focus on other crops like maize, rice and cocoa (Wiredu *et al.,* 2012; Agyei-Holmes *et al.,* 2011). Some also focused on the effect of a single technology like the minisett technology on yam farmers (Abubakar *et al.*, 2015). This study, therefore, seeks to estimate the effect of the adoption of the improved agricultural technologies on the productivity of yam-producing households in Ghana.

Methodology

The study was carried out in Ghana. Exploratory mixed methods involving both quantitative and qualitative data were used. This study used part of the baseline survey data that the Institute of Statistical, Social and Economic Research (ISSER) conducted in 2015 under the "Community Action on Improving Farmer Saved Seed Yam (CAY-Seed)" project in Ghana and Nigeria. The sampling frame was drawn from a list of farmers who participated in the Yam Improvement for Income and Food Security in West Africa (YIIFSWA) project. It further employed a focus group discussion and key informant interviews to gain further insight in the factors associated with yam productivity in Ghana. Two focus group discussions (Men FGD and Women FGD) were conducted in each of the 12 communities giving a total of 24 FGDs. A detailed discussion of the analytical methods and model specification (descriptive statistics and econometric) have also been provided in the next session. The entire analysis was done using the STATA software.

Effect of Adoption of Improved Technologies on the Productivity of Yam Farmers

Following the study of Killic *et al.* (2009) and Martens *et al.* (2006), farm production function for the effect of adoption of IATs on the productivity of yam farmers was specified as follows:

$$Y = \beta_0 + \beta_1 \text{Adopt} + \beta_2 X + \varepsilon \quad \ldots\ldots\ldots\ldots 1$$

Where Y is the productivity measured in output/ton, β_0 is the constant term, β_1 and β_2 are parameters to be estimated, Adopt is the dummy for household adoption decision; X is a set of household socioeconomic and production factors while ε is the error. The coefficient of β_1 is the main parameter of interest because it measures the effect of adoption of IATs on the productivity of yam farmers. A positive and significant value of β_1 would imply that adoption of IATs has a favourable effect on yam farmers' productivity. An important requirement for this estimation is that all the variables on the right hand side of the equation are all exogenous. However, there might be a reverse causality problem among these variables which leads to the problem of endogeneity. This implies that the magnitude or coefficient of the endogenous variable will be biased and misleading, because its magnitude is largely determined by the error term. This problem according to literature is obviously caused by omitted variables, selection bias and error in measurement (Cawley *et al*., 2015), and it is common with cross-sectional dataset. This problem according to literature can be effectively addressed with the use of appropriate tool, for instance an instrumental variable approach (Howley *et al*., 2015; Cawley and Meyerhoefer, 2012). The instrumental variable approach however, requires good instruments to properly correct for endogeneity. Two instruments were used to control for endogeneity of adoption of IATs. These are access to electricity and awareness of the existence of a technology. The first instrument is yam farmers' access to electricity, and it is believed that this social infrastructure directly facilitates adoption of IATs. Farmers' use of television and radio are powered by electricity, and can only influence productivity through adoption. The last instrument is yam farmers' awareness of IATs. This is considered a good instrument because it also has a direct effect on adoption, and can only affect productivity if the yam farmers' adopts the IATs.

Functional form of the model

As was indicated, a 2 Stage Least Squares (2SLS) IV (Instrumental Variable) approach was applied in this study. Thus the first stage is to test for the exclusion restrictions of the instruments (Wooldridge, 2013). This is the reduced form of the equation for our endogenous regressor. It can be specified as:

$$Y_2 = \beta_0 + \beta_1 Z_1 + \beta_2 Z_2 + \beta_2 Z_3 + \beta X + \varepsilon \ldots\ldots\ldots\ldots\ldots\ldots 2$$

Where Y_2 is the endogenous regressor (Adoption), β is the estimated parameter coefficients, Z_k are the various instruments, X is a vector of all other explanatory variables, and ε is the error term. In this process, there should be some correlation between Z_k and Y_2, to satisfy the requirement that the instruments affect the endogenous regressor. The second stage of the model can be specified as:

$$Y_1 = \beta_0 + \beta_1 \hat{} 2y + \beta X + \varepsilon \quad \ldots\ldots\ldots\ldots 3$$

Where Y_1 is the unbiased estimation of the dependent variable, endogenous β_j is the estimated parameter coefficients, while is the estimate of the endogenous variable, X is a vector of all other explanatory variables, and ε is the error term.

Specification tests

According to literature, the multivariate Cragg-Donald Wald F- test of the first stage regression; which tests if the instruments affect the endogenous variable must be satisfied. Stock *et al.* (2002) proposed a rule of thumb that the F statistics must exceed 10, to avoid instruments being adjudged as weak. For the IV model the Sagan statistic is reported, which tests the null hypothesis that all the instruments are valid. Howley *et al.* (2015) refers to it as the standard over identification test to check the validity of the instruments, and they identified this as a benefit of using the 2SLS approach. Also Cawley and Meyerhoefer, (2012) noted that proving the null hypothesis of no effect is impossible, and so casts some doubts about the instruments, but application of the Sargen test (or the Hansen Test when controlling for heteroskedasticity) of the validity, and failure to reject it means it cannot be considered invalid, and this supports the argument of validity for the included instrument. Also, if the estimated chi-square exceeds the critical chi-square value, we reject the null hypothesis, which therefore indicates that at least one of the instruments is correlated with the error, and therefore not valid (Gujarati, 2003). All the specification tests are reported in the result section. Following equation 3, the empirical model is explicitly specified as follows:

$Y_1 = \beta_0 + \beta_1 + \beta X + \varepsilon$

$Y = \beta_0 + \beta_1 Adopt + \beta_2 Age + \beta_3 Sex + \beta_4 Edu + \beta_5 Inc + \beta_6 Fmsize + \beta_7 Hiredlab + \beta_8 Ext + \beta_9 Elect + \varepsilon$ 4

Results and Discussion

Awareness and adoption of IATs

The result in Fig. 1 shows the level of awareness and adoption level of improved agricultural technologies identified in the study area. These IATs include: minisett, seed treatment, agrochemicals (fungicides, insecticides and herbicides) and fertilizer use. The analysis shows that these improved technologies had an average awareness and adoption level of about 71% and 43% respectively. The most prominent IAT in terms of level of awareness and adoption is the use of agrochemicals with an awareness level of 85% and 67% respectively. Its major use includes: clearing of the farm land, weeding of the farm and disease control, and that explains the relative high level of awareness and adoption. The next is the minisett technology with an awareness level of 63%, and an adoption level of 61%. The margin between the level of awareness and adoption of the minisett indicates that it is the most adopted of all the technologies in terms of the proportion of yam farmers that adopted, compared to the proportion that are aware of the minisett technology. The least of all the IATs in terms of awareness and adoption as shown in Fig. 1 is the use of fertilizer, with the awareness level of 58%, and an adoption level of 0.28% (apparently it was only one person that adopted it). The study sought to unearth the rationale behind this outcome using the FGDs. The consensus opinion was that they do not use it for yam production because their land is fertile. Further probe on why they do not use it revealed the following: most yam farmers claimed they grew up and observed that their parents never used anything called chemical fertilizer for yam production, and so to them it is a norm that has come to stay, and they are not ready to change it. Secondly, they indicated that some of them who were convinced to try it in the past discovered the yam produced with the use of fertilizer lost its quality of taste compared to others without fertilizer application. More so, that the fertilizer made the yams to grow so big, but reduced its shelf life due the large volume of water it contains (Men and Women FGDs, 2018).

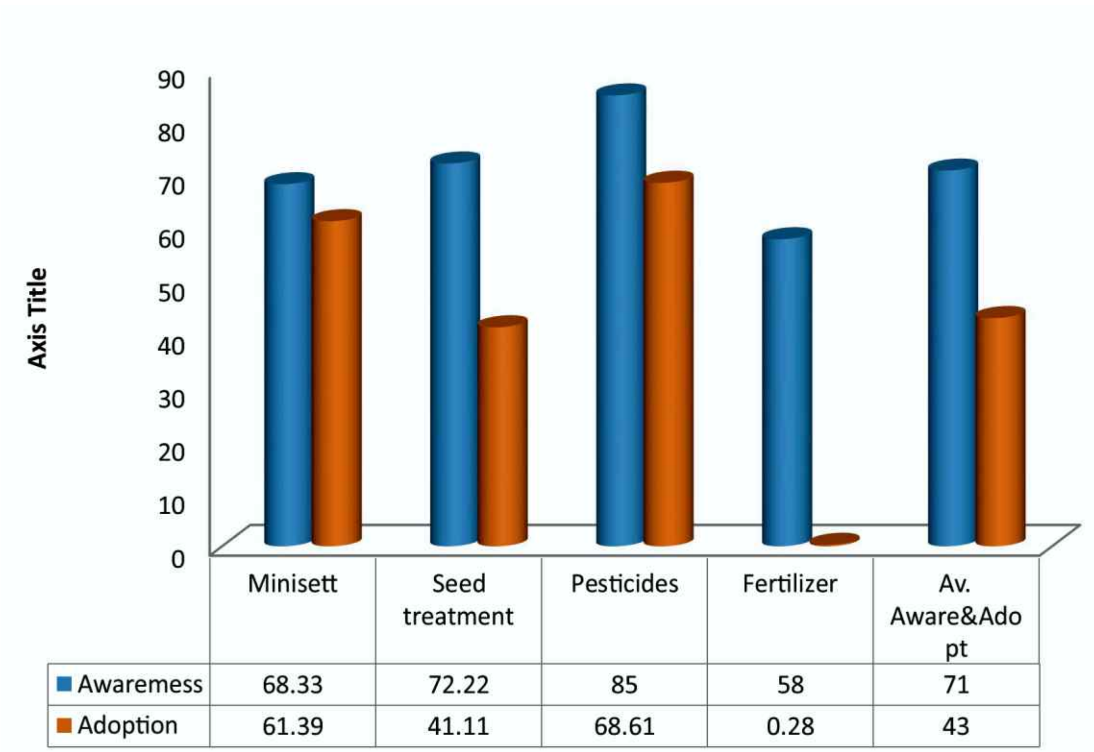

Fig. 1: Distribution of yam farmers according to their awareness and adoption of IATs

Effect of adoption of improved agricultural technologies on the productivity of yam farmers

This section therefore attempts to address the issue by empirically documenting the effect (if any) and magnitude of adoption of IATs on the productivity of yam farmers in the study area. The results on Table 1 show the outcome of the OLS regression in the first column, and IV regression on the second column. The OLS regression indicates a positive effect of improved agricultural technologies adoption on the productivity of yam farmers, and this is significant at 5% level of probability. However, this outcome may be biased because the dichotomous variable capturing the farmers' adoption of IATs is potentially endogenous, and this is confirmed by Hausman test of endogeniety at 10% level of probability. To address this endogeniety issue which renders the estimates of the OLS regression inconsistent, Instrumental Variable (IV) regression approach is then adopted. The results of the IV regression estimation are also reported in the second column of Table 1.

The results of different tests carried out to assess the relevance and validity of the instruments used in the analysis are reported below the regression estimates. Recall that the average extension contact and farmers' awareness of improved technologies by communities were used as the instruments. The F- test of the excluded instruments is greater than 10 and significant 1% level of probability. Therefore, we reject the null hypothesis that the excluded instruments used are not correlated with the endogenous variable. This implies that these instruments are relevant. More so, the hypothesis of weak identification of instruments is rejected due to the outcome of the KP LM statistics. Thus, the instruments used have strong explanatory power over the endogenous variable. Furthermore, the F- statistic of Cragg-Donald Wald, which is significant at 1% according to Stock-Yogo's table indicating that at least 99% of the OLS bias is corrected by the IV regression and this outcome, is acceptable.

Finally for the instruments to be valid, they must be orthogonal to the error terms of the productivity model. To check for this requirement, the study adopted the Hansen J test of over-identification. The P-value of the J statistic is 29.87%, greater than the 10%.This is consistent with the requirement; because it shows that the null hypothesis of over identification of instrument should be rejected, and this means that the instruments used in the regression are not correlated with the error terms of the structural model for productivity. The outcome of these entire tests authenticates the validity of the instruments. Hence the choice of IV regression will provide more robust estimates of adoption effect on yam farmers' productivity than the OLS estimates. The robust standard errors are also reported, which corrects the existence of any possible heteroskedasticity in the model.

The results of the IV estimation show a positive effect of the adoption of improved agricultural technologies on yam farmers' productivity at 10% level of probability. This is consistent with a-priori expectation and supports the hypothesis that there is a positive relationship between adoption of improved agricultural technologies and yam famers' productivity. The results further show that the magnitude of the effect of the IV regression (5.03ton/ha) is higher than the OLS regression estimate (0.3840ton/ha). This indicates that failure to address endogeneity problems in the empirical model could lead to underestimation of the parameters of adoption effect on productivity.

The discussion for this section is therefore based on the corrected estimates generated from the IV regression model. The results show that a unit increase in the yam farmers' IATs holding other factors constant, leads to an increase in his/her productivity by 5.0329tons/ha. Since the study controlled for other potential factors which could likely influence productivity, it therefore implies that the reported effect is actually coming from the adoption of IATs. This is consistent with a priori expectation and it could also mean the adopted technologies are effective. The reason is that the adopted IATs are supposed to act as a buffer to the yam throughout the production process in the field shielding the yam from the pests and diseases, and enhancing the soil to sufficiently support the overall growth.

The outcome of the FGDs also reveals a positive relationship between their adoption of IATs and yam farmers' productivity, hence authenticating the claim from the quantitative analysis. The yam farmers reported that since they started using the technologies, their yields have increased greatly and gave evidence of having enough ware yam to eat, sale and the one that matters most to them is the fact that they are equally able to secure healthy seed yams to plant for the next planting season, unlike before, when seed yam was scarce due to spoilage. They said "we *are sure to eat yam till the next harvest of the new yam*" (Nyinase Men FGDs, 2018). This also shows that adoption of these technologies has a trickling down effect which runs through to even post-harvest conditions of the yam. This outcome is consistent with the findings of Adeleye *et al.* (2010) and Essilfie (2018), who both found that the use of IATs significantly increased the yield of yam in South-West Nigeria, and income of maize farmers in Ghana.

Table 1: Regression results of the effect of adoption of IATs

Dep. Variable: yield (ton/ha)	OLS regression		IV regression	
Variable	**Coefficient**	**Robust Std. Err.**	**Coefficient**	**Robust Std. Err.**
Adoption	0.3840**	0.1732	5.0329*	2.6935
Age	-0.0014	0.0015	-0.0329	0.0237
Sex	0.0039	0.0619	3.1831***	1.0576
Education	-0.0166	0.0489	-2.1374***	0.8142
Income	0.0000	0.0000	0.0001*	0.0001
Farm size	0.0010	0.0206	-1.6828***	0.3390
Hired labour	-0.0096	0.0404	-1.4169*	0.7690
Asset ownership	0.1082**	0.0447	4.1485***	0.9117
Access to Extension	0.2200**	0.0386	0.9630	0.8215
Constant	0.2709**	0.1165	10.9084***	2.0748
Observations	360		360	
F(10, 346)	12.90		6.96	
Prob>F	0.000		0.000	
R-squared	0.2506		0.1375	
Tests of validity and relevance of instrument used in the IV regression				
		Test stat	**P-value**	
Relevance test of excluded instruments:				
Sanderson-Windmeijer F test, F(2, 346)		20.65	0.0000	
Weak identification test				
Kleibergen-Paaprk LM statistic		29.669	0.0000	
Cragg-Donald Wald F statistic		21.150		
Over identifying test: Hansen J stat		1.080	0.2987	
Hausman tests of endogeneity: Score chi2(1)		4.0969	0.0490	

Source: ISSER-CAYSEED Survey, 2015

Other factors that influenced the productivity level of the yam farmers' consequent upon their adoption of IATs include sex, education, income, farm size, hired labour and ownership of asset. The sex of the household head shows a positive and significant relationship with the productivity of the yam farmers. It implies that at I% level of probability, being a male household head increases the productivity of yam farmers by 3.183ton/ha. A plausible explanation to this outcome might be because yam production involves a lot of strenuous activities which the men are able to cope with more than their female counterparts, and so being a male household head places the yam producing household at advantage. Also, men unlike the women seem to have more access to land and other productive assets in the study area. This outcome is supported by the findings of (Wambua *et al.,* 2018) who indicated that being a male household head enhanced the production of beans in Kenya.

Educational level of the yam farmers is another factor that influenced the productivity of the farmers. The results show that farmers' educational level has a negative relationship with the productivity of the farmers, and significant at 1% level. This implies that a unit increase in the educational level of the yam farmers, leads to a 2.14ton/ha decrease in the productivity of the farmers. This is consistent with *a-priori* expectation as most educated farmers migrate to the cities in search of greener pastures, and those who did not migrate out of the community seek off-farm employments other than farming, hence depleting the agricultural labour available for yam production. The effect of this outcome has manifested as reduction in the magnitude of yam production. This was supported by Uematsu and Mishra (2010) who indicated that the willingness of small scale farmers to move to off-farm job in search of greener pastures could be the reason for this type of outcome.

The income of the household is another important factor in literature that determines productivity. Table 1, shows that it is directly related to the productivity of yam farmers and significant at 10% level. This outcome is also consistent with existing literature on determinants of productivity. According to the results, a unit increase in the income of the yam farmers leads to increase in productivity by 0.0001ton/ha. This change in productivity could be adjudged little though but it shows the direction of the effect of income on yam production in the area. Again, because these are smallholder yam farmers with low income status, could also give credence to this outcome. This result is supported by the study of Mwangi and Kariuki (2015) who in different studies reported that income has a positive impact on both adoption and the productivity of farmers. Farm size as shown in the Table 1, is indirectly related to productivity and significant at 1% level. This indicates that a unit increase in the size of the farm decreases farmers' productivity by 1.68ton/ha. Although, this is in line with *a-priori* expectation, and is supported by the studies of Yaron *et al*. (1992) and Harper *et al.* (1990), who found negative relationship between farm size and overall productivity of the farmers. This rather is expected to enhance the yield of yam in the study area however; it could be that these yam farmers planted other crops on the additional land to ensure food security for their households within the lag period, between planting and harvesting of yam.

Another dimension to this outcome could be lack of specialization and capacity to manage large farms. Increase in size of farm land also comes with additional cost, because additional resource inputs and management of these inputs is key. Therefore it is also natural that these small holder farmers who do not have capacity for managing larger farms will not manage the larger farms effectively, hence the reduced outcome as observed in this study. For labour, the study recorded a negative relationship with yam productivity, and this was significant at 10% level. A unit increase in the use of hired labour, reduced the productivity of the yam famers by 1.417ton/ha. This is against *a-priori* expectation, but was supported by the study of Panda (2015) who noted that labour input could have either positive or negative effect on productivity depending on the scale of production and management of other inputs. This inverse relationship between hired labour and farmers' productivity in the case of this study could be because of the small scale yam production in the study area. Therefore, increase in the investment for hired labour becomes counter-productive, because the input is not adding commensurate value in terms of total yield, rather it increases the production cost, and also depletes the amount of money required to invest in other inputs that could increase productivity.

Ownership of productive asset also had a direct relationship with the productivity of yam and significant at 1% level. This implies that a unit increase in the productive asset of the yam farmers leads to increase in productivity by 4.1485ton/ha. This conforms to *a priori* expectation, and is supported by Gershon (1987) as cited in Platteau (2015), who studied the impact of land ownership security on farmers' input use and value of output. Ownership of assets gives yam farmers a form of security, and serves as collateral for accessing credit from formal credit institutions. This makes funds available for investment in other variable inputs, which culminates in enhancing output per unit area.

Conclusion

The study examined the effect of adoption of IATs on the productivity of yam famers. This aims at understanding the magnitude and the direction of influence of adoption of IATs on farmers' productivity measured in terms of yield. It was realised using Ordinary Least Square (OLS) multiple regression and the Instrumental Variable Two Stage Least Square (IV 2SLS) regression models. The study observed that adoption of improved agricultural technologies have a positive and significant effect on the productivity of the yam farmers in the study area. The study based on the findings therefore recommend that yam be included in the list of root and tuber crops in the priority crops of the government of Ghana, since it has the potential of enhancing the food security and the livelihood of the rural poor and increase the foreign exchange earnings of Ghana, being the foremost exporter of yam. There is also need to encourage educated male and female farmers to remain in farming to enhance the adoption of innovations that will enhance productivity. Policies that will enable the farmers' access to more land devoted to sole yam production without interference from other cops to mitigate the current low productivity emanating from these crop combinations with yam.

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