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Improved rice variety adoption and its effects on farmers' output in Ghana

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Sub-Sahara Africa and for that matter Ghana, missed out of the first Green revolution. However, with the instrumentality of the former United Nations Secretary, Kofi Annan, through the Alliance for Green revolution in Africa (AGRA) and other bodies, the revolution is being introduced in some parts of Africa, including Ghana. The extent to which the new revolution would work depends on a careful study of the socioeconomic underpinnings of technology adoption. This study sought to investigate the factors that influence the adoption of improved rice varieties and its effects on rice output in Ghana. The method of analysis involved an estimation of treatment effect model comprising a Probit equation and a production function. The empirical results show that the adoption of improved rice variety had a positive effect on farm output. Other inputs that had significant and positive impact on output were farm size, labour and fertilizer. The probability of adopting improved rice variety was high for the following: farmers who had formal education; farmers who had bigger household sizes; and farmers who had smaller farms. Contrary to our a *priori* expectations, however, farmers who had access to extension services had lower probability of adoption. The authors recommend that farmers be supported with more fertilizer subsidization. Farmers should also form farmer groups to support one another on the field. Also, the fundamental problems of illiteracy among farmers must be addressed.

Key words: Ghana, improved rice seeds, technology adoption, treatment effect model.

INTRODUCTION

Agriculture has a direct influence on the attainment of at least five of the Millennium Development Goals (MDGs) (MoFA, 2010a). The first goal of eradicating poverty and extreme hunger can only be achieved through increased agricultural productivity.

Agriculture continues to play a pivotal role in Ghana's economy, contributing to about 30% of gross domestic product (GDP). The agricultural sector also provides employment to about 50.6% of the labour force and in 2010, it was the largest foreign exchange earner (MoFA, 2010a). The overall growth rate of the agricultural sector, vis-à-vis the current annual population growth rate of 2.6% is 2.8%. The small margin between these figures has serious implications for the attainment of food security, employment generation and improvement in rural incomes and national economy (NAPCDD, 2003).

In spite of the significant role agriculture plays in the provision of food, food shortage still persists among many households in Ghana (Carr Jr., 2001). Ghana depends largely on imported rice (400,000 tonnes/annum) to

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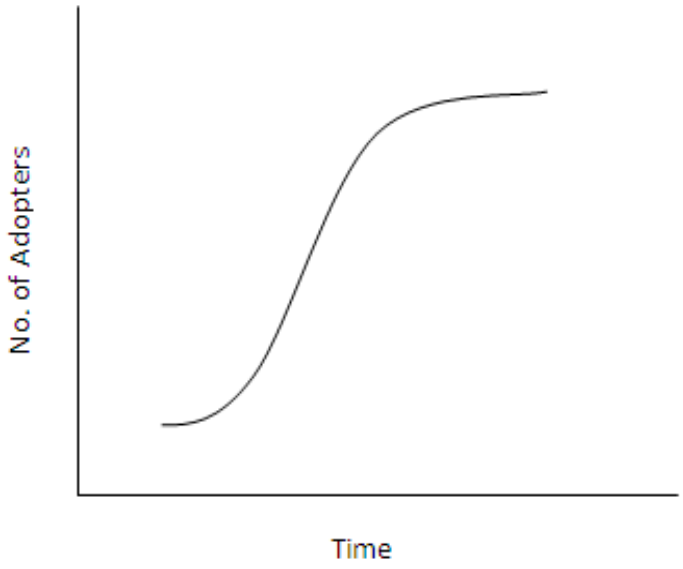

Figure 1. The s-shaped diffusion curve.

make up for the deficit in rice supply. The self-sufficiency ratio of rice in Ghana has declined from 38% in 1999 to 24% in 2006 (MoFA, 2010a).

The Government of Ghana in her drive to increase and promote the quality of locally produced rice in 2003, established and implemented the Nerica Rice Dissemination Project (NRDP). The main goal of the five year project was to contribute to poverty-reduction and food security through the adoption of high yielding NERICA upland rice varieties. Ten districts benefited from the implementation of the project which resulted in a cultivated area of 22,561.40 ha yielding about 56,400 metric tons of paddy Nerica rice (MoFA, 2010b). However, judging from the yields of farmers, there still appears a yawning gap between results of on-farm demonstration plots (6.5 Mt/Ha) and actual yields (2.4 Mt/ha) from the farmers' fields (MoFA, 2010b). Despite the prospects of improved varieties, adoption rates are still low. The objective of this study is to determine the socio-economic, farm characteristics as well as institutional factors that influence the adoption of improved varieties and the effects on rice output in Ghana.

MATERIALS AND METHODS

Literature review-diffusion of innovation

Rogers (1962) defined an innovation as an idea, practice or object that is perceived as new by an individual or other units of adoption. Also, he defined diffusion as the process by which an innovation is communicated through channels over time among members of the social system. The Innovation Diffusion Theory seeks to explain how, why and at what rate new ideas and technologies spread through cultures (Rogers, 1962). The origin of the theory is varied and spans over multiple disciplines. From the literature, the concept of diffusion was first studied by Gabriel Tarde in 1890 and then anthropologists Friedrich Ratzel and Leo Frobenius. Later on, Rogers made extensive studies and came up with four main elements that influence the spread of a new idea, namely; the innovation in question, the communication channels, time and the social system. These elements work in conjunction with one another. This means that for any technology to be adopted, it requires that first, the innovation should be communicated through a channel over a period of time, and this process takes place in a social system. The process relies heavily on human capital and the innovation must be widely adopted in order to be self-sustainable. Within the rate of adoption, there is a point where an innovation reaches mass saturation point; where the largest adoption rate is experienced. This is shown by a logistic curve with S shape as shown in Figure 1.

Rogers categorized the adopters as innovators, early adopters, early majority, late majority and laggards. As a new technology is introduced through a communication channel, innovators are normally the first to adopt the new technology, followed by the early adopters. These two categories are risk takers, who would adopt the technology despite the fact that they may not have full knowledge about its prospects. After some time when some positive benefits have been seen, the early majority joins and then the late majority. When the technology has proven to be good beyond every doubt, the laggards also join. However, despite some promising attributes of the technology, some people may not adopt it. The reasons are varying; some may not be aware of it, others may not have the means to access it, and some would still have some misgivings about the technology. Whatever, the reason, however, they would also have made a choice. It is important for socio-economists to intensify their research into the farmers' socio-economic, farm characteristics as well as some institutional factors that may encourage or discourage the adoption of agricultural innovations.

Rogers (1962) also identified five stages of accepting an innovation, namely; knowledge, persuasion, decision, implementation and confirmation. That is to say that when an innovation is introduced, the potential adopter needs to have knowledge about its benefits and limitations. After gaining the knowledge he/she needs to be persuaded that the benefits far outweigh the costs. If he/she is convinced he/she makes a decision to adopt the technology, otherwise he/she rejects it. Once a positive decision has been made, he/she implements it. Often times, this involves trying the technology on a small portion of the farmer's field. If it is successful, the technology is confirmed, and the farmer can increase the portion of his or her field in the next farming season.

Lastly, Rogers (1962) noted five attributes of a good technology as follows; simplicity, compatibility, trialability, relative advantage, and observability. That is to say that the innovation should not only be seen, it should be easy to understand and adopt. It should also be consistent with the farming practices already adopted by the farmer. Furthermore, the farmer should be able to experiment the new technology to know for him/herself its usefulness and viability.

Theoretical framework

Following Foltz's (2003) framework, technology adopters have a positive net willingness to pay for the technology or adaptation strategy. Farmers have what Foltz calls a reservation price $P_r = (w, k, \eta)$ for the technology that is greater than or equal to the actual market price P_m. He defined the reservation price as

the amount that an individual would be willing to pay for the technology given his asset position w; other inputs he uses, k; and the parameter of his preference, η. According to him, P_m is the given price of the technology which is constant for all individual. Thus, for a given individual, the dependent variable A is defined as an index variable for whether or not he/she adopts the new technology. It takes on the value zero and one as follows:

$$\begin{aligned} A=1 \quad if \quad P_r(w,k,\eta)-P_m>0 \\ A=0 \quad if \quad P_r(w,k,\eta)-P_m\le 0 \end{aligned} \tag{1}$$

where the variables are as defined. The function $P_r=(w,k,\eta)$ represents a shadow price for an individual adopting an adaptation strategy. The inference problem in terms of econometrics, according to Foltz, then becomes a question of parameterizing the equation that defines the net benefits of the technology to farmers. The standard model in the literature is the random utility model. Researchers are not able to observe the preference parameters of the utility function. It is however, assumed that they are known to decision makers.

Let these parameters be an unobserved variable so that the actual utilities of an individual can be written as:

$$U_i=P_{ri}(w,k,\eta)-P_m=z'\gamma+e_1 \tag{2}$$

where z is a set of characteristics of the decision maker observable to the econometrician, γ is a parameter vector and e_1 is the error term. Hence, $z'\gamma$ becomes an index function that allows us to estimate the probability of adoption $A=1$ in the following fashion:

$$\Pr ob\, P_r(w,k,\eta)-P_m>0=\Pr ob\,(z'\gamma+u_1>0) \tag{3}$$

Assuming that the disturbance term is normally distributed, this becomes a standard Probit model. By symmetry of the normal distribution, Equation 4 is obtained as follows:

$$\Pr\ ob\ (P_r-P_m>0)=\Pr\ ob\ (u_1<z'\gamma)=F(z'\gamma) \tag{4}$$

Where $F(\cdot)$ is the cumulative density function of the normal distribution.

This is then estimated using the maximum likelihood estimation, in which the likelihood function is as follows:

$$\ln L=\sum_{y_i=0}\ln(1-\Phi_i)+\sum_{y_i=1}\ln(\Phi_i) \tag{5}$$

Thus, in general the Probit model to be estimated to determine the factors influencing the adoption of improved rice varieties is of the form:

$$A^*=z'\gamma+u_1 \tag{6}$$

where A* can be viewed as an indicator for whether or not this latent variable is positive as depicted in Equation 7.

$$A=\begin{cases}1 \text{ if } A^*\ge 0 \text{ i.e } -u_1<Z'\gamma \\ 0 \quad otherwise\end{cases} \tag{7}$$

The rest of the variables are as defined.

Sample selection bias

According to Barnow et al. (1980), sample selection bias arises when in program evaluations, the treatment (or control) status of the subjects is related to unmeasured characteristics that themselves are related to the program outcome under study. In this case, they define the term bias as the potential mis-estimate of the impact of the treatment (or programme) on the outcome. In this present study, selection bias can arise when improved rice adoption is related to unmeasured characteristics like farmers' innate ability which are also related to their rice output. Sample selection has been well expounded in Heckman (1979) and Smit (2003). One common version of sample selection which is related to this present study is where information on the dependent variable is available for all respondents, but the distribution of respondents over categories of the independent variable of interest has occurred in a selective way.

For example, in this present study, the main objective is to determine the effects of improved rice adoption on output. Thus, there are two main categories of respondents, namely adopters and non-adopters of improved rice varieties. If adoption (normally specified as a dummy variable) is simply regressed on output, the estimate of the adoption effect may be biased because the distribution of respondents over the categories of adopters and non-adopters was not random. Adopters may differ in several (measured and unmeasured) ways from non-adopters. If these characteristics are related to output, the coefficient of the adoption variable may catch up these effects and be biased because of this. In other words, supposed an output equation was estimated and it was found that adopters on a whole had a greater output level than non-adopters, how sure would the researchers be that adopters' relatively high level of output was as a result of the adoption of improved variety and not other positive innate characteristics that adopters possess? The idea behind Heckman's sample selection procedure is to estimate a selection equation (the Probit model in this study) and use the predicted values to form a selection control factor (λ) equivalent to the Inverse Mills Ratio (IMR) which will serve as an additional regressor in the substantive equation. In this case, the pure effect of adoption on output was measured. Besides, the other determinants of output are freed from the effects of the unmeasured characteristics and therefore the coefficients are unbiased (Smit, 2003).

Thus, given a substantive equation of the form:

$$Y_i=X_i'\beta+e_2 \tag{8}$$

Where Y_i is output, X_i is a vector of farm inputs, β is a vector of parameters to be estimated, e_2 is the two sided error term also with mean zero and constant variance.

Equation 6 is estimated and the predicted values of adoption used to construct λ equivalent to the IMR, which is included in equation 8 as an additional regressor. According to Heckman (1979) when this is done the pure effects of adoption can be evaluated and also, the other explanatory variables in equation 8 are freed from the unmeasured characteristics, such as the farmer's innate ability.

Treatment effect model

Treatment effect model is similar to the Heckman's two stage sample selection model. The main difference between the two

Table 1. Definition of variables used in the study.

Variable	Definition	Expected sign
Age	Age of the farmer in years	+/-
Education	Number of years of formal education	+
Household size	Number of people in farmer's house eating in the same bowl	+/-
Farm size	Size of farmer's yam plot in acres	+
Extension	Dummy; 1 if farmer had access to extension service during farm season in question formal education; 0 if otherwise	+
Adoption	Dummy; 1 if farmer adopted improved rice seed; 0 if otherwise	+
y_1	Natural Logarithm of rice output in kilograms	+
x_1	Natural Logarithm of farm size in acres	+
x_2	Natural Logarithm of labour cost in Cedis	+
x_3	Natural Logarithm of seeds in kilograms	+
x_4	Natural Logarithm of fertilizer cost in Cedis	+

however, is that in the case of the former, the treatment condition (adoption in this case) enters the substantive equation to measure the direct effect on output (Maddala, 1983). Thus, the regression equation becomes:

$$Y_i = X_i'\beta + A_i\delta + u_2 \quad (9)$$

Where δ measures the effect of adoption on output and A_i is as defined earlier. Adding the IMR translates into:

$$\ln Y_i = \beta'\left(\Phi_i \ln X_i\right) + \delta'\left(\Phi_i A_i\right) + \sigma\phi_i + u_3 \quad (10)$$

(Maddala, 1983)

where ϕ_i and Φ_i are the probability density function (PDF) and the cumulative density function (CDF) respectively of the standard normal distribution, and $\Phi_i \equiv \Phi\left(w_i'\gamma\right)$. u_3 is two sided error term with $N\left(0, \sigma_v^2\right)$. The rest are as defined earlier.

EMPIRICAL MODEL

The empirical models of the study are as follows:

$$A = \gamma_0 + \gamma_1 Age + \gamma_2 Agesqd + \lambda_3 Education + \gamma_4 Extensio \quad (11)$$

(Adoption Model)

$$y_1 = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \delta_1 A + u_2$$

(Output model)
The variables are as defined in Table 1.

Data and study area

The data for this study come from the Statistical, Research and Information Directorate (SRID) of the Ministry of Food and Agriculture (MoFA) in conjunction with the Ghana Strategy Support Program (GSSP) of the International Food Policy Research Institute (IFPRI). It must be mentioned that the data was collected as a pilot study and as such the sample size for rice producers was only 414 from rice producing communities in thirteen selected districts in Ghana as follows: Gushiegu and Yendi districts of the Northern region, Bawku municipality and Kassena Nankana East in the Upper East region, Lawra and Sisala East in the Upper West of Ghana, North Tongu in the Volta, Sekyere Afram Plains in Ashanti, Assin North in the Central, Atiwa in the Eastern and Ga East and Ga West both in the Greater Accra Region of Ghana. The final data was sorted to select 406 because 8 of the farmers did not have all the information that are needed.

Definition of variables used in the study

Table 1 shows the definition of variables used in the estimation of the model and their expected signs. From the literature, the effect of the farmer's age is ambiguous; it can be positive or negative depending on the study. The argument is that older farmers may have more experience, resources, or authority that may give them more possibilities for trying a new technology. On the other hand, younger farmers have been found to be more knowledgeable about new practices and may be more willing to bear risk and adopt new technology because of their longer planning horizons. Education is also expected to have a positive effect on adoption because it increases knowledge thereby enhancing the ability to derive, decode and evaluate useful information for technology adoption.

Household size has been identified to have either positive or negative influence on adoption. Larger family size is generally associated with a greater labour force for the timely operation of farm activities. The negative relationship of the variable with adoption has been linked to increased consumption pressure associated with large family which does not permit them to have the means to invest in new technologies for their farms. Normally, farming households with bigger landholdings are supposed to have an enhanced ability to afford improved technologies and a greater capacity to cope with losses if the technologies fail. Furthermore, access to extension gives famers the opportunity to gain knowledge and also obtain some encouragement with respect to the adoption of technologies. Lastly, from neoclassical production economics output is a positive function of land (farm size), labour and

capital (seeds and fertilizer) (Koutsoyannis, 1979).

RESULTS AND DISCUSSION

The results and analyses of the model estimation are presented in this section. The descriptive statistics of the variables used in the study are first discussed.

Descriptive statistics of the variables used in the study

Majority of the respondents were males constituting 75.4% of the sampled population. Also, the percentages of respondents who used improved seeds and traditional seeds were 49 and 51, respectively while 54.5% had access to extension services. Furthermore, from Table 2 the mean age of the farmers was 48.3. This age falls within the adult population in Ghana. One of the challenges facing agriculture in Ghana is the ageing population of the farmers. The farming profession appears unattractive to the youth. The average years spent in school by the farmers was 2.15. In Ghana, six years is spent in primary school while an additional three years is spent in the Junior High School (JHS) to complete basic education. The 2.15 average years spent in school by the sample farmers attests to the fact that there was low level of education among the farmers. Specifically, 76.2% of the farmers had no formal education, while 10.9% each finished basic and secondary education. Only 2.5% made it to the tertiary level. The mean farm size of 4.92 compares with the national average of 5 acres. In Ghana, small-scale farmers are about 92% of the farming population (MoFA, 2010c). On the average, it took Gh⊄ 11.01 and Gh⊄ 6.50 of labour and fertilizer costs respectively to cultivate 4.92 acres of rice plot. The average quantity of seeds for the same plot size was 24.41 kg.

Determinants of improved rice variety adoption

From the results in Table 3, all the variables, except age and age squared were significant. However, household size and education had a positive effect on the probability of adoption, farm size and extension service had a negative effect on adoption. Our findings are consistent with that of Foltz in (2003) who argued that formal education helps farmers to understand the information about a technology which in turn facilitates the adoption of a technology. Similarly, education gives farmers the ability to perceive, interpret and respond to new information much faster (Uaiene et al., 2009; Nzomoi et al., 2007; Salasya et al., 1996). Also, the significance of the household size variable can be attributed to the fact that the large household size served as labor for their farm plot. However, the negative sign of the coefficients of extension service and farm size variables did not meet our *a priori* expectations. Normally, the extension contact should lead to increased probability of adoption, since farmers who have contacts with extension staff have the opportunity of learning about improved varieties. Also, normally, farmers who have large farms size tend to have a higher probability of adoption because they are able to allocate some portions of their field to cultivating the improved seed as a trial, pending their full acceptance of the new technology. In this present study, the negative coefficient means that rather farmers with smaller farms as well as those who did not receive extension services had high probability of adopting improved rice varieties.

The effects of adoption on output

The main objective of this study was to investigate the effects of improved seed adoption on rice output. In other words, the study sought to find out whether the adoption of improved rice seeds leads to increased output as opposed to the adoption of traditional varieties, other things being constant. From Table 4, not only was the adoption significant but it maintained its expected positive sign confirming our *a priori* expectation that the adoption of improved rice seeds leads to increased output. This is consistent with the findings of Wiredu et al. (2010), Uaiene et al. (2009) and Sserunkuuma (2005).

It can also be observed from the table that apart from seeds, all the other variables were significant and maintained their positive sign. The sum of the coefficient of the conventional input is 0.76, implying that there was decreasing returns to scale. A 100% increase in land led to a 26% increase in output while a 100% increase in labour led to a 21% increase in output. Also, while a 100% increase in seeds led to a 5% increase in output, a 100% increase in fertilizer led to a 24% increase in output.

The significance of lambda (λ) in Table 1 implies that selectivity bias was present in the model and that if it was not correct, the estimated coefficients, including the adoption variable, would have been bias, meaning that the pure effects of the explanatory variables on output could not be measured. Thus, the pure effects of the explanatory variables on output would not have been measured. However, the correction of the selectivity problem ensured that the estimated coefficients were freed from the effects of unobserved factors that correlated with the adoption variable.

Policy implication

As indicated earlier, the findings of this study are consistent with that of many studies that evaluated the effects of the Asian Green revolution that took place in the early 1960s (Johnson et al., 2003; Janvry and Sadoulet, 2002; Evenson and Gollin, 2000; Hazell and

Table 2. Descriptive statistics of the variables used in the study.

Variable	Mean	Standard Dev.	Minimum	Maximum
Age	48.63	16.44	4.00	90.00
Education	2.15	4.16	0	15.00
Household size	7.47	5.88	1.00	40.00
Farm size	4.92	5.32	0.50	42.00
Labour cost	110.11	251.24	2.00	2876.00
Seed	24.41	40.62	2.00	250.00
Fertilizer cost	60.56	93.92	0	850.00

Note that the amounts quoted here are in old Ghana Cedis. The equivalence is as follows: 2,000 Old Ghana Cedis=2 New Ghana Cedis=1 US Dollar.

Table 3. Maximum likelihood estimates for the parameters of the Probit adoption model.

Variable	Coefficient	Standard error	Z	P > |Z|	[95% Conf. Interval]	
Adoption						
Age	0.026	0.029	0.90	0.367	-0.031	0.083
Age²	-0.000	0.003	-0.74	0.460	-0.001	0.000
Education	0.518	0.225	2.30	0.021**	0.077	0.959
Extension	-0.330	0.189	-1.74	0.082*	-0.700	0.042
Farm size	-0.031	0.175	-1.79	0.074*	-0.065	0.003
HH size	0.666	0.017	3.96	0.000***	0.034	0.995
Constant	-0.966	0.693	-1.39	0.163	-2.325	0.393
λ	-0.585	0.338	-1.73	0.084*	-1.248	0.780
Rho	-0.461					

Source: Field Survey *** Significant at 1%, ** significant at 5%. Note: Dependent variable: Adoption of improved seeds. Number of observation = 406. Wald chi² (5) = 66.27 and pro > chi² = 0.000.

Table 4. Maximum Likelihood Estimates of treatment effect model-two step estimates.

Variable	Coefficient	Standard error	Z	P > |Z|	[95% Conf. Interval]	
Output						
Farm size	0.255	0.122	2.09	0.036*	0.016	0.494
Labor	0.212	0.628	3.38	0.001***	0.892	0.335
Seeds	0.550	0.801	0.69	0.492	-0.102	0.212
Fertilizer	0.240	0.055	4.38	0.000***	0.132	0.347
Adoption	1.419	0.535	2.65	0.008***	0.370	2.467
Constant	3.237	0.431	7.50	0.000***	2.392	4.083

Source: Field survey ***, significant at 1%, ** significant at 5%, * significant at 10%. Note: Number of observation = 406, Wald chi² (5) = 66.27, Prob > chi² = 0.000.

Ramasamy, 1991). These studies found that with complementary inputs like fertilizer, irrigation and insecticides, the improved varieties of rice and maize did far better than the traditional seeds. The net effects of the Green revolution was that many countries that were hitherto net rice importers became net exporters leading to overall increased world output. Proponents of the Green revolution argued further that with expanded market as a result of exports, farmers had the opportunity to increase their output, leading to increased income, and for that matter poverty reduction.

On the other hand, critics argued that the Green revolution led to income inequalities in favour of large-scale farmers who had access to the complementary inputs. They stressed that since the high yielding varieties of rice and maize could not do well without the

complementary inputs, little or no access on the part of poor small-scale farmers meant that they were often out-competed and marginalized by their well-to-do counterparts, leading to a further widening of the gap between them (Cleaver, 1972; Gadgil and Guha, 1995; Todaro and Smith, 2003). The implication then is that for the former to also benefit from the adoption of improved seeds, there should be conscious and affirmative efforts to support them in accessing the complementary inputs.

As indicated earlier, SSA and for that matter, Ghana, missed out of the initial Green revolution. However, with support from AGRA through the instrumentality of Kofi Annan, a former UN Secretary-General, the revolution has been re-introduced into the country. For the revolution to succeed this time, there is the need to correct the mistakes associated with the first one. Currently in Ghana, the fertilizer subsidy programme that was removed some years back has been restored. However, not only is the price of the input the same for all farmers, the mode of sale is such that large-scale farmers can have greater access to the disadvantage of small scale farmers. In the long run, if this is not checked the consequence would be that some small scale-farmers may buy the input at a higher price. Fortunately, in this study the probability of adoption was greater for small-scale farmers. Since they constitute over 90% of the farming population (MoFA, 2010c), they need to be supported. However, the fact that output increased with farm size means that large-scale farmers cannot be relegated to the background. Generally, both groups of farmers must be supported but there should be a conscious effort to ensure that large-scale farmers do not enjoy at the detriment of small scale farmers.

Conflict of Interests

The authors have not declared any conflict of interests.

List of acronyms: AGRA, Alliance for a Green revolution in Africa; CDF, cumulative density function; GDP, gross domestic product; GSSP, Ghana strategy support program; IFPRI, international food policy research institute; IMR, inverse mills ratio; JHS, Junior High School; MDGs, millennium development goals; MoFA, ministry of food and agriculture; NERICA, new rice for Africa; NRDP, rice dissemination project; PDF, probability density function; SRID, statistical, research and information directorate; SSA, Sub Saharan Africa; UN, United Nations.

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