ADOPTION OF GREEN REVOLUTION SERVICES AND POVERTY REDUCTION IN GHANA

SAMUEL A. DONKOH

Dept. of Agricultural Economics & Extension
University for Development Studies
Tamale, Ghana
sammidonkoh@yahoo.com

RICHARD TIFFIN

Dept of Agricultural and Food Economics
University of Reading
Reading, U.K

AND

CHITTUR SRINIVASAN

Dept. of Agricultural and Food Economics
University of Reading
Reading, UK.

ABSTRACT

In Sub-Saharan Africa (SSA) the technological advances of the Green Revolution (GR) have not been very successful. However, the efforts being made to re-introduce the revolution call for more socio-economic research into the adoption and the effects of the new technologies. The paper discusses an investigation on the effects of GR technology adoption on poverty among households in Ghana. Maximum likelihood estimation of a poverty model within the framework of Heckman's two stage method of correcting for sample selection was employed. Technology adoption was found to have positive effects in reducing poverty. Other factors that reduce poverty include education, credit, durable assets, living in the forest belt and in the south of the country. Technology adoption

itself was also facilitated by education, credit, non-farm income and household labour supply as well as living in urban centres. Inarguably, technology adoption can be taken seriously by increasing the levels of complementary inputs such as credit, extension services and infrastructure. Above all, the fundamental problems of illiteracy, inequality and lack of effective markets must be addressed through increasing the levels of formal and non-formal education, equitable distribution of the 'national cake' and a more pragmatic management of the ongoing Structural Adjustment Programme.

KEY DESCRIPTORS: Green Revolution, Technology Adoption, Poverty, Selectivity bias.

INTRODUCTION

Most of the World's poor people live in Tropical Africa where on the average, more than half of the people live on less than $1 a day (World Bank, 2006). About 18.5 percent of Ghanaians are extremely poor (ISSER, 2007). According to ISSER (2007; 21) "Although Ghana's poverty profile has improved in overall terms, there are widening income disparity in a number of regions that raise welfare and social concerns." The vision for Ghana's agricultural sector is "a modernized agriculture culminating in a structurally transformed economy and evident in food security, employment opportunities and reduced poverty" (MOFA, 2008; 4). In line with this vision, the specific objectives of MOFA (2008) includes: (I) the development and dissemination of improved varieties of seeds and planting materials, crop improvement, adaptation and multiplication of introduced varieties; and (II) the improvement in farm level operations (cultural practices), soil degradation and post-harvest handling, among others.

In recent history, the Green Revolution (GR) have led to significant increases in agricultural output; transforming the lives of millions of people world-wide (Gollin, Morris & Byerlee, 2005). The term GR

refers to 'specific plant improvements notably the development of High Yielding Varieties (HYVs) of rice and wheat' (Griffin, 1979; 2). However, it is worth-noting that the GR came as a 'package' involving not only HYV seeds but also chemical fertilizers, insecticides, pesticides, irrigation and mechanization (Brooks, 2005). The effects of the GR technologies have been a subject of intense debate and are well-documented (Hazell & Ramsamy, 1991; Evenson & Gollin 2000; Niazi, 2004; Gollin, Morris & Byerlee, 2005, Johnson, Hazell & Gulati, 2003). Generally, the effects have been thought of as mixed. Johnson, Hazell and Gulati (2003) indicate that the GR spurred economic growth in much of Asia helped in reducing world poverty significantly. On the other hand, critics of the revolution (Cleaver, 1972; Gadgil & Guha, 1995) argue that the revolution has rather increased income inequality and worsened poverty (Niazi, 2004). It is indicative that the rural poor did not receive a fair share of the benefits.

Arguably, Africa missed out in the first revolution for several reasons. The reasons are generally categorized under research, policy and infrastructure (Johnson et al., 2003; Dadi, Burton & Ozanne, 2004). In the area of research it is argued that the initial thrust of the revolution did not target most of Africa's staples like tubers and millets, instead, rice, and later, maize were targeted. Similarly, instead of developing "germplasm" that were suitable for African soils and climate, the process was short-cut by importing already developed ones from Asia. Lastly, it is argued that most African governments at the time were not interested in agricultural-led growth; rather they saw industrialization as the panacea for growth. Consequently, instead of producing food for local consumption they relied on importation of food products while they concentrated on industrialization. Lack of commitment to agriculture, and for that matter the GR meant that the provision of infrastructure and other complementary factors that facilitated the diffusion of the GR in Asia was lacking in Africa.

Since the early 1980s almost all African countries have embarked upon the Economic Recovery and Structural Adjustment Programmes (ERP/ SAP) (Kherallah, Delgado, Gabre-Madhin, Minot & Johnson, 2002). In the agricultural sector the tenets of the programmes implied the elimination of price controls on agricultural commodities, privatization of state farms and other state-owned enterprises, reduction of heavy taxation of agricultural exports, the removal of subsidies on agricultural inputs, and allowing greater competition in agricultural markets. While defenders of the programmes argue among others, that the reforms have reduced budget deficits and stimulated export production, concerns have been raised with respect to the apparent widening of the income distribution gap and the reduction in access to agricultural inputs of the GR type (Kherallah et al., *2002*). It has also been argued that unfair trade practices on the part of the EU and US (with subsidies legitimised by the World Trade Organization) have compounded the negative effects of structural adjustment. For instance, trade liberalization allows low-priced foreign agricultural products to enter African economies to the detriment of local production.

However, the motivation for this study is the fact that some of these problems are being addressed (though not at a pace that many would like) for a re-introduction of the GR. The initial problem of lack of political will appears to have been overcome, considering the growing commitment to agricultural development and food security as depicted in the formation of the New Partnership for Africa's Development (NEPAD) (Johnson et al., 2003) and the formation of the Alliance for a Green Revolution for Africa (AGRA) with Kofi Annan as the chairman, to help realize the vision. Above all, as Gollin and associates (2005) note, the revolution has led to the development of modern varieties (MVs) of almost all the African crops. It is against this backdrop that in this study we seek to find out whether the adoption of Modern Varieties (MVs) with other complementary inputs (as opposed to traditional inputs) leads to a reduction in the poverty levels of the farming house-

holds in Ghana. We do this within the framework of Heckman's (1979) two stage method of correcting for sample selection.

THEORETICAL FRAMEWORK

Technology is defined in terms of an innovation that is perceived as new and helps us to increase output. While adoption is defined as the extent of use of an innovation, the term "diffusion" is used to describe the spread of technology among a community, region, nation or even globally. Studies of adoption and diffusion behaviours were undertaken initially by rural sociologists (Feder, et al., 1985). Such sociological studies included Ryan and Gross (1943) and Rogers (1962). Rogers (1962) conducted studies on the diffusion of hybrid corn in Iowa, United States, and compared diffusion rates of different counties. Like his counterparts, he found that in most countries, diffusion was an S-shaped function of time. Thus, the rate of technology adoption initially increases and finally decreases. While identifying communication as the main driving force underlying the spread of innovation, they also found that counties that were farther away from commercial cities or the focal point (where the technology was first realised) had lower rates than those close to the focal point because of higher travel and transport costs. Griliches' (1957) seminal work on hybrid corn offers a good econometric approach to the study of diffusion and for that matter adoption of technology. He estimates a logistic function (the logistic function is similar to the probit model explained later in the study). Griliches' study confirmed the findings by Rogers and found variation in the parameters across districts and explained them by factors such as market size, corn acreage per farm and most importantly, differences in profitability in the districts. Feder and associates (1985) review theoretical developments and empirical studies on adoption of agricultural innovations in developing countries. They discover that adoption decisions are influenced by farm size, risk and uncertainty, human capital, labour availability, credit constraints, supply constraints, land ownership and rental arrangements, among others. Similarly, technologies will spread

fastest in areas where information about the innovation is readily available and most easily evaluated by potential adopters. This underscores the importance of education and extension services in the technology adoption/diffusion process.

Poverty is a function of household endowments which consists of two major groups, namely, human and physical capital (Grootaert, 1997). Human capital is embodied in the members of the household, and the ability to use this capital effectively in the labour market. Among others, it has to do with the age, sex and educational level of the members of the household, that of the head being very important. Physical capital, on the other hand, includes the amount of land, value of farm and non-farm equipment and value of durable assets. From the literature, credit and infrastructure are also important determinants of poverty.

METHOD OF ANALYSIS

Meaning of selectivity bias

In a regression context, selectivity bias is defined as when one or more regressors are correlated with the residual term (Ettner, 2004). The often cited example (Heckman, 1979; Smits, 2003) of selectivity bias is measuring the effects of education on income. However, we know that some women have little or no education and hence may earn little or no income. In this case, running a regression with income as a dependent variable (for men and women) and education as one of the explanatory variables may lead to biased estimates of the effect of education on income.

Consider a model of the form

$$y_i = X_i'\beta + u_i \quad \text{if} \quad y_i > 0 \qquad (1.2)$$

$$y_i = 0 \quad \text{otherwise}$$

where y_i is income; X_i is a set of explanatory variables (including education) that determine y_i; u_i is the error term; and β is the parameter to be estimated measuring the effects of X_i on y_i. If equation 1.1 is estimated with Ordinary Least Squares (OLS), the estimates will be biased because y_i is truncated implying that $E(u_i) \neq 0$. The idea behind Heckman's two stage method is to evaluate $E(u_i)$, substitute in Equation 1.1, and estimate it by OLS.

To further prove that the estimation of Equation 1.1 yields inconsistent estimates, let us find the expected value of y_i as:

$$E(y_i \mid y_i > 0) = \beta' X_i + E(u_i \mid u_i > -\beta X_i)$$

$$= \beta' X_i + \sigma \frac{\phi_i}{\Phi_i} \qquad (1.3)$$

where ϕ_i and Φ_i are the density function and the distributional function of the standard normal evaluated at $\beta' X/\sigma$. Thus, the second part of equation 1.3 is non-zero.

The two density functions evaluated at $\beta' X/\sigma$ is the Inverse Mills Ratio (IMR).

$$y = \beta' X_i + \sigma \frac{\phi_i}{\Phi_i} + v_i \qquad (1.4)$$

Re-writing equation 1.3,

Where $E(v_i) = 0$ (1.5)

Given 1.5, equation 1.4 can now be estimated. However, ϕ_i/Φ_i is not known. According to Maddala (1983) it can only be computed using β and σ in the ratio form (i.e. $\beta' X/\sigma$). Heckman's (1976) suggestion was that since the likelihood function of the probit model is well-behaved (i.e. has an error term with zero mean and constant variance), we define a dummy variable:

$$D_i = 1 \quad \text{if} \quad y_i \geq 0 \qquad (1.6)$$
$$D_i = 0 \quad \text{, otherwise}$$

where D_i is education. The probit model is then estimated by maximum likelihood. In this case, estimates of $\beta' X/\sigma$ can be obtained with which estimates of ϕ_i/Φ_i (i.e. $\hat{\phi}_i/\hat{\Phi}_i$) can be constructed. Having obtained $\hat{\phi}_i/\hat{\Phi}_i$, equation 1.4 can now be estimated (using $\hat{\phi}_i/\hat{\Phi}_i$ in place of ϕ_i/Φ_i) to obtain consistent estimates of β and σ. However, Maddala (1983; 222) further argues that if we use all the observations of y_i and not just the non-zero observations, we have:

$$\begin{aligned} E(y_i) &= \Pr ob(y_i > 0)\cdot E(y_i \mid y_i > 0) + \Pr ob(y_i \leq 0)\cdot E(y_i \mid y_i \leq 0) \\ &= \Phi_i\left(\beta' X_i + \sigma\frac{\phi_i}{\Phi_i}\right) + 0 \\ &= \beta'(\Phi_i X_i) + \sigma\phi_i \end{aligned} \qquad (1.7)$$

Thus after estimating 1.6 to obtain estimates of ϕ_i and Φ_i, 1.7 is estimated (using all the observations of y_i) to obtain estimates of β and σ. Equation 1.7 is very important for the model of our study.

Within a treatment effect model framework Key & McBride (2003) measure the impact of participating in production contract on hog farm productivity in the United States. The selection equation to measure the probability to contract is given as:

$$C_i^* = w_i'\gamma + u_i \qquad (1.8)$$

where

$C_i = 1$ if $C_i^* > 0, 0$ otherwise

w_i is a vector of operator, farm and regional characteristics and C_i is the observed value of the latent variable 'contracting'.

The substantive equation measures farm performance as:

$$y_i = X_i\beta + C_i\delta + \varepsilon_i \qquad (1.9)$$

where X_i is a vector of operator, farm and regional characteristics.

Key & McBride's (2003) argument is that they cannot simply estimate the substantive equation (without first estimating the selection equation) because the decision to contract may be influenced by unobservable variables like management ability that may also influence farm performance. This implies that the two error terms (in the selection and substantive equations) are correlated, leading to biased estimates of β and δ.

Thus, given that u_i and ε_i have a joint normal distribution with the form:

$$\begin{bmatrix} u \\ \varepsilon \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho \\ \rho & \sigma^2 \end{bmatrix}\right), \quad (1.10)$$

then it follows that the expected performance of those who contract is given as:

$$E[y_i \mid C_i = 1] = X_i\beta + \delta + E[\varepsilon_i \mid C_i = 1]$$
$$= X_i\beta + \delta + \rho\sigma\lambda_i \quad (1.11)$$

where $\lambda_i = \dfrac{\phi(-w_i'\gamma)}{1-\Phi(-w_i'\gamma)}$ is the IMR. (1.12)

Equation 1.12 implies that when we estimate equation 1.11 without the IMR, the coefficients β and δ will be biased, hence the use of Heckman's two-stage procedure. However, according to Key and McBride (2003), this procedure is consistent but not efficient. Efficient maximum likelihood parameter estimates can be obtained.

Empirical model

Along similar lines the models that explain GR technology adoption (1.13) and its effects on poverty (per capita consumption) (1.14) are summarized as follows:

$A_i = w_i'\gamma + e_{1i}$ (Adoption model) (1.13)

$\ln C_i = \gamma'(\Phi_i \ln w_i) + \delta'(\Phi_i A_i) + \sigma\phi_i + e_{3i}$ (Per capita consumption model) (1.14)

where:

A_i is the proportion of expenditure on GR inputs.

w_i is a vector of individual, community and regional socio-economic variables affecting the adoption of GR inputs and per capita consumption. They include, sex of household head, age of household head, education of household head, non-agricultural income of household, credit, durable assets, farm size, household size, household labour, extension distance[1] and locality, ecology and regional distance.

$\ln C_i$ is the (log of) household per capita consumption/welfare.

γ , δ , β , are parameters to be estimated that measure the effects of the above explanatory variables on the dependent variables.

ϕ_i and Φ_i are the probability density function (PDF) and the cu-

[1]Not all the variables appear in all the models. The specific ones that appear in the individual models are indicated in Tables 2 and 3 below. Also, the variables in the per capita consumption model are logged with the exception of the dummy variables. Note that for identification purposes we make sure that at least one variable that appears in the adoption model does not appear in the per capita consumption model.

[2]The total sample size of the GLSS data was 6,000 households covering the entire country. However, not all the households were crop farmers: considering the objectives of the study we were interested in crop farmers and whether they were adopters of GR technologies or not. We had a total of 3,520 households who were crop farmers. Some of the data were not at the household level but rather individual farmer levels, we needed to aggregate them. Both the sorting and the aggregation were done in Microsoft Excel and Microsoft Access and the estimation in LIMDEP.

mulative density function (CDF) respectively of the standard normal distribution, and $\Phi_i \equiv \Phi(w_i'\gamma)$.

e_{1i}, and e_{2i} are two sided error terms with $N(0,\sigma_v^2)$.

Data

The data for the study come[2] from the Ghana Living Standards Survey (GLSS) (Round 4-1998/99)[3]. The data were collected by the Ghana Statistical Services in conjunction with the World Bank. The sample size was 3,520 made up of 1890 (54%) households who had adopted GR technology and 1630 (46%) non-adopters.

The Adoption Variable (Proportion Data)

In many adoption studies the adoption variable has been one (1) and zero (0) for adopters and non-adopters respectively. The problem with this is a possible loss of information associated with such discrete variable (Feder et al., 1985). Ideally, we want an adoption variable that is continuous in order that partial adopters are also catered for. Secondly, we desire to consider the GR technology in a holistic manner. That is to say we need not only look at improved seed but also the complementary inputs. In some studies (Akinola, 1987; Doss & Morris, 2001; Nkonya et al., 1997; Abbay & Admassie, 2004) attempts have been made to consider improved seed and one or more of the complementary inputs such as fertiliser or tractor services. However, that is not enough considering the fact that six of the GR inputs can be distinguished, namely; improved seeds, inorganic fertilizer, insecticide, pesticide, irrigation and tractor service. It is argued that one of the important reasons why the revolution has not spread fast in Africa is the inability of farmers (especially small-scale farmers) to buy the

[3]A current edition (GLSSV (2007)) is out but it is not available to the authors as at the time of writing the paper.

complementary inputs that go with the improved seeds (Todaro & Smith, 2003). Thus, in this study the adoption variable is the proportion of total (variable) expenditure spent on GR inputs. In the data-set we have expenditure on GR inputs as part of the total expenditure on variable inputs. Thus, the adoption variable is by our own computation, expressing expenditure on GR inputs over total variable expenditure.

Crop Expenditure

Crop expenditure is measured as the value (in old Ghana cedis) of total variable expenditures[4], out of which we have the value of expenditure on GR inputs.

Household Welfare/Per Capita Consumption

Welfare has been computed (Ghana Statistical Service, 2000) as; household per capita consumption divided by the Greater Accra (January 1999) Price Index augmented by Ghana's equivalence scale. Households whose welfare falls above the upper poverty line (90,000 old Ghana cedis, or 9 New Ghana cedis) are considered rich. Those whose welfare falls below the upper poverty line (70,000 old Ghana cedis, or 7 New Ghana cedis) but above the lower poverty line are poor, while the extremely poor households are those whose welfare falls below the lower poverty line (Ghana Statistical Service, 2000). Thus, by implication, households' per capita consumption, welfare and poverty status are the same in this study. It is acknowledged that the welfare variable is narrow in scope, as it is basically household consumption expenditure; this

[4]This include expenditure on organic and inorganic fertilizer, insecticides, herbicides, storage of crops, purchased improved seeds and seedlings, irrigation, bags, containers and string, fuel, spare parts, hired labour, transport of crops, renting of animals and equipment, local and imported tools, repairs and maintenance, other miscellaneous expenses.

does not represent the wide range of factors such as leisure that go into the welfare or standard of living of a household.

Average Distance from Extension Centre

In Ghana there are extension centres among the communities. It is anticipated that the closer a household is to an extension centre the better the access to services and therefore the greater the probability of adoption.

Regional Distance

Regional distance is the distance in kilometres from the capital town, Accra, to the (capital town of the) region in which a household is situated. We are considering this as a determinant of poverty/welfare. In Ghana, the incidence of poverty is greater in the north than in the south (Ghana Statistical Service, 2000). We want to find out empirically the extent to which remoteness to the capital town affects households' poverty/ welfare.
The rest of the variables are defined in Table 1 below.

RESULTS

In Table 2 below the results of the estimated adoption equation 1.13 above are presented. We notice that all the variables hypothesized to determine technology in Ghana (except sex of household head) are significant; and even though extension distance is significant at 1%, it does not have the expected negative sign. The proportion of expenditure on GR inputs (adoption) is also greater for households whose heads are young or literate; households with greater amounts of labour supply, non-agricultural income and credit; and households living in urban centres.

Table 1: Summary Definition of Variables

Variable	Description
Sex of household head	Dummy variable; 0 if head is male and 1 if female
Age of household head	No of years
Education of household head	Dummy; 0 if head has had formal education and 1 if otherwise
Household size	No of members in the household
Household labour	No of members of household who worked on the farm in that farming season
Farm size/land area	Total size of household farm plot measured in acres
Credit	Amount in million of Ghanaian cedis
Non-agricultural income	Total amount of non-agricultural income earned and received in millions of cedis
Durable assets	Total value in millions of cedis of household durable assets
Extension distance	Distance in kilometres from household to the nearest extension centre
Locality	Dummy; 0 if household lives in urban centre and 1 if in rural area
Coastal zone (coast)	1 if household lives in the coastal zone and 0 if otherwise (i.e. household lives in the forest or savannah zone).
Savannah zone (sava)	1 if household lives in the savannah zone and 0 if otherwise (i.e. household lives in the forest or coastal zone).
Regional distance	Distance in kilometres from Accra (the national capital) to the capital of the region in which a household lives.
Crop expenditure	Natural logarithm of total variable crop expenditure
Adoption	Proportion of GR input expenditure on total variable crop expenditure (i.e. $0 \leq adoption \geq 1$).
Welfare/ Per capita consumption	Household total nominal expenditure divided by the product of Accra price index and the national equivalence scale.
Poverty status	Dummy, 0 if welfare < minimum poverty line; 1 if minimum poverty line < welfare < maximum poverty line; 2 if welfare > maximum poverty line.

Source: Field Survey Note: All amounts are in old Ghana cedis.

Table 2: Maximum Likelihood Estimates for Parameters of the Probit Adoption Model

Variable	Parameter	Coefficient	Standard Error	T-Ratio	P-value	Marginal Effects
Constant	γ	-0.646	0.103	-6.26	0.000	-0.1802
Sex of HH head	γ_1	-0.075	0.52	-1.45	0.147	-0.0208
Age of HH head	γ_2	-0.003	0.002	-1.78	0.076*	-0.0008
Education of HH head	γ_3	-0.104	0.53	-1.96	0.051**	-0.0287
HH labour	γ_4	0.008	0.005	1.68	0.094*	0.0023
Non- agric. income	γ_5	0.023	0.13	1.725	0.085*	0.0063
Credit	γ_6	0.113	0.050	2.247	0.025**	0.0314
Extension Distance	γ_7	0.006	0.002	3.269	0.001***	0.0017
Locality	γ_8	-0.139	0.65	-2.138	0.033***	-0.0403
	χ^2	45.55	-	-	0.000***	-

Source: Field Survey ***, significant at 1% ** significant at 5% * significant at 10%

Note: Dependent variable: Proportion of GR input expenditure on total variable crop expenditure. No. of observation= 3520. Degrees of freedom=3512. Log likelihood function and restricted log likelihood are -1746.096 and -1768.871 respectively. Marginal effects are computed at the means of the independent variables.

Table 3 on the other hand, presents the results of the estimated per capita consumption equation 1.14. The coefficients of the variables that are in logs can be interpreted as elasticities. It is observed that all the variables, except the age of the household head, are significant. Most of the signs are also expected. For

instance, we expect that credit and ownership of asset would lead to increased welfare. Also, the negative sign of the coefficient of regional distance means that welfare increases with living close to the national capital, thus confirming Ofori's (2002) observation that the standard of living in southern Ghana is higher than northern Ghana. Household size is negatively related to welfare. However, it is interesting to find that female-headed households have greater welfare than their male-counterparts.

Also, technology adoption leads to increased welfare. Notice that σ and ρ are significant. Recall that the former is the coefficient of the IMR and the latter measures the correlation between the error terms e_{1i} and e_{2i} of equations 1.13 and 1.14 respectively. The significance of σ and ρ implies that selectivity bias was present in our model and that if we did not correct it the estimated coefficients of γ and δ would have been biased, which further implies that we could not have measured the pure effects of the explanatory variables (including adoption) on per capita consumption. However, having corrected the selectivity bias problem, the estimated coefficients are freed from the effects of unobserved factors that may affect adoption and consumption.

For every 1 percent increase in credit or agricultural equipment, per capita consumption increases by 0.1 percent. In the case of durable assets, 1 percent change results in 0.4 percent change in per capita consumption in the same direction. The importance of household assets on welfare is also validated by Datt & Jolliffe (2005) who found households' assets to have a positive effect on per capita consumption.

Table 3: Maximum Likelihood Estimates for Parameters of the Consumption Model

Variable	Parameter	Coefficient	Standard Error	T-Ratio	P-value
Constant	γ	14.35	0.05	315.03	0.00
Sex of HH head	γ_1	0.14	0.02	7.41	0.00***
Age of HH head	γ_2	0.00	0.006	1.48	0.14
Educt of HH head	γ_3	-0.11	0.02	-5.38	0.00***
House hold size	γ_4	-0.55	0.01	-42.15	0.00***
Farm size	γ_5	0.06	0.01	8.08	0.00***
Durable assets	γ_6	0.04	0.002	20.02	0.00***
Agric. Equipment	γ_7	0.01	0.002	4.67	0.00***
Credit	γ_8	0.01	0.01	2.10	0.04**
Coast	γ_9	-0.11	0.02	-4.60	0.00***
Sava	γ_{10}	-0.10	0.3	-3.61	0.00***
Regional distance	γ_{11}	-0.06	0.01	-10.44	0.00***
Adoption	δ	0.08	0.04	1.84	0.07*
Rho	ρ	0.12	0.03	4.06	0.00***
IMR	σ	0.51	0.01	90.39	0.00***
Log likelihood function		-4965.94			

Source: Field Survey *** , significant at 1% ** significant at 5% * significant at 10%.

Note: Dependent variable: Log of per capita consumption. No. of observation = 3520.

Like our study, Coulombe (2008) and Lyn (1999) find that female-headed households have higher income than their male counterparts and in Cortes' (1997) study, the probability of being poor was lower for female-headed households than male-headed households. In Rodriguez's (2000) study, even though he found a negative relationship between the probability of being poor and the sex variable, (implying greater probability of being poor for female-headed households) the variable was not significant. However, Anyanwu (2005) found that female-headed households have greater probability of poverty than male-headed households in Nigeria.

There is general evidence that education is positively related to income. Education increases the stock of human capital, which in turn increases labour productivity and earnings (Schultz, 1988). The positive effect of education on household welfare is confirmed by a number of studies (Coulombe, 2008; Lynn, 1999; Datt & Jolliffe, 2005; Gibson & Rozelle, 2003; Rodriguez, 2000). However, while Canagarajah and Porter (2002) found that primary education has no effects on welfare (per capita consumption), in Anyanwu's (2005) study it increased the probability of being poor. Coulombe (2008) also found the number of children going to school has negative effect on welfare. Lastly, studies by Hussain and associates (2006) and Chirwa and associates (2002) found that the adoption of irrigation systems and participation in public works projects respectively reduced the probability of being poor.

DISCUSSIONS

In this section, we take a holistic picture of the results presented above. Sex of the household heads was not significant in determining adoption. However, it was significant in explaining per capita consumption. Rodriguez (2000) argues that the issue of feminisation of poverty is said to exist if poverty is more prevalent among female-headed households than among male-headed

households. In this study, we find the opposite in Ghanaian farming households: Female-headed households are richer than male-headed households. This may be attributed to the income generation activities that women in Ghana are introduced to and empowered to engage in by governments (GOs) and non-government organizations (NGOs) in recent time. Similar work by Donkoh (2006) shows that female-headed households have higher non-farm incomes than their male counterparts. Also, it is believed that women are generally better financial managers. The age of the household head was significant in determining adoption, with the proportion of GR inputs adoption being greater for households headed by young adults. The variable was not significant in determining per capita consumption. Generally, greater probability of adoption by younger household heads than older heads is attributed to progressiveness on the part of the former.

Literate-headed-households have greater proportion of GR technology adoption and high welfare than their illiterate counterparts. This is consistent with Duncan's (1997) assertion that education is essential for the progressive development of agriculture since access to relevant sources of information can increase one's chances of obtaining credit and adopting modern technology leading to increased welfare.

Larger labour force increases the proportion of GR input adoption. This is understandable considering the fact that GR inputs require a large labour force. However, when the number of dependents is high (making the household size significantly bigger than the labour force) it adversely affects households' welfare as shown in the results. Earlier, we noted that capital availability was very important in technology adoption and for that matter the economic development of a nation. From the results credit did not only influence technology adoption but as well, welfare. Similarly, while non-agricultural income increased adoption, ownership of durable assets and agricultural equipment positively influenced house-

holds' welfare. In the estimated results, urban dwellers, compared to rural dwellers have greater adoption[5].

It is a fact that the urban areas in Ghana, like many countries are better endowed with infrastructural facilities than the rural areas. Roads, irrigation, electrification and accessibility to extension services, among others, are necessary basic foundations on which effective adoption of GR technology rests (Johnson *et al.,* 2003). Poor transportation and other infrastructure make inputs not easily accessible. In the case of extension distance, even though the variable did not maintain its expected sign in the adoption model, the fact remains that the availability of extension centres in the communities are important in increasing adoption. The availability of the centres means that farmers have a better opportunity to access information as opposed to their non-availability. Similarly, the negative sign of the ecological zone variables (coastal and savannah) implies that households in the forest belt have greater consumption (welfare) than their counterparts in the coastal and savannah zones. Also, the further away a household is from the national capital the poorer it is. In Ghana the south in general and Greater Accra region in particular, have most of the national assets like ports and government establishments and are more developed.

GR technology adoption leads to a reduction in a household's poverty level (i.e. increases welfare). This is the main result of the study. The question now is, if so, why is it that not all the households in Ghana have adopted the GR technology? Earlier, we noted how the removal of subsides on agricultural inputs has made it more difficult for farmers to access the inputs. The other reason is the imperfection of markets in Ghana like many developing countries. For instance, information about the efficiency of

[5]The variable was excluded from the per capita consumption equation. Exclusion from a model meant that the variable was not significant and was highly correlated with other variables.

modern inputs is lacking and even where it is available the poor nature of transportation facilities and other infrastructure does not allow for the efficient allocation of inputs and outputs by the price system.

RECOMMENDATIONS

In the light of the above, the following recommendations are made:

- The efforts being made by GOs and NGOs in empowering women to go into non-farm activities should be extended to male-headed households also, in the form of promoting the establishment of small-scale industries. Financial management training should also be given to help them better manage their incomes;
- Policy makers should take the education sector very seriously, both short and long-term. To raise the adoption level of all, especially households whose heads are old, GOs and NGOs may expand the scope and intensify the adult education programme. Farmers should also be exposed to much more workshops and on-farm experimentation;
- The government must intensify its family planning programme to make the desired impact. Households must plan their families so as to be able to cater for them effectively;
- The formation of farmer groups should be encouraged. This could lead to exchange labour supply (popularly called *nnoboa*) as an alternative to hired labour (which might be expensive for most of the farmers);
- It is important that policy makers and donor agencies increase their financial assistance to support technology adoption and welfare while stringent measures such as effective supervision are taken to ensure that agricultural credit is used for the intended purposes and not misapplied;
- The government may also have to be circumspect about its property tax and other taxation systems that may be a disin-

centive to asset ownership considering the importance of asset ownership in increasing households' welfare. This could be by waving off such taxes or reducing them significantly;

- Since the cultivation of large farms leads to increased welfare, households with small farms may be given the financial and moral support to expand their farms;
- It is important that the level of infrastructure, especially in the rural areas is increased to facilitate adoption. More extension centres must also be provided and the extension workers well-motivated to work more effectively; and to bring the other regions (especially those in the north) up, it is important that the government takes its decentralization policy more seriously and also ensures a fair distribution of the 'national cake'; and
- The ongoing ERP/SAPs should be taken more seriously to ensure the effective functioning of markets. However, the recent re-introduction of subsidies on agricultural inputs will go a long way to increase the adoption and diffusion of such inputs.

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