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Investing in agrochemicals in the cocoa sector of Côte d'Ivoire: Hypotheses, evidence and policy implications

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Abstract

This paper presents empirical evidence to show how socioeconomic factors affect the adoption of and investment in agrochemicals in the cocoa sector of Côte d'Ivoire. The analysis uses primary farm-level data collected in 2002 from a nationally representative sample of more than one thousand cocoa farmers. The study describes the status of the adoption of various chemical inputs and uses a multiplicative heteroscedastic Tobit model to identify and quantify the impact of the socioeconomic environment on the incentive to invest. The results generally show that farmer, household and village characteristics are all important in explaining the farmers' decisions. The paper concludes by outlining a number of implications for strategic targeting of farmers and locations. These should serve as entry points for a successful diffusion of efficient pest, disease and soil management programs.

Keywords: Chemical input; Tobit model; Cocoa sector; Socioeconomic factors; Côte d'Ivoire

Cet article apporte une preuve empirique et explique la façon dont les facteurs socioéconomiques affectent l'investissement dans les produits agrochimiques ainsi que leur adoption dans le secteur de la production du cacao en Côte d'Ivoire. L'analyse utilise des données primaires collectées en 2002 concernant les exploitations agricoles; celles-ci se basent sur un échantillon national représentatif de plus de mille producteurs de cacao. Cette étude décrit le status de l'adoption de divers intrants chimiques et utilise un modèle

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Tobit hétéroscédastique multiplicatif pour identifier et quantifier l'impact de l'environnement socioéconomique sur les raisons qui poussent à investir. Les résultats montrent en général que les caractéristiques propres aux producteurs agricoles, aux ménages et aux villages jouent toutes un rôle important dans l'explication des décisions des exploitants agricoles. L'article se termine par la mise en évidence d'un nombre d'implications dans le ciblage stratégique des producteurs agricoles et des localisations. Celles-ci devraient servir de points d'entrée à une diffusion réussie de programmes de gestion efficaces du sol, des maladies et des insectes nuisibles.

Mots-clés: *Intrant chimique; Modèle Tobit; Secteur de production du cacao; Facteurs socioéconomiques; Côte d'Ivoire*

1. Introduction

The importance of agriculture to the progress of less developed countries or developing economies is now beyond dispute. A vast body of knowledge has been accumulated that assigns a major role to agriculture in the early stage of a nation's progress towards industrialization. In a period of rapid globalization and market liberalization, African countries are pursuing their comparative productive advantage to foster growth in a new liberal economic context. The pursuit of this comparative advantage implies a continuous if not a larger role for tropical commodity exports to generate foreign exchange and promote economic growth (World Bank 2003).

Like most other developing countries, Côte d'Ivoire is a typical example of an economy that depends on export proceeds from primary products, in this case cocoa. Since independence in 1960, the development of cocoa production for export and foreign investment has made Côte d'Ivoire one of the most prosperous tropical African states (Nkamleu & Kielland 2006). Over the past ten years, West African countries have contributed the largest quantity of the world's cocoa, ranging between 54% and 71% of the total production (Awua 2002; FAO 2004). Côte d'Ivoire's cocoa sector is of special interest. Its size has tripled in the past 25 years and it now accounts for over 40% of global cocoa production.

Because of its importance for the overall GDP, export earnings and employment, and its forward and backward linkages to the non-farm sector, growth in the cocoa sector will continue to be the cornerstone of economic development and poverty reduction in Côte d'Ivoire. In the 2001 season, more than 1.4 million tonnes of cocoa were exported. Cocoa contributes approximately 40% of exports, 14% of GDP and more than 20% of government income (Save the Children Canada 2003). To aid economic development, Ivorian governments and institutions have sought strategies for achieving higher, and sustainable, levels of production.

West Africa's, and particularly Côte d'Ivoire's, cocoa yields of around 300 to 600 kg/ha are substantially lower than those observed in Southeast Asia (Indonesia and Malaysia) where average yields exceed one t/ha (Kazianga 2002). These low yields per hectare partly reflect the low market prices and low revenue received by farmers in recent years, which have caused farmers to reduce the quantity of inputs they apply to their tree stock investments. The most important of these inputs, beside labor, are agrochemicals – fertilizers for soil fertility, insecticides and fungicides for controlling pests and diseases.

The use of chemical inputs is an important agricultural issue. These have played a significant role in increasing agricultural production in the developing world over the past decades (Mackauer 1989; Wilson 1989; Pretty 1995). In the early 1960s, developments in agricultural production led to what came to be called the Green Revolution. The technological package on which this green revolution was based included improved and high yielding seed, mechanization and chemical inputs. However, a low use of chemical inputs is still cited as a major factor limiting the productivity growth of agriculture in most of sub-Saharan Africa and of the cocoa sector in particular.

Means to increase cocoa production in Côte d'Ivoire include the provision of nutrients and control of pests and diseases. Appiah et al. (1997) reported a doubling of yields in on-farm trials in Ghana after the application per hectare of 4.94 bags of triple super phosphate and 2.47 bags of muriate of potash over a four-year period. Many hundreds of insects and pathogens have been recorded on cocoa, but only a small number of these are economically significant in West Africa (CABI Commodities 2004). The most significant disease attacking cocoa is the fungal disease 'black pod', which is responsible for an estimated yearly loss of about 44% of total global production. Several species of fungi can cause black pod, but only two, *Phytophthora megakarya* and *Phytophthora palmivora*, are economically significant. The cocoa swollen shoot virus (CSSV) is another damaging disease in Africa. Sucking pests, mostly mealybugs, transmit the virus. It affects leaves and pods and causes stem and root swellings.

Insect pests are also serious constraints to cocoa production in West Africa. *Cocoa capsids* or *mirids* (*Distanthiella theobromae* and *Salbegella singularis*) are widely perceived as the most damaging. In outbreak years, especially in areas where trees have been neglected, losses could be up to 75%. Other insect pests in West Africa are mealybugs (*Planococcus* and *Stictococcus* species). Parasitic plants are another serious problem, the worst being mistletoe, which is a particular problem in young plantations established after the primary forest has been cleared. *Meloidogyne* species are the most significant nematodes parasitic on cocoa because of the damage they cause and their wide distribution in cocoa producing regions.

To attain the goals of economic development and poverty alleviation, farmers need to be encouraged to increase cocoa production by using agrochemicals. To design such strategies, information is needed about farmers' current use of chemical inputs and the factors that affect the adoption of these and the intensity with which they are used. Addressing such problems presents opportunities for the intensive utilization of the few areas of land that remain for cropping. The objective of this paper is to quantitatively examine the factors associated with farmers' decisions to adopt and apply agrochemicals on their cocoa farms.

This originality of this study is that (1) unlike most adoption studies, which focus on specific regions, it uses data from a nationwide survey and therefore allows rare analytical opportunities, and (2) it concentrates on the expenditure rather than on the decision to use these chemicals or the quantity used. This helps explain why some farmers spend more on agrochemicals than others. The difficulty of collecting accurate data on the actual quantity used, and the fact that farmers do not use the same brand or the same form of chemical (some use liquid while others use powders or granules), means that analysis based on the quantities used, as in most previous studies, is less reliable. To our knowledge, no empirical study like this one has been carried out previously in the cocoa sector.

The rest of this paper is organized as follows. Section 2 outlines the econometric methodology and describes the survey from which the data to be analyzed is derived. Section 3 presents the empirical model specification, Section 4 discusses the results, and the final section reports conclusions and discusses the implications of the study.

2. Data and econometric model

2.1 Data source

This study uses data from the cocoa sector in Côte d'Ivoire that were collected during an extensive national survey conducted in 2002, designed to establish baseline information for quantifying the future impact of activities in cocoa growing areas. Population figures for the cocoa belt, obtained from a national census conducted in 1998, provided the opportunity for a random selection of households for the study. The interviewers visited 134 villages in 20 subdivisions. The villages or clusters of households were selected using a stratified random sampling procedure, and in each village randomly selected household heads were interviewed using structured questionnaires. A total of 1372 households were surveyed, representing a sampling rate of 0.34%. Of the 1372 farmers interviewed, 1188 were cocoa producers.

The questionnaires covered a wide range of topics, such as cropping systems, land, water and soil fertility management strategies, pest control technologies, and marketing strategies. Information was also collected on rural services and other socioeconomic characteristics of the households and their members. Detailed information on the quality and quantity of inputs and the cost of chemicals used on the cocoa farms during the previous cocoa season was collected and provides the focus of this paper.

2.2. Analytical model: The Tobit model

The farmers' expenditure decision is modeled using a Tobit procedure. The dependent variable is the amount spent on agrochemicals, which is censored at zero. To avoid the censoring bias that Ordinary Least Squares could generate, a Tobit censored at zero was used because chemical expenditure smaller than zero was not observed and many respondents reported zero expenditure.[1] The application of this kind of limited dependent variable model is not new. A few recent examples include Hussain et al. (1994), Doss & Morris (2001), Otsuka et al. (2001), Ransom et al. (2003) Nkamleu (2004), Holloway et al. (2004) and Nkamleu & Tsafack (2007). While other estimation approaches, such as the Heckman's model, could also generate unbiased results, the Tobit approach conserved degrees of freedom and is relevant in cases such as this one, where the independent variables had a continuous effect on the dependent variable.

In a typical household neoclassical framework, profit maximization is assumed to be the only driver of production behavior. In such a framework, the decision to invest in agrochemicals and the amount of expenditure will be driven by net returns, which are determined only by the market wage, input and output prices and the physical characteristics of the farm (Feder et al. 1985; De Janvry et al. 1991; Katungi 2007). However, almost all developing countries are characterized by an imperfect market for inputs and outputs, which increase the costs of market transaction. Prices and wages are therefore affected by the transaction costs, which are affected by the farmer's socioeconomic and demographic conditions, including endowments of land, labor, social capital and other assets. Under such conditions, the utility maximization framework for analyzing a farmer's production behavior and adoption decisions is appropriate (Nkamleu & Coulibaly 2000; Nkamleu 2006).

The farmer's investment decision is assumed to be based on an objective of utility maximization. We define the investment behavior by '*j*', where *j* = 1 for investment and *j* = 0 for non-investment. The investment in agrochemicals will provide the farmer 'i' with a satisfaction U_{i1} and the non-investment will give him a satisfaction U_{i0}. The underlying utility function, which ranks the preference of the i^{th} farmer, is assumed to be a function of farmer-specific attributes (the vector X, which includes farmers' socioeconomic characteristics and village-specific characteristics) and a disturbance term assumed to have a zero mean. This utility function may be written as:

$$U_{i1}(X) = \beta_1 X_i + \varepsilon_{i1} \text{ for adoption and } U_{i0}(X) = \beta_0 X_i + \varepsilon_{i0} \text{ for non-adoption}$$

Choices being rational, a farmer will choose the alternatives that maximize utility. The i^{th} farmer will chose to invest if and only if $U_{i1} > U_{i0}$. Thus, for the farmer i, the probability of investing in agrochemicals is given by:

[1] A recent paper by Holloway et al. (2004) pointed out that even when a Tobit procedure is used, incorrectly assuming that the true point of censoring in the sample is zero also imparts a bias to the parameter estimates.

$$\begin{aligned}\wp(Y_i = 1) &= \wp(U_{i1} > U_{i0}) \\ &= \wp(\beta_1 X_i + \varepsilon_{i1} > \beta_0 X_i + \varepsilon_{i0}) \\ &= \wp(\varepsilon_{i0} - \varepsilon_{i1} < \beta_1 X_i - \beta_0 X_i) \\ &= \wp(\varepsilon_i < \beta X_i) \\ &= \Phi(\beta X_i)\end{aligned} \tag{1}$$

Where β is the vector of parameters to be estimated, X is the matrix of the explanatory variables. Φ is the cumulative distribution function for ε. The functional form for Φ will depend on the assumptions made about ε. The Tobit model is based on the supposition that ε_i is an independent, normally distributed error term with zero mean and constant variance σ^2. As expenditure cannot be negative (the threshold is zero), the dependent variable can be written using an index function approach (Chow 1983; Maddala 1983; Adesina & Zinnah 1993).

$$\begin{aligned}&I_{i*} = \beta X_i + \boldsymbol{\varepsilon_i} \\ &Y_i = I_{i*} \text{ if } I_{i*} > 0 \\ &Y_i = 0 \text{ if } I_{i*} \leq 0\end{aligned} \tag{2}$$

where I_{i*} is an unobservable index variable denoting the difference between the utility of investing (U_{i1}) and the utility of not investing (U_{i0}). If $I_{i*} = U_{i1} - U_{i0} > 0$, then the individual farmer 'i' will invest in agrochemicals. Y_i represents a limited dependent variable, which simultaneously measures the decision to invest in agrochemicals and the amount of expenditure. The expected value of the amount spent on agrochemical inputs and the expected value of Y_i, given that $Y_i > 0$, is given by:

$$E(Y_i) = \Phi\left(\frac{\beta X_i}{\sigma}\right)\beta X_i + \sigma\phi\left(\frac{\beta X_i}{\sigma}\right)$$

And (3 & 4)

$$E(Y_i / Y_i > 0) = \beta X_i + \sigma \frac{\phi\left(\frac{\beta X_i}{\sigma}\right)}{\Phi\left(\frac{\beta X_i}{\sigma}\right)}$$

where ϕ is the density function and $\Phi = F_i$, the cumulative distribution function of the standard normal distribution. The impact of the change in explanatory variables on the dependent variable, which is the amount of expenditure, would be captured through elasticity.

$$\left[\delta E(Y_j) \big/ \delta Xj\right] X_j \big/ E(Y_j) \tag{5}$$

Following McDonald/Moffit's decomposition (Greene 1992)

$$\left[\delta E(Y_i) \big/ \delta Xj\right] X_j \big/ E(Y_i) = \left[\delta E(Y_i / Y_i > 0) \big/ \delta X_j\right] X_j \big/ E(Y_i / Y_i > 0) + \left[\delta\Phi\left(\frac{\beta X_i}{\sigma}\right) \Big/ \delta X_j\right] X_j \Big/ \Phi\left(\frac{\beta X_i}{\sigma}\right) \tag{6}$$

After development (Maddala 1983) we obtained:

$$\left[\delta E(Y_i) \big/ \delta Xj\right] X_j \big/ E(Y_i) = \beta_j \left[1 - \frac{\beta X_i}{\sigma} \frac{\phi(\frac{\beta X_i}{\sigma})}{\Phi(\frac{\beta X_i}{\sigma})} - \left(\frac{\phi(\frac{\beta X_i}{\sigma})}{\Phi(\frac{\beta X_i}{\sigma})}\right)^2\right] X_j \big/ E(Y_i / Y_i > 0) + \left[\frac{\beta}{\sigma}\phi\left(\frac{\beta X_i}{\sigma}\right)\right] X_j \Big/ \Phi\left(\frac{\beta X_i}{\sigma}\right) \tag{7}$$

Therefore the total elasticity of a change in the level of any independent variable consists of two effects: (1) the change in the elasticity of the amount spent by farmers who adopted agrochemicals, and (2) the change in the elasticity of the probability of adopting chemical inputs.

3. Empirical model

In this section, we present the variables used in the analysis. As described, the dependent variable is CHEMICAL, which represents the amount in CFA francs ($1 was about 700 CFA in 2001) of money spent on chemical inputs per hectare of cocoa farm.[2] Previous studies in sub-Saharan Africa have suggested that a wide range of economic, social, physical and technical aspects of farming influences the adoption of agricultural production technologies. We have included most of them as dependent variables in the regression. A description of the variables included in the empirical model is given in Table 1. The discussions and hypotheses about the independent variables included in the model are provided below.

SEX is a dummy variable that indexes the gender of the farm operator (0 = female, 1 = male). The use of pesticides requires watering the plants with heavy watering cans, which women are less likely to be able to carry. Also, it is generally hypothesized that male-headed households are more likely to get information about new technologies and take risks than female-headed ones (Asfaw & Admassie, 2004). Previous studies in Africa found that men generally were more likely to adopt chemical inputs, a result that also reflects the effects of the capital constraints faced by women (Matlon 1994; Nkamleu & Adesina 2000). We hypothesized that SEX is positively related to the adoption of chemical inputs.

AGE is the age of the farmer in years. It has been documented that young people are more likely to take risks associated with innovation (Rogers 1983; Alavalapati et al. 1995). A recent study by Gockowski and Ndoumbé (2004) has revealed that young farmers are more likely to adopt new agricultural technologies. We hypothesized that AGE is negatively related to expenditure on fertilizer and pesticides.

EDUCATION measures the level of education attained by the farmer. Here 0 = no formal education, 1 = primary school, 2 = secondary and 3 = postsecondary. Education enhances farmers' ability to acquire and synthesize information and to respond quickly to new environments and situations. Educated farmers have been found to be more likely to adopt agrochemicals (Nkamleu & Adesina 2000; Asfaw & Admassie 2004). It was hypothesized that EDUCATION is positively related to adoption and expenditures on fertilizer and pesticides.

NATIVE and IMMIGRANT are native and international migrant status variables that work as cultural controls. They take the value '1' if the farmer is native (respectively immigrant) and '0' otherwise. Some past studies in Africa show that migrants tend to be more active in agriculture and often more entrepreneurial in the use of new technologies (Polson & Spencer 1991; Adesina & Chianu 2002). This suggests that migrants are more risk-taking than natives and will be more likely to invest in chemical inputs. We hence hypothesized a negative relationship for NATIVE, and a positive relationship for IMMIGRANT.

[2] The dependent variable used considered only the monetary cost of agrochemicals. Other related costs, such as transport (individual and chemicals), labor for chemical spreading and additional harvest labor were not collected.

RURALORG indexes whether a farmer is a member of a rural organization or not (0 = no, 1 = yes). Since farmers in local organizations are more likely to be in contact with research, development and extension agencies, they are more likely to adopt innovations. Also, farmers who join farmers' associations may be generally more receptive to innovations or interventions in the community, and this may affect their attitude to adopting new technologies. Membership in farmers' groups was hypothesized to positively influence the adoption of chemical inputs.

CASHCRED is a dummy for whether the producer has received cash credit during the last 12 months or not (0 = no, 1 = yes). In recent years, with the liberalization of the cocoa sector, the credit area has undergone many changes owing to the withdrawal of government-subsidized credit programs. Farmers lack cash to pre-finance the acquisition of inputs. We hypothesize a positive relationship between CASHCRED and CHEMICAL.

RESIDENCE indexes whether or not a farmer lives in the village or in a 'cocoa camp', taking on the value '1' if the farmer lives in the village and '0' if the farmer lives in a cocoa camp. Farmers living in cocoa camps may be facing relatively low population pressure owing to a lower degree of 'urbanization', making land availability more elastic and permitting farmers to practice long fallows. As shown by Matlon (1994) and Adesina (1996), distant fields are usually more fertile, thus less demanding in the use of agrochemicals. We hypothesized a positive relationship between RESIDENCE and the expenditure in chemical inputs.

PAVED measures the distance from the village to the nearest paved road. Villages that are far from the paved road face several constraints that limit their access to innovations. Extension agents are rarely able to reach them because of the long distances, lack of operational funds and logistical constraints. It is hypothesized that the further the village is from the paved road, the lower the probability of agrochemicals being adopted.

WEST, EAST and SOUTHWEST are dummy variables to control for regions (West, East and Southwest provinces). These variables were codified: '1' if a farmer belongs to the province and '0' otherwise. These regional dummies will account for regional differences in agro-climatic conditions among the four regions. The Eastern region is the region of new cocoa settlements, with many newly established farms. In the Western region, cocoa farms are older, and this implies more soil depletion problems. A positive sign is hypothesized for the Western region and a negative sign for the Eastern. The variable for the Center West region is used here as the base.

TOTAREA measures the area cultivated by the farmer (in hectares). It has been documented that the cultivated area positively influences farmers' adoption of chemical inputs (Norris & Batie 1987; Kebede et al. 1990; Polson & Spencer 1991). The influence of farm size on the use of technologies may be due to economies of scale effects or the ability to bear the risks of new technology adoption (CIMMYT 1993). It is hypothesized that TOTAREA is positively related to the use of agrochemicals.

NFARM denotes the total number of cocoa farms or fields managed by a farmer. In Côte d'Ivoire, farmers commonly manage several small cocoa plots, in different locations.

Managing a given area of cocoa split into several farms is more time consuming than managing the same area contained in one plot. Having several farms will lower the economies of scale effect. Thus, after controlling for area, we expect that an increase in the number of plots is likely to decrease the probability of adopting chemical inputs.

SHADINDEX indexes the level of shade from trees on the cocoa farms (1 = no shade, 2 = low shade, 3 = medium and 4 = high). Studies in Cameroon have shown that although cocoa farms with a high level of shade are ecologically and environmentally beneficial (Gockowski et al. 2000), these farms also experience a higher rate of pest and disease outbreaks (Kazianga 2002). We hypothesized that farmers with relatively more shade on their farms would be more likely to adopt agrochemicals.

TAGEIDEX is the average age of the cocoa farms. The potential of cocoa production is determined by the planted area, planting density and tree characteristics, such as age. According to Kazianga (2002), there are three stages of yield potential over time. In the first stage (0 to 10 years), yield increases rapidly. During the second stage (11 to 30 years), yield still increases, but more slowly. Finally, in the third stage (> 30 years), yield decreases. We expect a less intensive management practice during the decreasing period, as trees are wearing out. We hypothesized a negative relationship between TAGEIDEX and CHEMICAL.

ADULTQUIV indexes the number of adult male equivalents residing in the household, where adult men from 18 to 54 years of age are given a unitary weight, women of the same age category are given a weight of 0.8, adult men over the age of 54 are also given a weight of 0.8, women over the age of 54 are given a weight of 0.7, and children under the age of 18 are given a weight of 0.5. Labor, more than land, is recognized as the main constraint to the expansion of African agriculture (De Janvry et al. 1995). Although chemicals may help increase the output, they may also compete with family labor. To maximize the benefit from family labor, a farmer may invest less in some competing technologies. It is, for example, more rational for large households to use the available labor for weeding instead of applying herbicide. A negative relationship between ADULTQUIV and CHEMICAL is hypothesized.

A growing econometric concern about such empirical regressions is the particular risk of the endogeneity of certain variables (Dhar et al. 2003; Doss 2006). Some variables in our model, particularly the total cocoa area (TOTAREA) and credit (CASHCRED), may bear a two-way relationship with the dependent variable. Increasing the area operated may affect the quantity of agrochemicals used and, conversely, an increase in the quantity of inputs may influence the area. Receiving cash credit may, on the one hand, increase the amounts spent on agrochemicals. On the other hand, the decision to use agrochemicals may compel the farmer to seek credit. We thus tested these variables for endogeneity, using the procedure developed by Rivers and Vuong (Wooldridge 2002). In a first step, we ran two OLS regressions of TOTAREA and CASHCRED variables on a series of exogenous variables including instrumental variables. In a second step, we used the estimated residuals from the first step as a regressor in a Tobit regression of agrochemical expenses. The significance level of the coefficients on the residual variable formed the basis of the exogeneity testing. The coefficients on the residuals were both significant. Thus, the null hypothesis of exogeneity for

TOTAREA on CASHCRED was rejected. We therefore use the two-stage instrumental variable method to estimate our Tobit model. In the first stage, OLS regression is used to obtain the predicted values of the endogenous variable (TOTAREA and CASCRED). In the second stage, the predicted values of area cultivated and cash credit (PRED_TOTAREA and PRED_CASHCRED) are substituted for TOTAREA and CASHCRED. These intermediate-stage results are not presented in detail in this paper, but it should be noted that in predicting TOTAREA and CASHCRED the proportion of cocoa revenue in the household revenue, the use of external workers, and the land area devoted to other important cash crops were used as instrumental variables in the OLS regressions.

Table 1: Descriptive statistics of the variables used in the model

VARIABLE	**Description**	**Mean**	**Std dev**	**Minimum**	**Maximum**
Farmer's characteristics					
SEX	Gender dummy of the cocoa farmer 1=male 0=female	0.96	0.20	0	1
AGE	Age of the producer (years)	49.24	13.61	21	87
EDUCATION	Producer's educational attainment 0= no formal education 1= primary school 2= secondary 3= post-secondary	0.57	0.74	0	3
NATIVE	Dummy for whether the producer is a native of the village or not 0=no 1=yes	0.45	0.50	0	1
IMMIGRANT	Dummy for whether the producer is a migrant from another country or not (international migrants) 0=no ; 1=yes	0.25	0.44	0	1
RURALORG	Dummy for whether the producer is a member of a rural organization 0=no 1=yes	0.34	0.48	0	1
CASHCRED	Dummy for whether the producer received cash credit in last 12 months or not 0= no 1=yes	0.11	0.32	0	1
Location's characteristics					
RESIDENCE	Farmer's residence 0= cocoa camps 1= in the village	0.61	0.49	0	1
PAVED	Distance of the house from the nearest paved road (km)	14.62	17.67	0	112
WEST	Dummy variable for Western region 1=West 0= elsewhere	0.13	0.34	0	1
EAST	Dummy variable for Eastern region 1=West 0= elsewhere	0.17	0.38	0	1
SOUTHWEST	Dummy variable for Southwest region 1=West 0= elsewhere	0.29	0.45	0	1
Farm's characteristics					
TOTAREA	Total area of cocoa farms (ha)	5.17	8.92	0.25	220
NFARM	Total number of cocoa farms/fields owned	1.50	0.77	1	7
SHADINDEX	Shade index of the cocoa farms 1=no shade 2=low shade 3=medium 4=high	2.14	0.92	1	4
TAGEIDEX	Average age of cocoa farms operated (years)	19.02	12.42	1	96
Household's characteristics					
ADULTQUIV	Household adult men – equivalent	7.21	4.37	0.7	36.7

Source: Survey data, 2002

4. Results

In Côte d'Ivoire, cocoa is produced by smallholder farmers, with small farms and little investment. Table 2 shows the adoption patterns of fertilizers and pesticides by region. Survey data reveal that 14% of the surveyed farmers have adopted fertilizers, and about 51% have adopted pesticides. The main types of insecticide used were Basudine and Thiodan, and gramoxone, herbextra and Foltaf were the main fungicides or herbicides. Overall, more than 52% of cocoa farmers use agrochemicals on their cocoa farms. The adoption patterns were found to differ statistically across regions. The adoption rate for fertilizers and pesticides was highest in the Southwest province.

Respondents indicated the average amount spent on chemical inputs. As Table 3 shows, the expenditure on agrochemicals per hectare per farmer is highest in the Southwest and West provinces. Generally, it appears that a cocoa farmer in Côte d'Ivoire spent less than CFA8000 (around $14) per hectare per cocoa season for agrochemicals. This was quite low compared with, for example, Cameroon, where farmers spend around $30/ha for fungicides only (Kazianga 2002).

Table 2: Percentage of farms with non-zero expenditure on agrochemicals by region

	West (n=159)	**Southwest (n=346)**	**Center West (n=476)**	**East (n=207)**	**Total (n=1188)**	**Test for regional difference (χ^2)**
Fertilizer	16 (10.1%)	110 (31.8%)	40 (8.4%)	4 (1.9%)	170 (14.3%)	***
Pesticides	70 (44%)	250 (72.3%)	191 (40.1%)	92 (44.4%)	603 (50.8%)	***
Total (agro-chemicals) [a]	71 (44.7%)	260 (75.1%)	200 (42%)	93 (44.9%)	624 (52.5%)	***

*** Significant at 1%

[a] Some farmers who use fertilizers also use pesticides. In the first column, for example, of the 16 farmers who use fertilizer, 15 also use pesticides.

Source: computed from survey data, 2002

Table 3: Average expenditure on chemical inputs by region (in FCFA/ha)*

	West (n=159)	Southwest (n=346)	Center West (n=476)	East (n=207)	Total (n=1188)	Test for regional difference (t-test)
For entire population (all cocoa farmers)						
Fertilizers	1314.9	7722.1	779.7	78.6	2751.1	***
	(5712)	(16101)	(3825)	(694)	(9794)	
Pesticides	4751.3	7130.1	4086.1	3256.6	4917.1	***
	(9166)	(9078)	(8472)	(5721)	(8469)	
Total (agro-chemicals)	6066.2	14852.2	4865.7	3335.2	7668.2	***
	(12052)	(20310)	(9901)	(5732)	(14351)	
For population of adopters (farmers using agrochemicals)						
Fertilizers	2944.7	10276.4	1855.6	175.1	5237.7	***
	(8293)	(17860)	(5738)	(1031)	(13027)	
Pesticides	10640.1	9488.5	9724.8	7248.6	9361.4	*
	(11228)	(9344)	(10779)	(6637)	(9746)	
Total (agro-chemicals)	13584.8	19764.9	11580.4	7423.6	14599.2	***
	(14976)	(21260)	(12484)	(6550)	(17061)	

*** Significant at 1% * Significant at 10% In brackets are corresponding standard deviations.

*$1 = 540 FCFA. When the survey was conducted (2001), $1 was around 720 FCFA.

Source: computed from survey data, 2002

The heteroscedasticity problem is an issue that commonly arises in cross-sectional data, such as those used in this analysis, and implies bias in the parameters estimated. Several ways have been suggested to test for heteroscedastic error terms (Greene 1993). Under the assumption of normality, a test of heteroscedasticity could be based on the likelihood ratio statistic. This test involves estimating the restricted model (model under homoscedasticity) and the unrestricted model (model under heteroscedasticity).

The likelihood statistic is given by -2[(restricted LogL)-(unrestricted LogL)]. This statistic is asymptotically distributed as chi-squared with degrees of freedom equal to the number of independent variables. Our Likelihood ratio test was -2[(-6620.09)-(-6577.13)] = 85.92, which exceeded the critical value in the table, implying the rejection of the hypothesis of homoscedasticity.[3] We then considered the multiplicative heteroscedasticity model estimation. In this variant of the Tobit model, the variance term of the disturbance, instead of being constant, is assumed to be of the form: $\sigma_i = \sigma \exp(\gamma' z_i)$.

Table 4 shows the estimated results of the heteroscedastic Tobit model. Because some variables have missing data, corresponding observations have been dropped and effectively only 1089 observations were used for the estimation. The model was estimated using the

[3] Using the Glejser test, we arrived at the same conclusion.

LMDEP econometric program, version 7.0. Generally, 11 variables are significant in explaining the adoption of agrochemicals:

The positive and significant sign of EDUCATION indicates that educated farmers have a greater likelihood of investing in agrochemicals.

NATIVE and IMMIGRANT are both significant. The positive sign of IMMIGRANT suggests that international migrant cocoa farmers are more likely to adopt and invest in agrochemicals than Ivorian nationals. At the same time, the negative sign of NATIVE suggests that farmers who are natives of the village are less likely to use agrochemicals. Native farmers are usually better off in terms of the quality of land farmed than migrants (national migrants) and immigrants. Thus, they may not need a large quantity of chemical inputs to produce an acceptable quantity of cocoa.

The significance of RURALORG reveals the positive influence of farmers' organizations on their members. This result gives credibility to the value of using farmers' groups to spread new technologies rapidly.

The coefficient of the credit (CASHCRED) is also positively significant as expected. The failure of rural cash credit institutions in the African rural sector has been viewed as one of the major constraints to technology adoption and agricultural development (Carney 1998). The gap left by the government's withdrawal of credit support and the failure of credit institutions is being filled by the informal sector, sometimes led by cocoa buyers. However, these buyers are traditionally characterized by farmers as highly usurious and in a position of considerable power owing to a lack of local competition. Further investigation is required to characterize the comparative advantage of farmers in credit arrangements of this type.

The coefficient of EAST is negative and significant while that of SOUTHWEST is positive and significant. This highlights the fact that farmers in the East province are less likely to invest in agrochemicals while those in the Southwest region are more likely to do so. The relative availability of high levels of biomass in the forest vegetation of the East and farmers' general perception that soil fertility is not yet a major problem probably explain this difference. This suggests that efforts to promote the use of agrochemicals should first target areas with relatively older cocoa farms, such as those in the Western region of the country.

As expected, the significance of PRED_TOTAREA suggests that farmers with large farms are more likely to invest in agrochemicals.

The negative effect of the number of cocoa farms (NFARM) indicates that farmers with several plots (ceteris paribus) are less likely to adopt agrochemicals. This may suggest that encouraging them to operate a few large plots rather than many small plots could be regarded as a policy relatively likely to increase productivity.

The coefficient of TAGEIDEX is negative and significant. The older the farms, the less likely agrochemicals will be used.

The coefficient of ADULQUIV is also significant and negative, indicating that, as expected, larger families are more likely to adopt agrochemicals. This suggests that family labor competes with agrochemicals in the cocoa sector of Côte d'Ivoire and should be accounted for when strategies are being designed for promoting soil and pest management technologies.

Table 4: Heteroscedastic Tobit model results of factors affecting cocoa farmers' expenditure on agrochemicals, Côte d'Ivoire, 2002

VARIABLE	**Coefficient**	**Standard error**	**t-Statistics**
Constant	-1704.41	5020.27	-0.34
Farmer's characteristics			
SEX	-2092.31	2722.99	-0.77
AGE	3.89	56.67	0.07
EDUCATION	2047.76	1170.38	1.75 *
NATIVE	-4315.01	1553.01	-2.78 ***
IMMIGRANT	6967.13	2105.65	3.31 ***
RURALORG	2375.71	1478.01	1.61 *
PRED_CASHCRED	45190.40	14778.80	3.06 ***
Location's characteristics			
RESIDENCE	1742.41	1621.42	1.07
PAVED	-10.76	33.01	-0.33
WEST	670.02	1945.72	0.34
EAST	-8951.78	2553.80	-3.51 ***
SOUTHWEST	4995.84	2040.24	2.45 ***
Farm's characteristics			
PRED_TOTAREA	1550.91	285.82	5.43 ***
NFARM	-2676.40	993.64	-2.69 ***
SHADINDEX	39.69	732.54	0.05
TAGEIDEX	-87.41	47.26	-1.85 *
Household's characteristics			
ADULTQUIV	-745.51	234.16	-3.18 ***
Sigma (σ)	12756.70	5339.77	2.39 **
Log likelihood = -6738.15			
Total sample = 1089			

* significant at 0.10; ** significant at 0.05; *** significant at 0.01

Table 5 shows the elasticity of the amount spent on agrochemicals and the elasticity of the probability of adoption (derived from equation 7). These elasticities can help predict the impact of policy changes on the adoption of agrochemicals by farmers. For example, if a farmer reduces the number of plots by 10%, the probability that he will adopt agrochemicals will increase by 2.22%, while the amount spent will increase by 1.44%.

The cumulative distribution function of the normal distribution $\Phi\left(\frac{\beta X_i}{\sigma}\right)$ is used to calculate predicted probabilities, following various scenarios (Table 6). We selected three important policy variables that were significant in the estimation and computed the probability of adoption for different scenarios. This highlights the effect of some dependent variables on the probability of adopting agrochemicals (Maddala 1983; Hailu 1990). The three variables chosen are education, whether or not a farmer is a member of a rural organization, and the number of plots. For each level of these variables, the equation of the conditional expectation of amount spent (equation 4) is used to evaluate the predicted levels of expenditure on agrochemicals (Table 7). These simulations highlight the possible importance of some policy actions.

Table 5: Elasticity of the predicted probability of adoption and expected expenditure on agrochemicals, Côte d'Ivoire, 2002

VARIABLE	**Total elasticity**	**Elasticity of expenditure on agrochemicals**	**Elasticity of the probability of adopting agrochemicals**
SEX	-0.1857	-0.0731	-0.1125
AGE	0.0178	0.0070	0.0108
EDUCATION	0.1053	0.0415	0.0638
NATIVE	-0.1714	-0.0675	-0.1039
IMMIGRANT	0.1739	0.0685	0.1054
RURALORG	0.0776	0.0306	0.0470
PRED_CASHCRED	0.4811	0.1895	0.2916
RESIDENCE	0.0980	0.0386	0.0594
PAVED	-0.0151	-0.0059	-0.0091
WEST	0.0086	0.0034	0.0052
EAST	-0.1425	-0.0561	-0.0864
SOUTHWEST	0.1399	0.0551	0.0848
PRED_TOTAREA	0.7511	0.2958	0.4553
NFARM	-0.3654	-0.1439	-0.2215
SHADINDEX	0.0078	0.0031	0.0047
TAGEIDEX	-0.1589	-0.0626	-0.0963
ADULQUIV	-0.5056	-0.1991	-0.3064

Note: Numbers not in bold are spurious since regression estimates were not statistically significant.

Source: Model results

Table 6: Predicted probability of adopting agrochemicals, by education, membership of rural organization and number of cocoa plots, Côte d'Ivoire, 2002

Education	member of rural organization	Number of farms/plots 1	2	4	6
None	No	0.53	0.45	0.29	0.17
	Yes	0.61	0.52	0.36	0.22
Primary education	No	0.60	0.51	0.35	0.21
	Yes	0.67	0.59	0.42	0.27
Secondary education	No	0.66	0.58	0.41	0.26
	Yes	0.72	0.65	0.48	0.32
Post-secondary education	No	0.71	0.64	0.47	0.31
	Yes	0.77	0.70	0.55	0.38

Source: Computed by the authors from model results

Table 7: Predicted agrochemical expenses (FCFA), by education, membership of rural organization and number of plots, Côte d'Ivoire, 2002

Education	member of rural organization	Number of farms/plots 1	2	4	6
None	No	10600	9600	8010	6780
	Yes	11500	10400	8670	7290
Primary education	No	11400	10300	8570	7220
	Yes	12400	11300	9300	7780
Secondary education	No	12300	11100	9190	7690
	Yes	18900	12100	9990	8310
Post-secondary education	No	13300	12000	9870	8220
	Yes	14500	13100	10700	8900

Source: Computed by the authors from model results

5. Conclusion

Many countries with high levels of agrochemical use are experiencing environmental problems associated with this intensive use (Wilson 1989; Pretty 1995). Sub-Saharan Africa, however, suffers from the opposite problem: too little use of agrochemicals. Only a few countries in sub-Saharan Africa apply average dressings of fertilizer of more than 20 kg/ha (FAO 2004). Such low levels of fertilizer use, and short fallow periods, represent a serious threat to agricultural sustainability.

This paper has focused on the expenditure on agrochemical inputs by cocoa farmers in Côte d'Ivoire. The main objective has been to identify the level of use and the factors that affect the intensity of use of such inputs. The findings highlight the fact that almost half the farmers are not using agrochemicals for cocoa production and that the average amount of money spent on purchasing these inputs is quite low. These observations suggest the need to focus research goals on the intensity of use of agrochemicals that has been achieved so far, and how to improve the rate of adoption. To this end, there is a need to design policies in line with factors determining the use of such inputs.

The econometric analysis using a Tobit model showed that agrochemicals are more likely to be adopted by farmers who have more education, or are immigrants to the area or member of a farmers' organization, or have large farms, or are able to obtain credit. Adoption is less likely for farmers who are native to the area, or who have farms in new settlement areas, or several plots or farms, or ageing cocoa trees or large families.

The use of chemical inputs is an important agricultural issue. They have played a significant role in increasing agricultural production in the developing world over the past decades. Along with high-yield crop varieties, and intensive agricultural practices, chemical inputs have formed one of the foundations of the so-called Green Revolution. To increase cocoa productivity towards the more than the one tonne/ha typically obtained in Southeast Asia, the use of agrochemicals must be urgently increased. For a successful policy of diffusion, there is need to design strategies oriented toward farmers who are less likely to adopt.

The increased awareness of the negative effects of agrochemical use has resulted in new emphasis being placed on reducing cocoa farmers' dependence on agrochemicals and on developing and using non-chemical means of pest control. The integrated pest management (IPM) and integrated fertilizer management (IFM) systems are now considered the preferred methods. These consider both crops and pests as part of an ecological system and combine natural factors that limit pest outbreaks and soil depletion while using chemicals as a last resort. Even though chemical reduction programs are not yet in place in Côte d'Ivoire, fertilization systems and pest control methodologies are expected to change substantially in the medium term. The development of such chemical reduction programs will require strategic targeting. For a first introduction and promotion of IPM and/or IFM as replacements for the use of agrochemicals, policies should be oriented toward farmers who are more likely to adopt them. The results of this study indicated the target group to whom extension efforts should be directed as entry points for a successful introduction.

The use of pesticide and fertilizer in developing countries increased rapidly in the late 1960s and 1970s in the wake of rapidly spreading agricultural modernization (Pretty 1995). Some developing countries, however, are encountering difficulties in increasing yields, in spite of increasing the doses of agrochemicals. The efficiency of chemical use is often quite low as a result of incorrect timing and poor application methods or a failure to maintain the balance between the main nutrients (nitrogen, phosphate and potassium) (Nyemeck et al. 2003). This indicates that it is important to consider not just increasing the use of these inputs as a stand-alone intervention, but coupling it with programs aimed at reducing managerial inefficiency. This will require the public sector and international agencies to play a more active role in research and extension activities in collaboration with farmers, to significantly improve farmers' technical efficiency. A promising possibility may be production programs to train farmers, where they will learn more about crop management and new chemical products.

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References

Adesina, AA, 1996. Factors affecting the adoption of fertilizers by rice farmers in Côte d'Ivoire. Nutrient Cycling in Agroecosystems 46, 29–39.

Adesina, AA & Chianu, J, 2002. Determinants of farmers' adoption and adaptation of alley farming technology in Nigeria. Agroforestry Systems 55, 99–112.

Adesina, AA & Zinnah, MM, 1993. Technology characteristics, farmers' perceptions and adoption decisions: A Tobit model application in Sierra Leone. Agricultural Economics 9, 297–311.

Alavalapati, JRR, Luckert, MK & Gill, DS, 1995. Adoption of agroforestry practices: A case study from Andhra Pradesh, India. Agroforestry Systems 32, 1–14.

Appiah, MR, Ofori-Frimpong K, Afrifa AA & Asante, EG, 1997. Prospects of fertilizer use in the cocoa industry in Ghana. Proceedings of the Soil Science Society of Ghana 15: 215–21.

Asfaw, A & Admassie, A, 2004. The role of education on the adoption of chemical fertilizer under different socioeconomic environments in Ethiopia. Agricultural Economics 30, 215–28.

Awua, PK, 2002. Cocoa Processing and Chocolate Manufacture in Ghana: The success story that demolished a myth. Saffron Walden, UK: David Jamieson and Associates.

CABI Commodities, 2004. Developing sustainable cocoa production systems. http://www.cabi.org/datapage.asp?iDocID=210 Accessed November 2005.

Carney, D, 1998. Changing public and private roles in agricultural service provision. Overseas Development Institute (ODI), London.

Chow, GC, 1983. Econometrics. Third edition. Singapore: McGraw-Hill.

CIMMYT (International Maize and Wheat Improvement Center), 1993. The adoption of agricultural technology: A guide for survey design. Economics program, CIMMYT, Mexico.

De Janvry, A, Fafchamps, M & Sadoulet, E, 1991. Peasant household behaviour with missing markets: Some paradoxes explained. The Economic Journal, 101 (409), 1400–17.

De Janvry, A, Edmonds, C, Murgai, R, Sadoulet, E, Warning, M & Winters, P, 1995. Poverty and rural labour markets in developing countries. ILO (International Labour Organization) Monograph, Geneva, Switzerland.

Dhar, T, Chavas JP & Gould, BW, 2003. An empirical assessment of endogeneity issues in demand analysis for differentiated products. American Journal of Agricultural Economics 85 (3).

Doss, CR, 2006. Analyzing technology adoption using microstudies: Limitations, challenges, and opportunities for improvement. Agricultural Economics 34, 207–19.

Doss, CR & Morris ML, 2001. How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana. Agricultural Economics 25, 27–39.

FAO (Food and Agriculture Organization of the United Nations), 2004. Cocoa production data – FAO agricultural data. http://www.fao.org/ Accessed 2 September 2007.

Feder, G, Just, RE & Zilberman, D, 1985. Adoption of agricultural innovation in developing countries: A survey. Economic Development and Cultural Change 33 (2), 255–98.

Gockowski, J & Ndoumbé, M, 2004. The adoption of intensive monocrop horticulture in southern Cameroon. Agricultural Economics 30, 195–202.

Gockowski, J, Nkamleu, GB & Wendt, J, 2000. Implications of resource-use intensification for the environment and sustainable technology systems in the Central African Rainforest. In Lee DR & Barrett, CB (Eds), 2001, Tradeoffs or Synergies? Agricultural intensification, economic development and the environment. CAB International, Wallingford, UK.

Greene, WH, 1992. LIMDEP Version 6.0 User's Manual and Reference Guide. New York: Econometric Software.

Hailu, Z, 1990. The adoption of modern farm practices in African agriculture: Empirical evidence about the impacts of household characteristics and input supply systems in the Northern Region of Ghana. Nyankpala Agricultural Research Report 7.

Holloway, G, Nicholson, C, Delgado, C, Staal, S & Ehui, S, 2004. A revisited Tobit procedure for mitigating bias in the presence of non-zero censoring with an application to milk-market participation in the Ethiopian highlands. Agricultural Economics 31, 97–106.

Hussain, SS, Byerlee, D & Heisey, PW, 1994. Impact of training and visit extension system on farmers' knowledge and adoption of technology: Evidence from Pakistan. Agricultural Economics 10, 39–47.

Katungi, EM, 2007. Social capital and technology adoption on small farms: The case of banana production technology in Uganda. PhD thesis, Department of Agricultural Economics, Extension and Rural Development, University of Pretoria, South Africa.

Kazianga, H, 2002. Adoption of improved cocoa technologies in Cameroon. PhD Thesis, Department of Agricultural Economics, Perdue University, West Lafayette, USA.

Kebede, Y, Gunjal, K & Coffin, G, 1990. Adoption of new technologies In Ethiopian Agriculture: The case of Tegulet-Bulga District, Shoa Province. Agricultural Economics 4, 27–43.

Mackauer, M, 1989. *La lutte biologique dans le contexte de la gestion des systèmes*. In Yaninek, JS & H. R. Herren (Eds), *La Lutte Biologique: une solution durable aux problèmes poses par les dépredateurs des cultures en Afrique*. IITA (International Institute of Tropical Agriculture), Ibadan, Nigeria.

Maddala, GS, 1983. Limited Dependent and Qualitative Variables in Econometrics. London: Cambridge University Press, London.

Matlon, PJ, 1994. Indigenous land use systems and investments in soil fertility in Burkina Faso. In Bruce, JW & Migot-Adholla, SE (Eds), Searching for Land Tenure Security in Africa. Dubuque, Iowa: Kendall/Hunt, pp. 41–69.

Nkamleu, GB, 2004. Productivity growth, technical progress and efficiency change in African agriculture. Africa Development Review 16 (1), 203–22.

Nkamleu, GB, 2006. Poverty and child farm labour in Africa: Wealth paradox or bad orthodox. African Journal of Economic Policy, 13 (1).

Nkamleu, GB & Adesina, AA, 2000. Determinants of chemical input use in peri-urban lowland systems: Bivariate probit analysis in Cameroon. Agricultural Systems 62, 1–11.

Nkamleu, GB & Coulibaly, O, 2000. *Les déterminants du choix des méthodes de luttes contre les pestes dans les plantations de cacao et café du sud-Cameroun*. *Revue Économie Rurale* 259.

Nkamleu, GB & Kielland, A, 2006. Modeling farmers' decisions on child labor and schooling in the cocoa sector: A multinomial logit analysis in Côte d'Ivoire. Agricultural Economics, 35, 319–33.

Nkamleu, GB & Tsafack, R, 2007. On measuring indebtedness of African countries. African Finance Journal 9 (1), 21–38.

Norris, PE & Batie, SS, 1987. Virginia farmers' soil conservation decisions: An application of Tobit analysis. Southern Journal of Agricultural Economics 52, 208–20.

Nyemeck, JB, Sylla, K, Diarra, I & Nyambi, 2003. Factors affecting technical efficiency among coffee farmers in Côte d'Ivoire: Evidence from the Center West Region. African Development Review 15 (1), 66–76.

Otsuka, K S, Suyanto, TS & Tomich, TP, 2001. Evolution of land tenure institutions and development of agroforestry: Evidence from customary land areas of Sumatra. Agricultural Economics 25, 85–101.

Polson, R & Spencer, DSC, 1991. The technology adoption process in subsistence agriculture: The case of cassava in southwestern Nigeria. Agricultural Systems 36, 65–78.

Pretty, JN, 1995. Regenerating Agriculture. London: Earthscan.

Ransom, JK, Paudyal, K & Adhikari, K, 2003. Adoption of improved maize varieties in the hills of Nepal. Agricultural Economics 29, 299–305.

Rogers, EM, 1983. Diffusion of Innovations. Third edition. London: Macmillan.

Save the Children Canada, 2003. Children still in the chocolate trade: The buying, selling and toiling of West African child workers in the multi-billion dollar industry. Working paper series, Children in the global trade, No 1.

Wilson, L, 1989. Preface. In Yaninek, JS & Herren, HR (Eds), *La lutte biologique: Une solution durable aux problèmes posés par les dépredateurs des cultures en Afrique*. IITA (International Institute of Tropical Agriculture), Ibadan, Nigeria.

Wooldridge, JM, 2002. Econometric Analysis of Cross Section and Panel Data. Massachusetts Institute of technology.

World Bank, 2003. A Multi-Country Agricultural Productivity Program for Africa. Washington: World Bank.