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ESTIMATING THE INTERLINK BETWEEN AGRICULTURAL PRODUCTION DECISIONS: A CASE OF MAIZE FARMING HOUSEHOLDS IN NIGERIA

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ABSTRACT

The problem of market failure in developing economies forces farmers to use production inputs way below their optimal levels. It can also spur them to explore multiple production strategies as a hedge against poor yield. This study utilized multivariate analysis to investigate the synergies and/or tradeoffs of sustainable production decisions among maize farming households in Nigeria. Using a nationally representative dataset, the Multivariate Probit model employed for the analysis comprised a system of three simultaneous equations modelling the factors that influence the joint decisions to use certified maize seeds, agrochemicals and conserve crop biodiversity. Our findings suggest that farming households' decisions related to these production strategies are significantly interlinked and strong complementarities exist among them. Household size and non-farm asset ownership have the strongest influence on the probability of jointly implementing the trio production strategies. Thus, highlighting the importance of endowment effects (human capital and economic resources) in strategic decision-making among farm-families. These findings have important policy implications because they suggest that the enactment of policies promoting the use of any of these production strategies among smallholder farmers can have spillover effects on the use of others. Hence, culminating in the emergence of a more resilient food production system.

Keywords: Maize farming, Production decisions, Interdependence, Multivariate analysis.

INTRODUCTION

Maize is the most widely grown food crop and it accounts for more than one-half of cereal grains produced worldwide. Africa accounts for about 7% of the totality of global production and Nigeria is the second largest producer of maize in the continent (PwC, 2021). Research efforts by scientists have led to the development of high-yielding maize varieties that are tolerant to the vagaries of nature. Howbeit, maize yield in Nigeria has remained low at less than two tonnes per hectare (Kamara *et al.,* 2020; 2014). Availability of high-quality seeds of suitable varieties is crucial to achieving highly productive and resilient cropping systems (Cavatassi *et al* 2012). However, farmers' reluctance to transit from open-pollinated varieties to improved seed varieties remains a major challenge to increasing maize output in Nigeria.

Seed is the basic input for successful crop production and its quality optimizes the potentials of other complementary technologies. Therefore, it's affordability is essential for productivity growth (Awotide *et al.*, 2013). The provision of certified seeds of high-yielding varieties to smallholder and marginal farmers who produce the bulk of food consumed in developing economies like Nigeria is touted to boost the chronically low agricultural productivity, and its consequent negative welfare implications (Ali *et al.,* 2015). Farmers are expected to augment certified seeds with complementary technologies like fertilizers, herbicides, irrigation, pesticides *etc*. to optimize their performance. The bane of most Nigerian farmers is that high-quality seeds (Awotide *et al.*, 2013) and other complementary yield-enhancing inputs needed for market-oriented production is usually not within their means. While the use of high-quality seeds is further limited by poor adaptation to local conditions, the use of complementary technologies is often rendered uneconomic, either due to the dominant rain-fed nature of farming, and or high transaction costs (Di Falco *et al.*, 2006).

Availability and affordability of certified seeds can also incentivize farmers to combine the attributes of such improved varieties with those selected and maintained in their localities (Benin *et al.*, 2003). According to Chavas and Di Falco (2012), since farmers in developing economies often face poorly functioning factor markets and cannot rely solely on the market to constantly provide them with seeds that meet the qualities they require, they may grow more diverse varieties of crops to ensure that their production needs are met. Crop biodiversity refers to both planting different crops, as well as planting different species of one crop. It increases the genetic diversity of food supply, especially for crops like maize, rice wheat *etc.* that make up a significant proportion of global food consumption (Difore, 2021).

Having functionally similar plants that respond differently to the vagaries of agricultural production contributes to crop resilience. For instance, pest populations are more likely to thrive when faced with a genetically uniform cropping system. Difalco and Chavas, (2005) demonstrated that biodiversity plays a significant role in reducing yield variability under low pesticide use. However, such risk-reducing effects was observed to disappear with heavy pesticide application. This suggests the presence of strong interaction effects between agrochemicals, biodiversity and yield. According to Bangwayo-Skeete *et al.* (2012), advocating *in situ* crop biodiversity conservation in the policy space can provide governments with an opportunity to harmonize policy decisions that promote sustainable food production systems without jeopardizing farmers' needs and concerns. For instance, policy designs that enhance the complementarities between ecological management strategies and the use of improved agricultural technologies like certified seeds and agrochemicals.

Farmers' production decisions with respect to improved agricultural technologies have received considerable attention in several streams of literature and have often been analysed in different contexts. While the mainstream empirical evidence has focused on such decisions for individual technologies, relatively fewer strands (Kassie *et al.* 2013; Nditu *et al.* 2014; Chilot *et al.* 2015; Murrendo *et al.* 2016; Gebremariam and Tesfaye 2018, Katengeza *et al.* 2019; Ojo and Baiyegunhi, 2020; Adhikari and Khanal 2021) have investigated the interrelatedness in the adoption decisions of multiple production strategies. This study attempts to contribute to the scarce evidence on interdependence in agricultural production decisions, particularly in Nigeria where the bulk of empirical studies does not account for such interrelatedness. To our knowledge, this is the first attempt to utilize a nationally representative dataset to achieve this objective. In light of the preceding line of reasoning, this study, therefore:

1. analyzed the nature of interdependence in farming households' decisions to cultivate certified maize seeds, utilize agro-chemicals and conserve biodiversity *in situ*
2. examined the factors influencing the probability of utilizing the trio production strategies in Nigeria

METHODOLOGY

<u>Study area and data:</u> This study was conducted in Nigeria, a Sub-Saharan African country located between latitudes 4^0 and 14^0 north of the equator and longitudes 5^0 and 15^0 East of the Greenwich meridian. Nigeria is situated in a tropical climate region with an ample supply of both rain and sunshine. Agricultural production is the mainstay of the economy though relatively fewer national

resources and attention have been devoted to its advancement for more than four decades. Over 70% of the farming activities are carried out by resource-poor smallholder farmers who produce the bulk of domestic output under rainfed and fragile climatic conditions.

Data for this study was obtained from the third wave of the Nigerian Living Standard Measurement Survey-Integrated Survey on Agriculture (LSMS-1SA) commonly referred to as the Nigerian General Household Survey (GHS) that was conducted in the 2015-2016 year. The GHS data is a nationally representative panel dataset collected jointly by the World Bank and the National Bureau of Statistics using a stratified random sampling method. The third wave of the GHS panel was purposively chosen out of the four available panels because it is the only wave that contains information on the use of certified seeds by farming households. A total of 4,581-panel households were interviewed in wave three, indicating an attrition rate of about 8.4% since the baseline survey. Out of the 1,712 maize plots that were surveyed in this wave, 626 observations were dropped primarily due to outliers and missing information on important variables that are required in the econometric modelling. Some of the farmers cultivated maize in different farm locations and this information was taken into consideration during data processing such that the number of households was different from the number of observed plots. At the end of the cleaning exercise, data from 947 households and 1,086 surveyed maize plots were eventually used for analyses.

Binary responses were employed to operationalize household decisions regarding the production strategies. Operationalizing the use of certified seeds was straightforward since the dataset contains a yes/no question in that regard. Agrochemicals that were reportedly used by most of the farming households in the dataset include inorganic fertilizers, herbicides, and pesticides. Households that used at least one of these technologies were identified as users of agrochemicals and otherwise as non-users. For biodiversity conservation, farming households that practised mixed-cropping and/or inter-cropping were labelled biodiversity conservators while those that practised mono-cropping as specialised maize farmers (non-biodiverse). We also included a vector of covariates (age and education of household head, household size, farm size, labour, extension access, climate shock, soil fertility and slope) as control variables. These variables have been reported in previous studies to be significant determinants of implementing these production strategies.

Conceptual Modelling: The analysis of the production decisions of farming households begins with the basic assumption that a farmer is a risk-averse agent and tries to manage risk by making strategic production decisions that will maximize their expected utility. Since farmers adopt a mix of strategies to overcome the vagaries of agricultural production and improve their welfare, their behaviour entails simultaneous decision-making rather than complete independence of alternatives in decision-making. According to Kassie *et al.* (2013), adoption decision is intrinsically multivariate and attempting univariate modelling excludes useful economic information in terms of interdependence. Hence, the need to account for the likelihood of this occurrence in investigating the adoption decisions of farming households. We, therefore, tested the following hypotheses:

H_{01}: All cross-equation correlation coefficients for the use of certified maize seeds, agro-chemicals and biodiversity conservation are not statistically different from zero

H_{02}: The joint insignificance of the factors influencing the likelihood of using the trio production strategies

Estimation Strategy: The Multivariate Probit (MVP) regression provides information about the interdependence of production decisions and their simultaneous uptake probabilities while allowing for potential correlations between unobserved disturbances (Teklewold *et al.,* 2012). Deb and Trivedi (2006b) asserted that an advantage of the multivariate normal specification is that it imposes no bounds on the correlations. it recognises the correlation in the error terms of the decision equations, estimates a set of binary probit models simultaneously while accounting for the relationships among the observed strategies and is thus more efficient than a univariate probit estimator that analyses each strategic production decision separately (Nditu *et al.,* 2014).

Following Chilot *et al.* (2015); Ojo and Baiyegunhi (2020), since the utility obtainable from these decisions is unobserved, the latent outcome variable S_{ik}^{*} that corresponds to the likelihood of the observed binary outcome for each of the production strategies given a set of controls earlier outlined is specified as:

$$S_{ik}^{*} = \beta_k' X_{ik} + \varepsilon_{ik}$$

(1)

$$S_{ik} = 1 \; if \; S_{ik}^{*} > 0, and \; zero \; otherwise$$

Where X_k represents a vector of relevant controls (as previously defined) obtained from existing empirical findings, β_k is a vector of coefficients to be estimated, and ε_k is the disturbance term that has a multivariate normal distribution, zero mean and unit variance. The system of Simultaneous Probit models is estimated as:

$$\begin{cases} S_{i1} = \beta_1' X_{ik} + \varepsilon_{i1} \\ S_{i2} = \beta_2' X_{ik} + \varepsilon_{i2} \\ S_{i3} = \beta_3' X_{ik} + \varepsilon_{i3} \end{cases} \qquad (2)$$

The MVP model was fitted using the maximum simulated likelihood approach. The model assumes that the error terms follow a multivariate normal distribution with $E[\varepsilon] = 0$ and variance-covariance matrix as shown below:

$$cov(\varepsilon) = p = \begin{bmatrix} 1 & .. & p_{13} \\ . & \ddots & . \\ . & & . \\ p_{31} & .. & 1 \end{bmatrix} \qquad (3)$$

The error term variance of the matrix is equal to one (diagonal elements) and the off-diagonal elements represent correlations between the different strategies (Adhikari and Khanal, 2021).

RESULTS AND DISCUSSION

Summary Statistics: Table 1 shows the results of the summary statistics of the variables utilised in this study. Farming household heads were mostly males, with a mean age of 53 years and approximately five years of formal education. The average household size comprised about eight persons, cultivating less than one hectare of farmland. About 17% of the households cultivated maize in more than one location and 78% affirmed that they owned land(s) that are not used for farming purposes. The majority of the farmers were also affirmative concerning the use of the production strategies. The highest proportion (78%) was observed for the use of agrochemicals and the lowest proportion (69%) was for the use of certified seeds. Interestingly, only 13% of the respondents had access to extension information. Finally, with regards to plot-level characteristics, 78% of the respondents reported that their farmlands were very fertile, 72% reported that they cultivated maize on flat (levelled) plots and 12% experienced climate-related shocks that impacted their maize output. Other covariates on plot-level characteristics were dropped during the econometric estimation due to collinearity.

Empirical Model Diagnostics: Table 2 presents the estimates of the MVP regression model. The significance of the Likelihood Ratio (LR) test enables us to reject the null hypothesis of no correlation between the error terms of the three equations, thus demonstrating the appropriateness in the estimation of the MVP model over three single-equation Probit models. Also, the Wald statistic shows that the covariates included in the model jointly explained the probability that maize farming households simultaneously utilize these strategies. This enables us to reject the null hypothesis of joint insignificance of the hypothesized covariates in explaining households' decisions regarding the production strategies.

Nature of Interdependence of Agricultural Production Strategies: The result from Table 2 suggests that the decision to cultivate certified maize seeds, utilize agrochemicals and conserve crop biodiversity is jointly determined, and this assertion is demonstrated by the significant values of all the pair-wise correlation coefficients (rhos). This implication of this finding is that these strategies are not mutually exclusive, as the decision to use any one of them does not preclude the others. Complementarity was observed to exist among them strategies as indicated by the positive values of the rhos. The strongest complementarity was observed for the joint decision to cultivate certified maize seeds and conserve crop biodiversity (0.1778). This is closely followed by the joint decision to cultivate certified maize seeds and apply agrochemicals (0.1550). Farmers are not oblivious to the fact that the potentials of certified seeds are optimised when combined with agrochemicals. The least complementarity was observed for the joint decision to apply agrochemicals and conserve biodiversity (0.1337). This is probably because these two production strategies are different approaches to achieving the same objective of improving crop yield. Our results have important policy implications because they suggest that the enactment of a policy promoting any of these strategies may have spillover effects on the uptake of others. Since significant complementarities exist among these strategies, utilizing them can ultimately lead to the emergence of a more resilient food production system if strongly advocated and painstakingly implemented.

Factors Influencing the Probability of Joint Utilization of Agricultural Production Strategies: Socioeconomic and plot-level characteristics are significant determinants of households' production decisions as shown in Table 2. The age of a farming household head significantly influences the probability of using agrochemicals and conserving biodiversity. While younger household heads are more likely to apply agrochemicals on their maize plots, the older ones are more inclined to conserve biodiversity instead. Concerning the use of agrochemicals, our findings support the reports of Gebremariam and Tesfaye (2018); Murrendo *et al.* (2016) and Nditu *et al.* (2014) who reported that older farmers are less likely to utilize relatively newer technologies such as chemical fertilizers and pesticides. For crop biodiversity conservation, our results however refute the findings of Ahikari and Khanal (2021) and Ojo and Baiyegunhi (2020), who reported that older farmers are less likely to embrace crop biodiversity conservation.

Farming household heads with more years of schooling have higher probability of conserving crop biodiversity. Better-educated farmers are more enlightened about the dynamic benefits of crop biodiversity than their less-educated counterparts. This is in sync with the findings of Ahikari and Khanal (2021) and Chilot *et al.* (2015). Larger farming households are more probable to use certified seeds and agrochemicals but are however less probable to conserve biodiversity. Larger farm families take advantage of the widely known yield-enhancing characteristics of certified seeds and agrochemicals and at the same time engage in other off-farm activities to support their livelihoods. Although a larger household size may mean the availability of more family labour, our findings, however, show that this is not always the case. Larger households are less inclined to spend more time on the farm as inter and mixed cropping require. According to Wainaina *et al.* (2014), they appear to substitute family labour for other yield-increasing inputs.

Households with larger farm sizes have higher probability of cultivating certified seeds. This is probably because of the economies of scale to be derived from the purchase of such seeds in substantial quantities. This can be uneconomical for smaller farm sizes. Gebremariam and Tesfaye (2018) reported similar findings. They are however less likely to conserve biodiversity, perhaps, due to the relatively higher opportunity cost of maintaining crop biodiversity on larger farm sizes. Hence, they tend towards specialization which is more popular with large farm holdings. While this finding corroborates the report of Arslan *et al.* (2017), it, however, refutes the findings of Bozzola and Smale (2020) and Benin *et al.* (2003) who reported that households with larger farm sizes grow more diverse cereals.

Asset ownership which is a measure of household wealth is proxied by ownership of non-agricultural land(s). From the result, it can be inferred that the less endowed farming households have higher probability of cultivating certified maize seeds. This refutes the findings of Ali *et al.* (2015) who reported a positive relationship between households' endowment and the use of certified seeds. Also, the less endowed farming households are more likely to use agrochemicals and less likely to conserve biodiversity. This may appear counter-intuitive, but it also shows that this category of households is very intentional about their production activities. They, therefore, tend towards specialization. Access to extension information increases the probability of using agrochemicals and conserving crop biodiversity. This resonates with the reports of Ojo and Baiyegunhi (2020). Extension contacts represent sources of information required to make an informed decision on the most suitable local production technologies that are available and within the reach of farmers.

Turning to plot-level characteristics, the results show that certified seeds are more probable to be cultivated in soils with good (highly fertile) quality, perhaps to optimise the returns from farmers' investment in purchasing them. However, biodiversity is more probable to be conserved on relatively poorer (less fertile) or damaged soils to take advantage of the beneficial ecological relationships tantamount to what is obtainable in legumes-cereals intercrop. Also, planting different crops (or varieties) in soils of low quality can be viewed as a hedging behaviour among farming households, because it protects them against total crop failure. With regards to the slope of the farmland, our results show that agrochemicals are less probable to be applied on flat (levelled) plots and more probable to be applied on plots with a steep slope. This is probably because steep-sloped plots are more prone to the detrimental activities of erosion and flooding and are consequently less fertile than flat plots that are less prone and can retain more nutrients and moisture. This agrees with the report of Teklewold *et al.* (2012).

SUMMARY AND CONCLUSION

Agricultural production is very susceptible to several external influences such as the vagaries of nature, market failure, farmers' production decisions, amongst others. Farmers adopt a mix of innovations to overcome the production challenges they encounter. This entails simultaneous decision-making rather than complete independence of alternatives in the decision-making process. This study analysed maize farming household production decisions (specifically, cultivation of certified seeds, application of agrochemicals and biodiversity conservation) using the MVP regression model that provides information about the interdependence of production decisions and their simultaneous implementation probabilities while allowing for potential correlations between unobserved disturbances.

Our findings show that these decisions are significantly interlinked, and strong complementarities exist among them. Although several socioeconomic and plot-level characteristics significantly influenced the probability of the joint decisions, household size and non-farm asset ownership were the strongest determinants of the probability of implementing these production decisions. Thus, showing the importance of endowment effects (human and economic resources) in farming households' strategic decision-making. The policy implication of these findings is that promoting the use of any of these strategies among smallholder farmers can have spillover effects on the use of others, and ultimately lead to the emergence of a more resilient food production system.

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Table 1: Definition of variables and summary statistics

Variable	Definition of variables	Mean	Std. dev.
Dependent variables			
Seed certification	Farmers that cultivate certified maize seeds = 1, otherwise = 0	0.69	-
Biodiversity conservation	Farmers practice mixed cropping and/or intercropping = 1, monocropping = 0	0.74	-
Complementary technologies	Farmers that use at least one type of agrochemical = 1, otherwise = 0	0.78	-
Socioeconomic factors			
Sex	Male = 1, Female = 0	0.92	-
Age	Age of household head measured in years	52.54	13.84
Education	Number of years spent schooling	4.98	5.12
Household size	Number of individuals in a particular household	7.97	3.49
Maize plots	Number of maize plots owned by household	1.21	0.50
Agricultural extension	Farmers who received extension information = 1, otherwise = 0	0.13	-
Non-farm asset	Farmers who indicate they own land(s) not used for farming = 1, otherwise = 0	0.78	-
Plot-level characteristics			
Farm size	Size of farmland measured in hectares	0.87	0.89
Good soil	Soil with high fertility = 1, otherwise = 0	0.78	
Flat plot	Soil with a flat surface = 1, otherwise = 0	0.72	-
Climate shocks	households that experienced at least any or all of the following in the preceding 5 years: drought, flooding, pest and disease infestation that caused crop failure = 1, otherwise = 0	0.12	-

Source: 2015/2016 Living Standard Measurement Survey - Integrated Survey on Agriculture (LSMS-1SA) for Nigeria

Table 2. Estimates from the MVP model

Covariates	Certified seeds		Agrochemicals		Biodiversity conservation	
	Coefficient	P>|z|	Coefficient	P>|z|	Coefficient	P>|z|
Age	-0.0041 (0.0031)	0.1910	-0.0162*** (0.0036)	**0.0000**	0.0097*** (0.0033)	**0.0030**
Education	0.0088 (0.0085)	0.2990	0.0036 (0.0093)	0.699	0.0270*** (0.0941)	**0.0020**
Household size	0.0282*** (0.0120)	**0.0190**	0.0452*** (0.1230)	**0.0000**	-0.0284*** (0.0117)	**0.0150**
Farm size	0.1231*** (0.0496)	**0.0130**	-0.0026 (0.0510)	0.960	-0.1606*** (0.0470)	**0.0010**
Non-farm asset	-0.5877*** (0.0960)	**0.0000**	-0.4633 (0.1018)	**0.0000**	0.2338*** (0.1068)	**0.0029**
Extension information	-0.0298 (0.1270)	0.8140	0.4307*** (0.1582)	**0.0060**	0.2741*** (0.1348)	**0.0420**
Climate shock	0.0236 (0.1310)	0.8570	0.1522 (0.1506)	0.3120	0.1602 (0.1328)	0.2280
Good soil	0.4287*** (0.0980)	**0.0000**	-0.0733 (0.1112)	0.509	-0.5344*** (0.1150)	**0.0000**
Flat slope	-0.1595* (0.0970)	**0.1000**	-0.2736*** (0.1077)	**0.0110**	0.1490 (0.0980)	0.1280
Steep slope	0.3494 (0.3000)	0.2450	0.8511** (0.4732)	**0.0720**	0.2988 (0.2851)	0.2950
Constant	0.2511 (0.2424)	0.3000	1.5722*** (0.2721)	**0.0000**	0.6050** (0.2484)	**0.0150**
Joint decision parameters	Agrochemicals and certified seeds (rho21)			0.1550*** (0.0569)	**0.0070**	
	Biodiversity conservation and certified seeds (rho31)			0.1778*** (0.0552)	**0.0010**	
	Biodiversity conservation and agro-chemicals (rho32)			0.1337** (0.0599)	**0.0260**	
LR test of rho21 = rho31 = rho32 = 0: chi2(3) = 20.8332, Prob > chi2 = **0.0001**						
Wald chi2 (30): 244.11, Prob > chi2= **0.0000**						
Log-likelihood: −1734.3749						
N = 1,086						

Note: Figures in parentheses are standard errors. * Represents the level of significance at 10%, ** represents the significance level at 5% and *** represents the level of significance at 1%.

Source: Analysed from: 2015/2016 Living Standard Measurement Survey - Integrated Survey on Agriculture (LSMS-1SA) for Nigeria.