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Endogeneity Test of Seed on Yield in Nigeria

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ABSTRACT

Researchers treated seed technology and crop yield as exogenous, thereby generating bias estimates. In practice, seed technology increases yield and it's stimulated by social capital and other factors. This paper develops a choice model of maize-seed exogenously, then tested and corrected for causality. A multistage sampling procedure was adopted using seven Agricultural Development Programme zones drawn from purposively selected Oyo and Osun states. A block each was randomly selected per zone. Twenty-one cells were randomly selected, then data were collected from 385 respondents using a structured questionnaire: Data were analyzed using Ordinary Least Square and Two-Stage Least Square α 0.05. Durbin score chi2(1) = 6.65 (p= 0.009) and Wu-Haussmann F (1,37) = 6.431 (p = 0.012), showed reverse causality that was resolved by the Two-Stage Least Square model. The Two-Stage Least Square result indicated that education (β=-0.53), seed quantity (β=-0.13), seed price (β=-0.08), negatively affected the choice of seed and yield while farm size (β=2.05), fertilizer (β=0.004), herbicide (β=0.22), output-price (β=0.02), meeting attendance index(β=0.02), and improved seed ((β=2.66), had a positive influence. Social capital spurs the use of improved seed, thereby increase maize yield. Consequently, active participation in social groups and the use of improved seed is recommended to increase yield.

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Introduction

Maize is an important cereal crop in Nigeria. It provides food and fuel for human and feed for livestock (Dei, 2017). In addition, many products such as oil, glucose, starch, and flour obtained from maize provide value-added and are rich products in all respects (Kaya and Gözübenli, 2019). Maize has been taking over acreages of land from millet and sorghum. About 4.8 million hectares cultivated to maize in 2018 yielded 10.2 million tons, putting Nigeria on top as the highest producer in Africa (F.A.O, 2017). Plant breeders and agronomical researchers had helped to develop high-yielding varieties that are tolerant to diseases, drought, and low nitrogen (Bailey-serres, Parker, Ainsworth, Oldrovd, and Schroeder, 2019). In spite of this development, maize yields are still low in Nigerian. Quality seed is key to increasing crop yield. Lack of access to seed means low yield and food insecurity. Despite the efforts of the government and private seed industry, the availability of improved seeds to farmers are still low. Improving the productive capacity of farmers in Nigeria through productivity increases is an important policy goal, but this has not been fully achieved (F.A.O, 2009; Komolafe, Adeoti, 2018). It, therefore, means improvements in factor productivity beyond land expansion are required. Access to productive resources such as land, inorganic fertilizer, pesticides, improved seed varieties, irrigation facilities and mechanical power, education and financial services that are critical determinants of agricultural yield must be accessed by farmers (Feed the Future and The United State Agency for International Development, 2017). Besides, drip irrigation draws attention in terms of higher efficiency for maize (Kaya and Bostan Budak, 2022). It was found that the farmers using drip irrigation systems had higher yields of about 20% (Kaya and Bostan Budak, 2019). Social capital is a strong variable that motivates farmers' access to improved technologies and equally promotes their use (Komolafe, and Adeoti, 2018). Seed technology is identified as the greatest instrument that increases farm yield, as it sets the upper limit to crop yields and determines the productivity of other agricultural inputs (Bailey-serres, Parker, Ainsworth, Oldrovd, and Schroeder, 2019). Consequently, to increase crop yield, it will be compulsory to find institutional arrangements such as social capital that guarantee access to improved and high-yielding seed varieties. The role plays by social capital in stimulating the use of improved technology is obvious in that it enhances

cooperation and facilitates extension and adaptive participatory action (Husen et al., 2017). Therefore, this study determines the effect of the usage of improved maize seed acquired through social capital on the yield of maize.

Materials and Methods

The sampling frame for this study consists of farmers growing maize under a sole-cropping system in the southwestern geopolitical zone of Nigeria, which comprises six states namely: Ekiti, Lagos, Osun, Ogun, Ondo and Oyo. The Agricultural Development Project Sampling (ADP) frame was adopted in the collection of data. A multistage sampling procedure was used for this study. In the first stage, two states were purposively selected based on the level of maize production (Oyewo, 2011 Komolafe, Adeoti, 2018). According to (Olaniyan, 2015; Komolafe, Adeoti, 2018). Nigeria has been grouped into four categories: high, medium to high, medium, and low maize production potential. In the southwestern geopolitical zone of Nigeria, Oyo State was grouped as medium to high potential and Osun State was grouped as a state with medium potential. In this first stage, purposive selection of Oyo and Osun states were made. 'These states are a good representative of the three major agro-ecological zones in the Southwestern States of Nigeria. These are the forest, guinea savannah and the derived savannah zones' Oladejo, Adefemi, Ladipo and Olasupo, (2012); Komolafe and Adeoti (2018).

In the second stage, a random selection of one block from each ADP zone was made and in the third stage selection of three cells from each block was done and maize farmers were randomly selected from each of the cells in the fourth stage. The selection was made proportionate to the size of the cell. Total of 400 farmers were guarded to fill the structure questionnaires used in data collection, but only 385 of the questionnaires gave consistent responses and were analyzed. The distribution across the ADP zones is shown in Table 1.

Analytical Techniques

The study employed Ordinary Least Squares (OLS) and Two-Stage Least Square (2SLS) Models to show the effect of improved maize seed usage on yield and to solve the endogeneity problem.

Measurement of the Social Capital Dimensions

The social capital dimension measurement is explained following (Grooteart, 2002; Adepoju and Oni, 2012; Komolafe and Adeoti, 2018).

The capability of social capital in the form of Local Groups fulfilling its role in disseminating information, facilitating collective decision making and reducing opportunistic behavior, depends on various aspects of the association, reflecting its structure, its functioning and its membership.

The focus of this study was on six aspects of Local Groups as described below:

Meeting attendance index: The percentage of farmer's attendance in meetings scheduled per annum Achida, Garba, Abdullahi (2018).

Density of membership index: The share of member's participation in associations in their locality scaled up to 100. The density index is expected to be positively related to the benefit received from social groups (Achida, Garba, Abdullahi, 2018).

Heterogeneity index: Measures the proportion of similarities and differences in socioeconomic characteristics of members of the same local associations in relation to the three most important local associations a member belongs to (Adepoju and Oni 2012 Achida, Garba, Abdullahi, 2018).

Table 1. Procedure for selecting maize farmers based on Agricultural Development project sampling frame

State	zones	Blocks	Cells Selected	Sample Frame	No of questionnaire Administered	No of questionnaire analyzed
Oyo	Ibadan/Ibarapa	Ibarapa central	Lawore	223	21	18
			Alapa	140	15	14
			Maya	141	14	14
Oyo	Ogbomoso	Ogo Oluwa	Ajawa	191	20	19
			Yede	208	22	21
			Idewure	150	15	15
Oyo	Oyo	Iseyin	Efunlete	185	19	18
			Ajegunle	199	20	20
			Eleke	210	21	21
Oyo	Saki	Saki east	Oje Owods	230	23	23
			Sepeteri	223	22	22
			Ago Amodu	201	20	20
Osun	Osogbo	Ede north	Araromi	208	21	21
			Kajola	199	20	20
			Abogunde	192	19	16
Osun	Ilesa	Oriade	Ijeda	221	22	22
			Ijebu-jesa	216	22	22
			Ijaregbe	195	18	17
Osun	Iwo	Iwo	Alebiosu	146	15	15
			Afingba	135	14	13
			Agbede	183	17	15
Total					400	385

Source: Survey, 2019

Decision-making index: Measurement of member's involvement in decision-making in associations. The three most important social groups to which a member belong is considered to estimate the percentage involvement of a member. (Yusuf, 2008; Adepoju and Oni, 2012; Achida, Garba, Abdullahi, 2018).

Cash contribution index: Measures the percentage of cash contributed to local associations with respect to the maximum amount scheduled to be contributed (Adepoju and Oni 2012; Achida, Garba, Abdullahi, 2018).

Aggregate social capital index: It is the multiplicative social capital index. The index is the product of density membership, heterogeneity index and decision-making index of a member in their various social groups. (Saxton and Benson, 2005; Adepoju and Oni 2012; Komolafe and Adeoti, 2018).

Endogeneity Problems of the Ordinary Least Square (OLS) Estimation

Ordinary least squares estimation is the most used regression method (Gujarati, 2003; Greene, 2003; Stock and Watson, 2003).

$$Y = \beta_0 + \beta_{1\,X_I} + \beta_{2\,X_2} \ldots\ldots\ldots + \varepsilon_I \quad (1)$$

Y is the yield of maize
β = parameters to be estimated
x_i= sets of explanatory variables
ε_I = Error term

Socio-economic variables.
M_1 = Farm size (Ha)
M_2 = Labour (Man-days)
M_3 = Quantity of fertilizer (kg)
M_4 = Quantity of herbicide (kg)
M_5 = Usage of improved maize seed (Dummy 1 if yes and otherwise = 0)
M_6= Age of farmers (years)
M_7 = Gender (Dummy Male = 1 female = 0)
M_8 = Farming experience (years)
M_9 = Years of formal Education (years).
Variables influencing seed usage
M_{10} = Price of maize seeds (N /kg)
M_{11} = Unit price of output (N/kg)
M_{12}= Quantity of fertilizer used (kg)
M_{13}= Farm size (ha)
Social Capital Index
M_{15}=Heterogeneity index
M_{16}=Decision-making index
M_{17}= Amount of loan obtained through association (N).
M_{18}=Meeting attendance index

In this kind of study there is the possibility of endogeneity problems, if the ordinary least squares assumptions don't hold, but if errors are homoscedastic that is the variance of the error term (ε_I), is constant in each period, then OLS estimation is the best linear unbiased estimator (Stock and Watson, 2003; Wooldridge, 2006). Otherwise, if OLS estimation is inconsistent and failed to converge to the population parameter producing biased coefficients. Then endogeneity problem is established, it means the regressor is correlated with ε_I. This violates the OLS assumption exogeneity (Wooldridge, 2006). This problem arises if either 'X is endogenous' or β not identified. There are three possibilities for exogeneity violation:

- *Omitted variables:* Here a variable that affects the dependent variable and is also correlated with the explanatory variable(s), is omitted from the model (Wooldridge, 2006). The exogeneity condition is violated therefore, there is presences of endogeneity.
- *Errors-in-variables:* The problem occurs when the true value of X, is unobserved.
- *Simultaneous causality:* This situation occurs when the causality runs in both directions: from the regressor(s) to the dependent variable and vice visa. This leads to biased and inconsistent coefficients.

Solving The Endogeneity Problems Using Instrumental Variables

Instrumental variables focus on the variations in X which are uncorrelated with ε disregarding the variations in X that bias the OLS coefficients (Gujarati, 2003).

The Two-stage least square has advantages over the more conventional maximum likelihood (ML) method for the structural equation model (SEM). These advantages include: it does not require any distributional assumptions for right-hand side (RHS) independent variables; they can be non-normal, binary, etc. In the context of a multi-equation non-recursive SEM, it isolates specification errors to single equations, (Guilhem, 2008; Bollen, 2001). It is computationally simple and does not require the use of numerical optimization algorithms. It easily caters for non-linear and interaction effects, Bollen and Paxton (1998). It permits the routine use of often ignored diagnostic testing procedures for problems such as heteroskedasticity and specification error, Pesaran and Taylor (1999). The most general structural form of the production function can be expressed as (Ersado, 2003):

Structural Equation

$$Yi = \beta 0 + \beta_1 X_I + \beta_2 W_{i1} + \ldots + \beta_1 + r\, W_{ri} \ldots . + \varepsilon_I \quad (2)$$

Where Yi = i th observation on the dependent variable
Xi = is the i th observation on the endogenous explanatory variable W_{i1} …. W_{ri} are the i th observations on each of the r exogenous regressor (i.e. control variables or covariates) ε_I = error term. 'instruments' Z are taking to estimate in a two-step procedure the causal impact of Xi on Yi conditional on the covariates W. The two-stage least squares estimation is the commonest IV estimator (Hahn et al., 2004; Murray, 2006), and is applicable in this works. In a first stage or the 'reduced form equation, the endogenous regressor is regressed on the instrument(s) and covariate(s) that the first stage isolates the variation in Xi that is not correlated with ε_i. The resulting fitted value, is then used in the second stage (i.e. the structural equation) instead of the endogenous regressor.

$$Y = \beta 0 + \beta_1 D + \beta_2\, W_1 + \mu_1 \quad (3)$$

Where;
Yi = Yield of maize (Tons/ha)
D = maize seed (kg)
Wi = Vector of explanatory variables
β = Vectors of respective parameters
μ = Error term.

The potential endogeneity of D in equation (2) was resolved. The 2SLS was applied to replace the actual problematic D variable in the equation by a counterpart variable that is purged of its stochastic or random component to ensure that the ordinary least square procedure could be applied. In order to do this, a reduced form equation was specified as a function of all the exogenous variables in equation (4) and a set of instrumental variables as:

$$D_i = \delta_i + \delta_2 Z_i + \varepsilon_I \quad (4)$$

Where Zi is a vector of instrumental variable which exerts impacts on the use of maize seed but not on maize yield. The predicted values from this OLS- estimated reduced form equation (4) defined as Di is then inserted into the structural equation to replace the problematic Di. As a result, equation (5) can be reduced to the following reduced-form equation that can be estimated by using the OLS:

$$Y_i = \delta_i Z_i + \delta_2 W_i + \mu_i \ldots \quad (5)$$

The explanatory variables Wi are as earlier defined, while the vector of instruments Zi, include social capital variables and socioeconomic factors influencing seed demand. Yi= maize yield (Ton/ha).

δi = Vector of parameters to be estimated
μ = the disturbance term.
Wi = Set of explanatory variables
Socio- Economic Variables
W1 = Farm size (Ha)
W_2 = Labour (Man-days)
W_3 = Quantity of fertilizer (kg)
w_4 = Quantity of herbicide (kg)
W_5 = Usage of improved maize seed (Dummy 1 if yes and otherwise = 0)
W_6 = Age of farmers (years)
W_7 = Gender (Dummy Male = 1 female = 0)
W_8 = Farming experience (years)
W_9 = years of formal Education (years).
Variables Influencing Seed Usage
W_{10} = Price of maize seeds (N /kg)
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W_{12} = Quantity of fertilizer used (kg)
W_{13} = Farm size (ha)
Social Capital Index
W_{14} =Density of Membership index
W_{15} =Heterogeneity index
W_{16} =Decision making index
W_{17}= Amount of loan obtained through association (N).
W_{18}=Meeting attendance index

Test of Endogeneity

To test whether the decision to adopt the use of improved maize seed is correlated with yield, an instrumental variable (IV) was used. Since the seed is one of the inputs that produce yield, therefore the causality between maize seed and yield runs in both directions and this will cause OLS to be biased. In order to address the endogeneity problem, it was necessary to isolate the exogenous impact of maize seed on yield; instrumental variables (IV) were used. The variable used is highly correlated with the usage of maize seed and uncorrelated with yield. Variables such as contact with extension agents, distance to the seed sales point, and social capital variables were considered as potential instruments for maize seed usage. The 2SLS reduces the correlation of explanatory variables with the error term (Olayemi, 1998; Gujarati, 2003). Hence, the regression parameters are better enhanced.

Analysis of Seed Used and Yield of Maize Farmers

Correlation Values of Instrumental Variables with Maize Seed

The result of the correlation analysis of the seed and specific instrument for the usage of improved maize seed in Table 2 revealed that aggregate social capital, meeting attendance, decision-making index, cash contribution index, the density of membership and heterogeneity are highly correlated with the usage of improved seed and they are therefore used as instrumental variables (Adepoju, 2012). They were tested for over identification and the test was not significant meaning the use of all the significant variables as instrumental variables were valid.

Ordinary Least Square Result

The result of the ordinary least square model is presented in Table 2. The R2 =0. 862. The variables included in the model explain 86% of the model. Quantity of fertilizer ($P<0.001$), the quantity of herbicide used ($P<0.001$), farm size ($P<0.001$), and labor ($P<0.1$), are socio-economic characteristics that positively and significantly affect maize yield while farming experience (<0.1) is negative but significant (Latruffe and Piet 2013).

Table 2. Correlation values of instrumental variables with maize seed

	Maize seed	P>
Seed distance	-1.080	0.330
Ext contact	0.037	0.473
Unit maize price	-0.034	0.501
Aggregate social capital	0.134**	0.003
Meeting attendance	0.369***	0.000
Decision index	0.259***	0.000
Density index	0.359***	0.000
Cash contribution index	0.254***	0.000
Heterogeneity index	0.190***	0.000

Source: Survey, 2019

Table 3. Effect of usage of improved maize seed on yield under different approach

Variable	2SLS		OLS MODEL	
	Coefficient	P>t	Coefficient	P>t
Age	0.012	0.236	0.005	0.600
Sex	0.251	0.410	0.191	0.488
Marital Status	-0.105*	0.016	-0.481	0.133
Household Hsize	-1.0E-05*	1.000	0.004	0.910
Years of Education	-0.528**	0.001	-0.308**	0.005
Farming_Experience	-0.017	0.130	-0.026*	0.012
Farm Size	2.048***	0.000	2.102** *	0.000
Fertilizer Quantity	0.004***	0.000	0.005** *	0.000
Herbicide Quantity	0.218***	0.000	0.174** *	0.000
Hired Labour	0.024*	0.019	0.020*	0.041
Extension Contact	-0.077	0.668	-0.132	0.421
Loan Volume	2.4E-06*	0.017	4.34E-06**	0.005
Seed Distance	-0.007	0495	-0.118**	0.001
Seed Quatity	-0.129***	0.000	0.020**	0.006
Unit Seed Price	-0.001**	0.005	-0.006	0.620
Outprice	0.015**	0. 002	-0.001	0.906
Aggregate Social Capital	-1.01E-06	0.471		
Cash Contribution Index	2.80E04	0.725	-0.0028	0.507
Meeting Attendance Index	0.002 **	0.002	0.008*	0.033
Heterogeneity Index	-0.001	0.729	0.010	0.292
Decision Making Indexd	-0.001	0.498	0.013	0.335
Densty Index	0.009*	0.026	0.006*	0.054
Maizeseed Type	2.664 **	0.006	0.547*	0.043
Constant	-0.963	0.538	1.60	0.304
R^2	0.8223		0.862	
AdjR^2			0.853	
Prob > F	0.000		0.000	

*** 1% significant level; **5% significant; *10% significant level; Source: Survey, 2019

Good cultural practices enhance yield better than the years a farmer had spent in planting maize. Type seed planted (P<0.001), seed quantity (P<0.01) and seed distance (P<0.01) as the seed variables that significantly affect maize yield. Seed quantity (P<0.01) is the only seed variable that negatively and significantly contributes to maize yield. This implies that as the quantity of seed increases farmers tend to use the local seed to reduce seed cost. The volume of loans (P<0.01), meeting attendance index (P<0.1), and decision-making index (P<0.1), as the social capital variables that positively and significantly contribute to maize yield.

Endogeneity Effect of Improved Maize Seed Under Different Approach.

In the earlier analysis maize seed is treated as an exogenous variable. However, seed procurement is at a cost and is affected by the farmer's choice, equally seed affects yield and yield affects the choice of maize seed. Endogeneity test was done and the causality effect of seed on yield was discovered. It, therefore, becomes important to isolate the endogenous impact of seed on yield. The study tested the existence of a causality effect with the aid of an instrumental variable (2SLS).

The endogeneity effect of seed on yield is empirically testable by means of instrumental variable estimation. The major challenge is to find a suitable instrument for the choice of seed: The instrument must determine seed choice but not yield.

Test of Over Identification Restrictions

Sargan (score) chi2(5) = 7.92598 (p = 0.1604)

Basmannchi2(5) = 7.60997 (p = 0.1791

Correlation values of instrumental variables with maize were estimated and variables that significantly correlated with seed were used as instruments for the choice of seed. Over identification test was conducted for the instrumental variables and it was not significant. This implies that the instrumental variables all together are valid. The study tested the existence of causality effect with the aid of these instrumental variables using the 2SLS. Trust as an instrumental variable has been used in earlier studies on social capital (Narayan and Pritchet (1997) and Yusuf (2008). Since there is the presence of endogeneity, the null hypothesis that improved maize seed is not endogenous to maize yield was rejected.

Test for Endogeneity

Ho: variables are exogenous

Durbin (score) chi2(1) = 6.64778 (P = 0.0099)

Wu-Hausman F (1,367) = 6.43132 (P = 0.0116)

Two stage least square result: The 2SLS result indicated that marital status (P<0.1), household size (P<0.1), years of education (P<0. 01), farm size (P<0.001), fertilizer quantity (P<0.001), herbicide quantity(P<0.001), hired labour (P<0.1) distance to the seed sales point (P<0.1), unit seed price (P<0. 01) quantity of seed planted (P<0.001), output price (P<0.01), meeting attendance index(P<0.01), density index (P<0.1) and maize seed type (P<0.01) have a significant effect on yield. The estimation of the endogeneity effect of improved maize seed shows the presence of reverse causality.

Conclusions

The study provides empirical evidence that the choice of improved maize seed is influenced by social capital. The social capital indices that influence seed choice were the meeting attendance index and density index. This finding is supported by Zeleke, et al, (2023), and the yield is influenced by the usage of improved maize seed this finding also corroborates Mutanyagwa , (2017). finding. The instrumental variable method indicates that there is a reverse causality effect between seed usage and the yield of maize. This outcome disagrees with the finding of Amare et al, (2012). Therefore, improved maize seed is an endogenous factor that affects the yield of maize in the study area.

Policy Implications and Recommendations

- Usage of the improved seed of maize increases the yield of maize. It means that to increase maize output in Nigeria adoption of this improved seed should be enhanced using workable policies.
- Social capital improves the choice of improved maize seeds and their usage. This suggests that farmers should be encouraged to belong to more local-level associations as governments at all levels are increasingly using local associations as channels through which farmers can access numerous benefits like loans and farm inputs.

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