Research Article

www.dergipark.org.tr/en/pub/mediterranean

MEDITERRANEAN AGRICULTURAL SCIENCES
(2023) 36(1): 37-46
DOI: 10.29136/mediterranean.1189118

Farm households' input demand and output supply response to price shocks in Nigeria

Chioma Patricia ADEKUNLE[1], Kao PAPA[2], Nelson Sergeo TAGANG TENE[3]

[1]Federal University of Agriculture, Department of Agricultural Economics and Farm Management, Abeokuta, Ogun State, Nigeria
[2]University of Lome, Togo, Department of Agricultural Economics
[3]University of Yaounde, II Department of Public Economics, Cameroon

Corresponding author: C. P. Adekunle, e-mail: adekunlecp@funaab.edu.ng
Author(s) e-mail: jonaspapakao@gmail.com, sergeo.tagang@yahoo.com

ARTICLE INFO

Received: October 14, 2022
Received in revised form: November 21, 2022
Accepted: November 23, 2022

***Keywords*:**

Food commodities
Production
Panel data
Smallholders

ABSTRACT

Panel data on farm household output for a full range of commodities are scarce, and as a consequence, only a few other studies have considered estimating farm household output supply and input demand response to price changes in Nigeria using panel data within the multiple inputs and multiple outputs frameworks. This study examined the extent to which farm households' respond to production inputs and output price changes using panel data covering the period 2010-2016. Specifically, to determine whether a commodity output's price positively affects its supply and other output categories; and whether an input price negatively affects its usage in Nigeria within the multiple input and multiple output (MI-MO) framework. The translog profit function was used to simultaneously examine the production response of farm households' in terms of the factor demand and produce supply. Seven output supply and four input demand equations were estimated. The results indicated that the response of output supply to own price ranged from 0.59 for animal products and 1.24 for cereals. The own-price demand elasticities of farm input range from -0.82 for mechanisation to -1.46 for intermediate inputs. Also, a substantial degree of farm households' response to input price shocks. Farm inputs and outputs were economic complements to price changes. Therefore, price policy issues aimed at improving the production response of farm households' to both input and output price shocks should be developed with a particular focus on farm inputs.

1. Introduction

Despite the reforms in Sub-Saharan Africa (SSA), agricultural policy in the last decades, reduced productivity has been linked to a weak supply response among other factors to market signals (Di Marcantonio et al 2014). The notion that the supply response of farmers' to price changes is generally very low and/or absent has not been widely accepted as studies have shown that smallholders respond to price signals. However, this argument has attracted controversy in policymaking (Haile et al. 2015).

Response to agricultural production is associated with the change in agricultural output due to commodity price changes (Mythili 2008), and in Nigeria, this is policy-induced (Obayelu and Salau 2010). Nigerian major commodity farm producers have been directly hit by the burden of commodity prices, so when prices increase they earn more profits, but suffer losses and absorb shocks when there is a price fall. Consequently, food commodities have become unstable in both prices and demand and this discourages production, thus making outputs and possible export potentials suffer (Mesike et al. 2010).

In the last two decades, smallholder farmers have been subjected to shocks in output and input prices in Nigeria of which the implications on their welfare have been much debated. Molitor et al. (2017) posited that to be more resilient against price shocks, smallholder farmers need to diversify their cropping practices. However, this behavioural response can only be successful if they can respond to input prices as well as technological change.

Price and change in technology are important tools for improving agricultural productivity. The availability of appropriate technology should be followed by a positive price policy to stimulate agricultural production through the desired level of input allocation. To achieve desired growth in agricultural output, policymakers are faced with the challenges of formulating agricultural policy, as there is a close link between output supply and input demand (Kumar et al. 2010). Hence, understanding how farm households' respond to output and input price signals constitutes crucial information for policymakers in achieving farm productivity. Even if subsistence farming is not considered an important driver of economic growth, it has still a major influence on the welfare of the farming population (Poulton et al. 2006). Moreover, understanding the relationship between input and output prices, food supply, and input demand could improve the market participation of smallholders (Barrett 2008). The agricultural supply response measurement is useful, not only to policy stakeholders but to other decision-makers such as farmers and production marketing chain actors. The degree of farmers' responsiveness to price shocks provides a rich

This study was conceptualized, conducted and reported in accordance with the Research Ethics Policy of the Federal University of Agriculture Abeokuta, Nigeria.

understanding of agricultural sector roles in the economy, particularly domestic responsiveness to price shocks.

Most agricultural systems of production are characterized by multiple inputs and outputs, despite this fact, most agricultural production systems' econometric models have used a single equation production function. This approach is based on a single output, such as wheat, or aggregates all outputs into an output index. It is important to note that, agricultural production decisions on output depend on decisions about other outputs. Therefore, examining only one output leads to specification error as this does not take into account the multiple-output nature of agricultural production. Besides, in a situation of aggregate output index, vital information on the relationships between various output categories is lost. In either case, the estimated parameters validity of such supply response elasticities is called into question.

The well-functioning of farm input markets is a crucial condition for the competitiveness and growth of rural development, particularly in the agricultural sector. Besides, the functioning of the input markets themselves is influenced by changes in agriculture input price, output price, and the rural economy. Despite the Nigerian government's efforts at restoring the country's agricultural sector to its pride through policy and programs, there has been a failure to significantly get rid of the constraints affecting the development of the agricultural system of which input and output prices are important. This is partly due to the lack of empirical work on agricultural supply response in Nigeria. Motivated by this concern, this study attempts to overcome some of these problems in the case of output supply response estimates for the Nigerian food staples to input and output price shocks. This study aims to estimate a system of input demand and output supply responses for Nigerian agriculture using a multi-input and multi-output profit function framework.

The theoretical framework is grounded on the premise of supply response in agrarian production. Supply response generally refers to the variation in agricultural output production and acreage substantially as a result of price changes (Olayide and Heady 1982). This implies that the supply response concept refers to shifts, and the movements along the supply curve mainly due to the price-output quantity relationship can be only isolated in theory, ceteris paribus. Supply response entails the agricultural production output response to product price change. This may be due to the use of more or fewer inputs that may be a result of the price variation. Again, the supply response may be induced by a variation in farm size. Also, the changes in technology under the influence of product variables such as price, credit, rainfall, market information, and so on, may bring out both output supply, and input demand response. Hence, supply response has to do with the drivers of the movement of the output supply curve (Akanni and Okeowo 2011).

Supply response estimation of food crops, such as the input use changes, has been reported in several studies (Battese et al 1998; Dawson and Lingard 1989). But, few studies have reported the supply response of input demand to changes in price. Profit function analysis is an approach to describe the system of input demand and output supply response to changes in price (Olwande et al. 2009). Numerous studies on agrarian commodity economics have framed their analyses within the single commodity (multi-input, single-output) framework. Within this single commodity framework, it's implicitly or explicitly assumed that allocation of inputs is separable and independent of output allocation decisions. The challenge of a single commodity framework seems to be inappropriate as many agricultural production systems are characterized by multi-product farms as food crops cultivated in both dry and wet land areas are practically in the form of mixed cropping and/or inter-cropping. Based on this diversification type, farmers make decisions on planting several crops and the allocation of the required input simultaneously. Under this framework, production decisions about an output are very likely to be related to the production decisions concerning other outputs.

The production technology describes all feasible options available for the transformation of inputs into outputs. In the Multiple Inputs-Multiple Outputs (MI-MO) framework, the production technology may be described by way of a production transformation set. The boundary of a production transformation set can be represented in equation (1) as follows:

$$f(X, Y, Z) = 0 \quad (1)$$

Where:

$Y = Y_1, Y_2 \ldots, Y_m$ is a vector of m non-negative outputs,

$X = X_{m+1}, X_{m+2} \ldots, X_n$ is a vector of (n-m) non-negative variable inputs, and

$Z = Z_{n+1}, Z_{n+2}, \ldots, Z_p$ is a vector of (p-n) non-negative quasi-fixed inputs.

Equation (1) is the implicit form of Y= fX; Z, That is, Y-fX; Z= fY, X, Z= 0. The variable inputs are inputs that are full changes to their profit-maximizing levels within one sample period. Quasi-fixed inputs, on the other hand, are inputs that do not necessarily change fully within one sample period.

It is obvious that the production transformation set, F, is determined principally by the technological knowledge state, and physical laws such as climate. For instance, the process of production of crop outputs is limited by agronomical, and other technical aspects. It is also affected by non-technical aspects such as government regulations, e.g. pollution control in the form of pesticide usage restriction and government intervention in output price support.

It is worth noting that a production transformation set possesses certain regularity properties, such as (i) Domain, (ii) Continuity, (iii) Boundedness, (iv) Smoothness and Twice Differentiability, (v) Convexity, and (vi) Monotonicity, of which details can be found in Siregar (1991). Among these regularity properties, convexity and monotonicity are often assumed to hold for the production transformation set. The reason is that the economic behavior implied by profit maximization would always be consistent with these properties being true for the production transformation set.

In the primal approach of profit maximization, a set of output supply equations and input demand equations can be obtained, by estimating equation (1). However, there are at least three major disadvantages to this approach. First, the production function direct estimation using ordinary least squares (OLS) leads to the simultaneity bias as input levels are endogenous. As well, OLS estimation of the output supply equations is inefficient as the error terms are most likely correlated contemporaneously. The same thing also applies to OLS estimation of the input demand equations. Second, if equation (1) is used to examine production decisions, the output supply, and input demand equation derivation is much more complex as it involves solving a constrained profit maximization (Wall and Fisher 1987). Third, the profit function involves only the prices of outputs and inputs and the quantity of quasi-fixed inputs, which are not endogenous, unlike the production function.

The dual approach is not subjected to these disadvantages. Assuming that a producer aims to maximize variable profits and that a production technology set can be represented by equation (1), the profit maximization problem in the dual approach can be expressed as follows:

$$\prod(\mathrm{P,W,Z}) = \max((P'Y - W'X; F(Y,X;Z) \leq 0)) \qquad (2)$$

Where:

P= $P_1, P_2, \ldots, P_m$ is a vector of output prices,

R= $R_{m+1}, R_{m+2}, \ldots, R_n$ is a vector of variable input prices, and the inequality < allows for a case of output inefficiency.

Where P is a vector of Y output prices, W is a vector of X input prices, Y is a vector of P output quantities, x is vector of R input quantities. Other definitions of $\prod(\mathrm{P,R,Z})$ to be used here are:

$$\prod(\mathrm{P,W,Z}) = \max((P'Y - C(W'Y)) \qquad (2a),$$

and

$$\prod(\mathrm{P,W,Z}) = \max(R(P,X) - W'X)) \qquad (2b)$$

Where:

$C(W'Y)$ is the firm's cost function and $R(P,X)$ is the firm's revenue function (Diewert 1974).

As is well known, the vector of Hicksian or constant output demand functions, μ(W, Y), is obtained from C(W, Y) by simple differentiation with respect to W. Similarly, the vector of compensated (i.e., constant input) output supply functions V(P, X) is derived from R(P, X) by differentiation with respect to P. Finally, the Marshallian vectors of output supply and input demands Y(P, W) and X(P, W), respectively] are obtained from $\prod(\mathrm{P,W})$ by differentiation with respect to P and W, respectively.

The derivatives of the Hicksian demand function with respect to input prices, $\frac{\delta\mu_i}{\delta w_j} = \frac{\delta^2 C}{\delta w_i \delta_{w_j}}$ reflect movements along an isoquant for given output levels. Similarly, the derivatives of the compensated output function $\frac{\delta V_K}{\delta P_g} = \frac{\delta^2 R}{\delta P_K \delta_{P_g}}$, reflect movements along the production possibility frontier, i.e., at constant input levels. Thus, to measure compensated factor demand and output supply elasticities using only knowledge of the profit function estimates, the second derivatives of the cost and revenue functions must be expressed in terms of the profit function in equations (3) and (4).

As with equation (1), equation (2) also has certain regularity properties. It is shown by McFadden (1978) that if properties (i) and (iii) are adhered to in the production technology set, then 'Π' is a convex, positively linearly homogenous, closed, and continuous function in both variable input and output prices for every positive fixed input (property vii). Furthermore, if production technology set (F) holds properties (i), (ii), and (iii), then, as shown by McFadden (1978), 'Π' will be continuous jointly for all variables input and output prices and for all fixed inputs (property viii). Another property of 'Π' is that it is monotonic in prices (property ix). Alternatives to equation (2) are revenue maximization and cost minimization. Since profit is revenue minus cost, it is obvious that revenue maximization and cost minimization are special cases of profit maximization. Given its more general nature, profit maximization is preferable to the other two.

Duality means that if both the production function (F) and profit function (Π) fulfill certain regularity properties, the production function or the profit function can be applied to equally well describe the production technology. Duality proofs can be found for instance in Jorgenson and Lau (1974) and McFadden (1978). McFadden (1978) shows the duality between production transformation sets and profit functions using the mathematical theory of convex conjugate functions. As was mentioned, a production technology set satisfying properties (i) and (iii) will result in a profit function satisfying property (vii). McFadden (1978) shows that a profit function holding property (vii) will yield a production transformation set satisfying properties (i), (iii), (v), and (vi). It follows that the profit function as well as the output supply and input demand functions, which may be derived from the profit function, can be treated as if they come from a production technology that satisfies the properties of monotonicity and convexity even if these properties do not hold for the production technology. The output supply and input demand functions can be obtained by taking the profit function's first derivative using Hotelling's lemma as follows:

$$\frac{d\prod(P,R,Z)}{dP_i} = Y_i(P,R,Z) \quad (3) \qquad \text{for } i = 1,2,3\ldots\ldots\ldots, m,$$

and

$$\frac{-d\prod(P,R,Z)}{dR_j} = X_j(P,R,Z) \quad (4) \qquad \text{for } j = m+1, m+2, \ldots, n,$$

Where:

$Y_i(P,R,Z)$ is output supply equations, and $X_j(P,R,Z)$ is input demand equations. Since, from (1), X, Y, and Z are positive, (3) and (4) indicate that profit is expected to monotonically increase with output prices and quasi-inputs, and monotonically decrease with input prices, respectively. Assuming profit maximization, without assuming convexity and monotonicity of production function, fundamental propositions of neo-classical profit maximization behavior can be elaborated as in the following equations:

$$\frac{dY_i(P,R,Z)}{dP_i} = \frac{d}{dP_i}\left(\frac{d\prod(P,R,Z)}{dP_i}\right) = \frac{d^2\prod(P,R,Z)}{dP_i^2} \qquad (5)$$

Since Π is a convex function, then $\frac{dY_i(P,R,Z)}{dP_i}$ which is the slope of supply functions, is positive. Furthermore:

$$\frac{dY_i(P,R,Z)}{dR_j} = \frac{d}{dR_j}\left(\frac{-d\prod(P,R,Z)}{dR_j}\right) = \frac{-d^2\prod(P,R,Z)}{dR_j^2} \quad (6)$$

Since Π is a convex function, then $\frac{dY_i(P,R,Z)}{dR_j}$, which is the slope of input functions, is negative.

Another important proposition of the output supply and input demand functions is the symmetry in cross-price effects.

$$\frac{dY_i(P,R,Z)}{dP_j} = \frac{d}{dP_j}\left(\frac{d\prod(P,R,Z)}{dP_i}\right) = \frac{d}{dP_i}\left(\frac{d\prod(P,R,Z)}{dP_j}\right) = \frac{dY_j(P,R,Z)}{dP_i} \qquad (7)$$

$$\frac{dX_j(P,R,Z)}{dR_i} = \frac{d}{dR_i}\left(\frac{d\prod(P,R,Z)}{dR_j}\right) = \frac{d}{dR_j}\left(\frac{d\prod(P,R,Z)}{dR_i}\right) = \frac{dX_i(P,R,Z)}{dR_j} \quad (8)$$

There are several characteristics of a production technology that are useful for modeling a production technology. The characteristics are (a) homogeneity, (b) homotheticity, (c) separability and homothetic separability, and (d) non-jointness. Hasenkamp (1976) and Weaver (1983) show that the production function is uniformly homogenous of degree c (where c≠1) in outputs if and only if the profit function is homogenous of degree 1/(1-c) in output prices and fixed factors. Similarly, the production function is homogenous of degree 'c' in variable input if and only if the profit function is homogenous of degree 1/(1-c) in output prices and the profit function is homogenous of degree – c/(1-c) in variable input prices. If a continuously differentiable function is homogenous with degree c, then its first derivative is homogenous with degree c/c-1 in variable input prices.

Production technology is almost homothetic if it can be expressed as follows:

$$F[H(Y,X;Z)],X;Z) \quad (9)$$

Where F is monotonic in H, and H is homogenous of degree one in Y. It is apparent from (9) that every homogenous function is homothetic but a homothetic function is not necessarily homogenous.

Separability characteristic forms the basis of aggregating data. Partitioning outputs and inputs into three subsets: N_1= (Y_1, Y_2, …, Y_m), N_2= (X_{m+1}, X_{m+2}, …, X_n), and N_3= (Z_n+1, Z_m+2, …, Z_p), production technology is weakly separable if it can be written as follows:

$$F[a_1(N_1), a_2(N_2); a_3(N_3)] = 0 \quad (10)$$

Where a_1, a_2, and a_3 are aggregator functions. Weak separability is a necessary condition, but not a sufficient condition for consistent aggregation. Both conditions are satisfied by the characteristic of weak homothetic separability. However, if the production function is assumed to be homogenous of degree one, as is usually done, the conditions for weak separability and weak homothetic separability are the same (Wall and Fisher 1987). A function is weak homothetic separable in N_i if it is both homothetic and weakly separable in N_i. In terms of the profit function, given that the duality properties hold, Weaver (1977) and Lau (1978) show that production function is homothetically separable in a group of commodities (outputs or inputs) if and only if the profit function is homothetically separable in that commodity's prices.

Lau (1978), defines a production function to be non-joint in inputs and/or in outputs if single production functions exist. Ball (1988), states that when an output is produced by a production technology that is joint in input quantities, decisions about its production depend on choices made about other outputs, e.g. the level of each output produced is dependent upon the prices of competing outputs. So a production function can be represented by a set of independent functions as follows:

$$F_i(Y_i, X_{ij}; Z_{ik}) = 0 \quad (11)$$

Where X_{ij}= amount of variable input X_j allocated to output Y_i, and Z_{ik}= amount of quasi input.

Z_k allocated to output Y_i. Non-jointness is not of much interest in agriculture because the use of multiple inputs is virtually the rule (Wall and Fisher 1987).

Concerning elasticities, Lau (1972) shows that substitution elasticity is not sufficient as a description of a production technology. In addition, substitution elasticity does not have a straightforward interpretation in the case of MI-MO, whereas the price elasticity does. Following Weaver (1983) and Wall and Fisher (1987), the price elasticities of output supply and input demand, respectively, are:

$$E_{ih} = \frac{dY_i}{dP_h} \cdot \frac{P_h}{Y_i} = \frac{d^2\prod}{dP_i dP_h} = G_{ih} \cdot \frac{P_h}{Y_i} \quad (12)$$

for all i, h = 1, 2, …, m, and

$$E_{jk} = \frac{dX_j}{dR_k} \cdot \frac{R_k}{X_j} = \frac{d^2\prod}{dR_j dR_k} \cdot \frac{R_k}{X_j} = G_{jk} \cdot \frac{R_k}{X_j} \quad (13)$$

For j, k= m+1, m+2, …, n, where G_{jk} is the (j, k)-th element of the inverse of the Hessian of production technology. Equations (12) and (13) are termed Marshallian elasticities because they are not derived from an input or output-constrained function (Hicksian function) but are from an unconstrained profit function (Marshallian function). These elasticities signs are used to conclude whether outputs or inputs are gross substitutes (Eih > 0, Ejk < 0) or gross complements (Eih < 0, Ejk > 0).

2. Materials and Methods

2.1. Study data

The study used the 2010-2016 nationally representative Nigeria General Household Survey (GHS), extracted from the World Bank website. It was a production data panel survey of six (6) visits conducted during post-planting and post-harvest agricultural seasons in Nigeria. The three (3) waves consisted of two (2) visits to the household in each of the waves: the post-planting visit occurred directly after the planting season between August-October. The post-harvest visit occurred after the harvest season between February-April. This study was conceptualized, conducted and reported in accordance with the Research Ethics Policy of the Federal University of Agriculture Abeokuta, Nigeria.

This study focused on the analysis of output supply and input demand response based on the major field crops and factors of production. Thus, both the input and output categories were constructed. Three output categories were identified (crops, livestock, and non-farm income) following Ball (2002). However, the crop output category was further grouped into five (5) which were i. cereals, ii. pulses/seeds/nuts, iii. roots and tubers, iv. vegetables and fruits, and v. other crops/agricultural by-products. A total of seven (7) output categories (cereals, pulses, root crops, vegetables and fruits, other crops, animal products). Four (4) variable input categories (labour, agrochemicals, intermediate inputs, mechanisation were used for this study. Non-farm income was used as a reference group. Thus, the production response has 11 equations (7 output supply equations, and 4 input demand equations). Also, a time dummy variable was used to capture technological change.

2.2. Analytical techniques

This study made use of a profit function derived from the framework of profit maximization. This approach to the profit function requires detailed information on all input and output prices to examine the effects of these on farmers' resource allocation opinions. A duality relationship exists between profit and production function. Widely, the approach of duality was applied to provide a comprehensive relationship between inputs and output prices (Siregar 2007). The duality approach allows the estimation of the farm output supply and input demand grounded on flexible approximations of the profit function and/or the cost function (Chambers 1988; Diewert 1974). The duality approach states that the profit and production function describes the input demand and output supply response if both functions satisfy regular properties of monotonicity and convexity. Hence, a profit function can be treated as if it is derived from a production function (McFadden 1978).

Following Lau (1972) the normalized profit function was derived through the consideration of the production function with the neoclassical properties that describe the transformation of variable and fixed inputs into outputs. Linear homogeneity of degree one in prices of output and input, and symmetry restrictions were imposed a priori. The restricted profit function is approximated by the translog function:

$$\ln \prod_R^* = \alpha_0 + \alpha_i \sum_{i=1}^{m} \ln P_i + \beta_j \sum_{i=1}^{n} \ln X_j + {}^1/_2 \sum_{i=1}^{m}\sum_{j=1}^{m} \beta_{ij} \ln P_i \ln P_j + {}^1/_2 \sum_{j=1}^{n}\sum_{k=1}^{n} \delta_{jk} \ln X_j \ln X_k + \sum_{i=1}^{m}\sum_{j=1}^{n} \rho_{ij} \ln P_i \ln X_j + + \sum_{i=1}^{m} \gamma_{it} \ln P_i t + \sum_{j=1}^{n} \emptyset_{jt} \ln X_{jt} + \theta_t t + {}^1/_2\, \theta_{it}\, t^2 \quad (14)$$

Where:

$\prod_R^* =$ Restricted profit, normalized by cereal output price (P_1)

P_i= normalized output prices for the other output categories

X_j= normalized input prices of the inputs categories (labour, biochemical, intermediate inputs, and mechanisation)

t= period (time trend)

α_0, α_i, γ_{ij}, δ_{ik}, β_k and θ_{kh} are parameters estimated.

ε= Random error

The partial derivatives of the profit function to output price or input price yield a system of output and input share equations using Hotelling's lemma.

$$d \ln \Pi^* /_{dInP_i} = \frac{P_i X_i}{\pi} = S_i \quad (15)$$

When equation (14) is applied to equation (15), yields this share equation:

$$S_i = \alpha_i + \sum_{j=1}^{m} \beta_{ij} InP_j + \sum_{j=1}^{n} \rho_{ij} InX_j + \gamma_{it} t, \quad i = 1, \dots \dots .., m \quad (16)$$

Since, both the input and output share equations come from a single profit share equation. Therefore, the cereal share equation was dropped and share equations were estimated jointly using the Seemingly Unrelated Regression (SURE) procedure. Joint estimation of the input demand equations and output supply equations ensures consistent parameter estimates (Ball 1988).

The multiple input–multiple output (MI-MO) framework, is based on the premise that crop production decisions are related to those of other crops. Hence, the error term of one equation is correlated to those of other equations. This makes ordinary least squares (OLS) not applicable in the estimation of the share equations. Also, because of the imposition of the cross-equation restriction, OLS is not appealing. The correlation and cross-equation restriction can be overcome by using SURE.

Equation (3) is the final estimation used for this study. The parameters were estimated jointly using an iterative SURE procedure of SHAZAM (Window Professional). The restricted model is one where the homogeneity and symmetry conditions are imposed.

2.2.1. Estimation of own and cross-price elasticities

The second-order derivatives of the profit function yield the input and output response elasticities (Weaver 1983). The own-price and cross-price elasticities respectively are:

$$\eta_{ii} = \left({}^{\beta_{ii}}/_{S_i} \right) + S_i - 1 \quad (17)$$

$$\eta_{ij} = \left({}^{\beta_{ii}}/_{S_i} \right) + S_j \quad (18)$$

Where:

η_{ii}= own price elasticity

η_{ij}= cross price elasticity

S_i= ith share equation, at the sample mean

3. Results and Discussion

3.1. Description of farm households production data

The GHS captured three major income-generating activities in Nigeria which were agricultural production, wage employment, and non-farm livelihood activities. Table 1 shows that agriculture (52.5%) is the most common activity in post-planting. This was followed by non-farm activities (20.8%) and wage employment (12.6%). However, in the post-harvest, nonfarm enterprises and wage employment were common. Household involvement in agriculture was much lower (37.4%). This indicated that post-harvest is a season of inactivity between harvest and planting for the next season. Besides, agricultural activities are the dominant jobs of rural farmers while non-farm enterprises are more common for urban farmers. In the post-planting season, North East and North West zones (65.78% and 62.82% respectively) had the highest participation in agricultural activities, also in post-harvest visits (45.82% and 47.34%). North Central and North East held an average of 3.2 and 3.0 plots of

Table 1. Farm households' characteristics in Nigeria

Characteristics	North Central	North East	North West	South East	South-South	South West	Urban	Rural	Pooled
Main Income Generating Activities									
Post-planting period									
Agriculture (%)	58.6	65.7	62.8	48.9	38.8	35.7	30.9	66.5	62.5
Wage employment (%)	25.6	13.2	22.7	20.1	17.8	24.2	24.2	19.3	30.8
Nonfarm Enterprise (%)	10.8	9.3	7.4	20.3	18.4	15.3	18.3	8.6	12.6
Post-harvest period									
Agriculture	44.5	45.8	47.3	24.3	18.5	13.8	10.8	36.6	47.4
Wage employment	15.4	19.3	20.4	15.6	25.2	23.6	18.4	15.8	18.5
Nonfarm Enterprise	11.6	8.9	7.7	12.7	16.1	17.8	17.1	8.56	10.8
Farm Plot Holdings									
Number of Farm Plots	3.5	3.0	2.5	2.3	2.7	2.8	2.3	2.5	2.5
Average Farm Size (Hectares)	0.6	0.7	0.5	0.4	0.4	0.8	0.4	0.9	0.7
Farm Input Use									
% Fertilizer	28.5	50.7	92.8	46.8	8.0	9.3	44.6	48.2	47.8
% Pesticide	10.2	17.4	46.3	5.6	4.0	35.3	20.9	20.7	20.7
% Herbicide	48.2	45.7	30.0	7.0	15.8	30.2	30.0	30.6	30.5
%Purchased Seed	12.5	12.8	33.2	37.7	19.4	15.2	32.8	21.5	22.6
% Animal Traction	4.6	54.8	45.5	0	0	0	10.0	23.1	21.5
Average Workdays of Household Labour	186.4	185.5	146.9	90.6	102.3	96.2	92.4	148.2	128.3
Average Workdays of Hired Labour	45.2	28.3	54.8	20.11	25.5	70.42	30.2	42.6	44.2
Major crop grown (%)									
Cereals	31.5	58.8	30.5	24.4	23.5	15.0	40.7	34.2	45.4
Pulses	36.9	28.5	13.2	16.4	16.2	18.3	24.4	18.3	30.2
Roots and Tubers	78.3	55.2	19.5	14.5	28.3	20.9	44.6	30.4	40.5
Fruits and Vegetables	34.6	21.3	33.2	30.4	33.3	20.4	26.3	22.1	27.6
Livestock Ownership (%)									
Calf(male)	2.32	5.8	2.5	0	0	0	0	2.7	2.2
Calf(female)	2.14	5.3	3.5	0	0	0	0	3.0	2.6
Cow	17.2	23.5	21.0	1.1	0.2	2.5	6.5	16.5	15.4
Bull	7.6	15.6	15.4	0	0	0	1.4	11.0	9.2
Ox	2.5	19.4	3.8	0	0	0	0.4	5.9	5.2
Goat	61.2	72.1	79.1	56.0	45.8	53.7	58.8	68.7	67.3
Sheep	18.5	42.1	57.8	6.9	0.7	4.9	24.3	34.2	33.0
Chicken(local)	73.9	66.4	55.5	74.2	60.2	68.3	55.5	65.2	64.8
Duck	4.3	8.5	1.3	0	2.3	2.5	1.6	3.2	3.0
Guinea fowl	1.3	4.2	9.8	0	0	0	1.2	4.8	4.4
Utilization of Livestock									
Sales	24.4	45.3	20.5	36.0	32.6	21.2	24.3	28.9	28.5
Slaughter	29.5	38.9	19.2	37.9	29.2	36.1	29.2	29.0	29.0
Others	0.4	2.4	0.9	1.1	0.8	1.0	0.5	1.2	1.1

Source: computation from LSMS Panel Data (2010-2016).

farmland respectively. The average farm plot size is less than 1 hectare for Nigeria. Average farm size in rural (0.9 hectares) areas were larger than in urban (0.4 hectares) areas. The northern region's farm sizes were generally larger than those in the southern regions.

Information on farm input use across zones revealed that 47.3% of the households used fertilizers, 20.7% used pesticides, 30.5% used herbicides, 22.9% used purchased seeds, and 21.4% used animal traction on their farm plots. However, farm plots operated by rural households utilized more fertilizer, herbicide, animal traction, and labour, than those operated by urban households. Households in urban areas used more pesticides and purchased seeds than those in rural areas on their plots. Moreover, labour input use captured by workdays showed that average household labour workdays (128.3) are larger than that of hired labour workdays (44.2). Crop cultivation is dominated by rural farmers. Maize is mostly cultivated, accounting for the highest (45.4%) household participation in all the crop cultivation categories. Followed by roots and tubers (40.5%) and pulses (30.2%).

The number of livestock by type of animal and geographical region revealed that goats (66.8%) and chickens (63.6%) were commonly owned animals, followed by sheep (33.1%), and cows (15.1%). By region, goats and chickens were mainly owned. Also, 29% of livestock-owning households slaughtered, 28.5% sold, and 1.1% used livestock for debt payment.

3.2. Testing of the production technology properties

The estimation of the share equations was the first step in testing the production technology properties. The parameter estimates of the seemingly unrelated regression technique of supply response to changes in both output and input prices as presented in Table 2. Nine of the ten own-price coefficients were significant at the 1% level. A total of sixty-five (65) parameters were contained in the table, out of which, forty-six (46) were significant at various levels. The coefficients of cross-price were the most significant, and the time trend coefficients were generally significant. Time trends that captured the level of technology had a significant and positive effect on fruits and vegetables, other foods, biochemical inputs, intermediate inputs, and mechanisation and were negatively significant for roots and tubers, and labour. There was no structural change in the production of cereals and pulses because both coefficients were statistically insignificant.

In addition to the imposed properties of symmetry and homogeneity, the other properties of a profit function that globally cannot be satisfied with the translog function were monotonicity and convexity (Fulginiti and Perrin 1990). Monotonicity and convexity were checked after the estimation. Monotonicity entails that the fitted values of the supply of output are positive and input demand equations are negative. However, the monotonicity restriction is violated if the predicted output shares are negative and/or input shares are positive. Also, the convexity necessary condition is that all the own-price elasticities must have the expected signs (positive). The adding-up property is satisfied since the functions are specified in share form.

3.3. Elasticities of input demand and output supply

The own and cross-price elasticities of output supply and input demand equations obtained directly from the profit function estimates are shown in Table 3. Model estimation subjected to the theoretical restrictions ensures that own-price elasticities of output supply are positive and negative for input demand. The expected positive signs of the own-price elasticities of output supply were consistent for profit maximization.

The own-price elasticities of cereals, pulses, and other foods supply were elastic while that of roots and tubers, fruits and vegetables, and animal products ranges between 0.54 and 1.31. The inelastic nature of own-price elasticities of roots and tubers (0.6859), fruits and vegetables (0.6818), meats, and animal products (0.5402) implies that qunatity produced were less responsive to their price change (increase) when compared with other output categories that were elastic. However, cereals, pulses, and other foods were more sensitive and responded quickly to, price changes. Anand et al. (2016) posited that supply is perfectly elastic in output prices and that it is the input demand that adjusts to clear markets.

Since this study is based on multiple outputs and multiple inputs frameworks, the cross-output supply elasticities became more appealing allowing the identification of substitution and complementarity possibilities among the output and input categories specified. In terms of elasticities of output cross-price, 65% of them were positive, suggesting a complementary relationship between the output supplies. The gross complementarity of output categories would increase the production of all outputs. This would occur if the input usage increase resulted from an output price increase which sufficiently shifted the production transformation frontier outward to allow absolute price increase implying that, as the commodity price rises, new inputs are drawn into the production given that the input elasticities in response to output prices, promoting an increase in the production of other outputs as well.

Given the output price elasticities in Table 3, if a general rise in output prices is not offset by higher input prices, a relatively elastic response output would be induced, but it will not equally affect all the commodities (Fulginiti and Perrin, 1990). However, cross-price elasticities between cereals and pulses, cereals, and roots/tubers were negative, suggesting the competitive relationship between output supplies of cereals and pulses; cereals, and roots/tubers.

Output supply elasticities to input prices were inelastic and mainly positive, implying that an increase in the output price would lead to an increase in input demand to produce more.

The estimated input demand results revealed that the own-price elasticities of all input demand have expected negative signs, and were price elastic except mechanisation input demand. The own-price elasticities of labour, agrochemicals, and intermediate inputs demand were elastic and negative ranging between -1.14 to -1.48 implying a high degree of responsiveness to input price, and that the labour farm employment level may dramatically decrease as a result of a wage increase.

Besides, the gross complementarity of the input pairs suggested a reduction in output would be accompanied by reductions in the demand for all production factors. A general rise in input prices, with output prices constant, would result in a reduction of the use of labour, agrochemicals, and intermediate inputs much more than any other input (mechanisation). The magnitude of these elasticities suggests that policy issues affecting labour wages, intermediate inputs, and agrochemicals will not have a noticeable effect on output levels as well as input use.

As for the estimated cross-price elasticities, there is the existence of input/output prices on input demand and output supply of cross-effects. This cross-effects relationship justifies the multiple outputs- multiple input (MO-MI) nature of the crops, and the course, of the analyses in the present study. Comparing the output supply own-price elasticities, and the input demand own-price elasticities were higher, in absolute terms. This indicated that policy on commodity prices of both outputs and inputs may be effective, and hence should be implemented directly. However, such policy should be politically desirable, and focus more on production inputs than outputs as higher magnitudes were found for input demand than output supply.

4. Conclusion and Recommendation

Studies have argued that farmers do not respond to economic shocks such as price and income, particularly in less developed countries. This study examined farm input demand and output supply response to price shocks using the restricted translog profit function by estimating both the revenue and cost shares model and imposing appropriate restrictions. The own-price inelastic nature of the food crop supply in Nigeria particularly roots/tubers and fruits/vegetables implied that farmers' revenue decreases as more of the quantity produced were increased.

The own-price elastic nature of input demand of biochemical and intermediate inputs suggested that efforts to increase input prices through removal of price subsidy, would significantly reduce the utilization of the inputs, and also decrease inputs producer’s revenues.

Table 2. Seemingly unrelated regression parameter estimate for share equations

	Output Share Equations						**Input Share Equation**				
Explanatory Variables	**Cereals**	**Pulses**	**Roots & Tuber**	**Fruits & Vegetables**	**Animal Products**	**Other Food**	**Non-farm**	**Labour**	**Biochemicals Inputs**	**Intermediate inputs**	**Mechanisation**
Constant	-0.516	0.005***	0.439***	0.041***	0.009	0.002	0.001	0.551***	0.048***	0.397***	0.025***
		(3.65)	(47.46)	(5.58)	(0.68)	(0.27)	(0.40)	(87.90)	(7.00)	(62.87)	(4.81)
Cereals	**0.139**										
Pulses	0.016	**-0.031*** **									
		(-4.54)									
Roots & Tuber	-0.176	-0.054***	**0.003*** **								
		(-12.31)	**(43.76)**								
Fruits & Vegetables	0.006	0.023***	-0.024***	**0.007***							
		(6.39)	(-10.08)	**(1.93)**							
Animal Products	0.008	0.052***	-0.079***	-0.004	**0.036*** **						
		(10.12)	(-20.89)	(-1.18)	**(5.08)**						
Other Food	0.006	0.025***	-0.015***	0.006***	-0.001	**-0.006** **					
		(9.38)	(-7.45)	(2.56)	(-0.17)	**(-2.24)**					
Non-farm	0.001	0.001	-0.005***	0.001	0.005***	-0.002**	**0.002***				
		(0.94)	(-5.21)	(0.49)	(3.33)	(-2.24)	**(1.74)**				
Labour	0.005	0.003	0.013***	-0.003**	-0.006**	-0.002	-0.000	**0.045*** **			
		(1.09)	(4.56)	(-2.11)	(-2.26)	(-1.08)	(-0.58)	**(16.67)**			
Biochemicals	-0.005	0.011***	-0.012***	0.009***	-0.012***	0.001	-0.000	-0.007***	**0.005***		
		(3.60)	(-4.48)	(4.53)	(-2.24)	(0.46)	(-0.12)	(-3.41)	**(1.92)**		
Intermediate Inputs	0.009	-0.015***	0.005*	-0.006***	0.026***	-0.001	-0.000	-0.037***	0.005**	0**.028*** **	
		(-5.11)	(1.93)	(-3.54)	(9.86)	(-0.45)	(-0.19)	(-17.58)	(2.43)	(9.73)	
Mechanisation	-0.008	0.005**	-0.006***	0.001	-0.007***	0.000	-0.000	-0.001	-0.005***	0.003**	**0.002**
		(2.23)	(-3.78)	(0.46)	(-2.94)	(0.08)	(-0.38)	(-0.65)	(-3.07)	(2.44)	(1.16)
Time	0.027	0.015	0.011***	-0.004***	0.002	0.003***	-0.000	-0.017***	0.013***	0.003***	0.002***
		(1.50)	(7.402)	(-5.53)	(1.37)	(4.61)	(-1.54)	(-17.84)	(12.57)	(2.9)	(3.98)
System R2		0.063	0.181	0.012	0.045	0.015	0.004	0.095	0.043	0.043	0.003

Note: 1. The parameters of the share equation for cereals products were calculated using the constraints implied by linear homogeneity in prices 2. values in parentheses are t-statistics. 3. ***, ** and * imply the associated coefficient is significant at 1%, 5% and 10% levels respectively 4. Single equation measures ??of fit? are not generally applicable in systems estimation.

Table 3. Farm output supply and ınput demand elasticities

	Output Supply Equation							Input Demand Equation			
Categories	Cereals	Pulses	Roots and Tubers	Fruits and Vegetables	Animal Products	Other foods	Nonfarm Income	Labour	Agrochemicals	Intermediate inputs	Mechanisation
Cereals	**1.246**	-1.680	-0.142	0.680	0.514	0.738	0.533	-0.442	0.355	-0.452	-0.095
Pulses	-0.147	**1.164**	-0.067	0.927	0.615	1.490	0.267	-0.118	-0.278	-0.077	0.313
Roots & Tubers	-0.101	-0.186	**0.685**	-0.641	-0.486	-0.510	-0.309	-0.333	0.120	-0.318	-0.030
Fruits & Vegetables	0.039	0.207	-0.052	**0.681**	-0.018	0.337	0.103	-0.017	-0.155	-0.011	0.055
Animal Products	0.118	0.550	-0.158	-0.075	**0.540**	0.070	0.790	-0.086	-0.085	-0.156	-0.176
Other foods	0.031	0.244	-0.030	0.247	0.012	**1.129**	-0.273	-0.015	0.029	-0.016	0.022
Non-farm Income	0.009	0.018	-0.007	0.031	0.060	-0.113	**0.797**	-0.006	-0.006	-0.007	-0.002
Labour	-0.467	0.484	0.497	0.318	0.398	0.374	0.408	**-1.150**	0.348	-0.375	-0.421
Biochemicals	0.055	0.167	-0.026	0.420	--0.057	0.108	0.054	0.051	**-1.445**	0.079	-0.116
Intermediate inputs	0.472	-0.314	0.469	0.213	0.710	0.416	0.434	-0.371	0.531	**-1.487**	-0.583
Mechanisation	0.005	0.070	0.002	0.056	--0.044	0.031	-0.009	-0.023	-0.043	-0.032	**-0.850**

Source: Author's Computation, 2019

inputs would lead to less efficient utilisation of the agrochemical and intermediate inputs. In addition, the possible increase in the agrochemical and intermediate inputs prices after the removal of subsidy would create incentives (higher prices) for the producers and traders of the inputs. The inelastic nature of mechanisation suggests that attempts to increase its prices would not significantly reduce its utilisation. Therefore, considering the vulnerable nature of food crop farmers to input prices in Nigeria, such a reduction should be undertaken gradually.

References

Akanni KA, Okeowo TA (2011) Analysis of aggregate output supply response of selected food grains in Nigeria. Journal of Stored Products and Postharvest Research 2(14): 266-278.

Anand R, Kumar N, Tulin T (2016) Understanding India’s Food Inflation: The Role of Demand and Supply Factors. IMF Working Paper. Asia and Pacific Department.

Ball VE (1988) ‘Modeling supply response in a multiproduct framework’, American Journal of Agricultura1 Economics 70(4): 813-825.

Ball VE (2002) “Productivity and Growth in Postwar Agriculture.” Paper presented at the Joint OECD/UNECE/Eurostat/FAO Seminar on Agricultural Statistics, Paris, France, 21-22.

Battese GE, Coelli TJ, Prasada Rao DS (1998) An Introduction to Efficiency and Productivity Analysis. Kluwer Academic Publishers. London.

Barrett CB (2008) Smallholder market participation: Concepts and evidence from eastern and southern Africa. Food Policy 33(4): 299-317.

Chambers RG (1988) Applied Production Analysis, Cambridge, U.K., Cambridge University Press.

Dawson PJ, Lingard J (1989) Measuring farm Efficiency over time on Phillipine Rice Farms. Journal of Agricultural Economics 40: 168-17.

Di Marcantonio F, MoralesOpazo C, Barreiro-Hurle J (2014) Determinants of food production in Sub Saharan Africa: The impact of policy, market access and governance. Paper for the 2014 EAAE Congress in Ljubljana, Slovenia, 26-29 August.

Diewert WE (1974) “Applications of Duality Theory,” in M. Intriligator and D.A. Kendrick (eds.), Frontiers of Quantitative Economics, Vol. II, Amsterdam, North- Holland Publ. Co., 106-206.

Fulginiti LE, Perrin RK (1990) Argentine Agricultural Policy in a Multiple-Output, Multiple-Input Framework. University of Nebraska-Lincoln DigitalCommons@University of Nebraska-Lincoln. Faculty Publications: Agricultural Economics. 9.

Haile MG, Kalkuhl M, von Braun J (2015) Agricultural supply response to international food prices and price volatility: a cross-country panel analysis. Paper prepared for presentation at the EAAE 2014 Congress ‘Agri-Food and Rural Innovations for Healthier Societies’pp1-14.

Hasenkamp G (1976) Lecture Notes in Economics and Mathematical Systems: Specification and Estimation on Multiple-Output Production Functions, Berlin: Springer-Verlag.

Jorgenson DW, Lau LJ (1974) "Duality and Differentiability in Production," Journal of Economic Theory 9(1): 23-42.

Kumar P, Shinoj P, Raju SS, Kumar A, Rich KM, Msangi S (2010) Factor Demand, Output Supply Elasticities and Supply Projections for Major Crops of India. Agricultural Economics Research Review 23: 1-14.

Lau LJ (1972) “Profit Functions of Technologies with Multiple Inputs and Outputs”, Review of Economics and Statistics 54: 281-289.

Lau LJ (1978) "Applications of Profit Functions " Production Economics; A Dual Approach to Theory and Appli- cations, ed. M. Fuss and D. McFadden. Amsterdam: North-Holland Publishing Co.

McFadden D (1978) Cost, Revenue and Profit Function in M. Fuss and D. McFadden (eds) Production Economics: A Dual Approach to Theory and Application, 3-109. Elsevier North Holland.

Mesike CS, Okoh RN, Inoni OE (2010) Supply response of rubber farmers in Nigeria: An application of Vector Error Correction Model. Agricultural Journal 5: 146-150.

Molitor K, Braun B, Pritchard B (2017) The effects of food price changes on smallholder production and consumption decision-making: evidence from Bangladesh. Geographical Research 55(2): 206-216.

Mythili G (2008) Acreage and yield response for major crops in the pre- and post-reform periods in India: A dynamic panel data approach. PP Series 061, Indira Gandhi Institute of Development of Research, Mumbai.

Obayelu AE, Salau AS (2010) Agricultural response to prices and exchange rate in Nigeria: Application of Co-integration and Vector Error Correction Model. Journal of Agricultural Science (2): 73-81.

Olayide SO, Heady EO (1982) Introduction to Agricultural Production Economics. Ibadan University Press, Ibadan, Nigeria, pp. 89.

Olwande J, Ngigi M, Nguyo W (2009) Supply Responsiveness of Maize Farmers in Kenya: A Farn-Level Analysis. International of Agricultural Economics 2009 Conference, Beijing, China.

Poulton C, Kydd J, Dorward A (2006) Overcoming market constraints on pro-poor agricultural growth in sub-Saharan Africa. Development Policy Review 24(3): 243-277.

Siregar H (2007) Elasticities of Output Supply and Input Demand of Indonesian Food Crops and Their Policy Implication: Multi-input Multi-output Framework. Socio Economic of Agriculture and Agribusiness 7(2): 1-15.

Wall CA, Fisher BS (1988) Modeling a Multiple Output Production System: Supply Response in the Australia Sheep Industry, University of Sydney Printing Service. Sydney.

Weaver RD (1977) ‘The Theory and Measurement of Provisional Agricultural Decisions’, Unpublished PhD Thesis, Wisconsin: University of Wisconsin.

Weaver RD (1983) "Multiple Input, Multiple Output Production Choices and Technology in the U.S. Wheat Region", American Journal of Agricultural Economics 65: 45-56.

This study was conceptualized, conducted and reported in accordance with the Research Ethics Policy of the Federal University of Agriculture Abeokuta, Nigeria.