Multi-Crop Supply Response in a Risky Production Environment: Evidence from the Sudano-Sahelian Zone of Nigeria

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Abstract

This paper is based on the premise that the impact of climate variability and change on crop production decision can be either positive or negative depending on the crop, cropping system and variation in weather patterns. Using time series data (1994-2009) pooled across the sub-regional (states) level in the Sudano-Sahelian zone of Nigeria, two systems of regional multi-crop supply equations represented by a normalized quadratic indirect utility function, assuming linear mean-variance risk preferences were estimated. Parameter estimates with seemingly unrelated regression (NSUR) estimation technique indicate that expected weather and climate risk have impacted negatively on the expected supply of millet and sorghum in spite of risk hedging opportunities provided by a multiple cropping system. Thus, government should increase investment in weather forecast infrastructure so as to reduce the mismatch between expected and actual weather realization and institutions that will support the introduction of crop weather index insurance should be established.

Keywords: Climate Variability, Multi-Crops Supply, Sudano-Sahelian Zone

JEL Classification: Q12, D81, D84

Résumé

La présente étude repose sur l’hypothèse que l’impact de la variabilité climatique et du changement climatique sur la décision de production agricole peut être positif ou négatif selon la culture, le système de culture et la variation des conditions météorologiques. À l'aide de données en séries chronologiques (1994-2009) regroupées au niveau sous-régional (États) dans la zone Soudano-Sahélienne du Nigéria, deux systèmes d’équations d’offre multicultures régionales représentés par une fonction d'utilité indirecte quadratique normalisée, en supposant que des préférences pour le risque en moyenne-variance linéaire ont été estimées. Les estimations des paramètres avec une technique d'estimation de la régression apparemment sans rapport (NSUR) indiquent que les risques météorologiques et climatiques prévus ont eu un impact négatif sur l'offre prévue de mil et de sorgho en dépit des possibilités de couverture des risques offertes par un système de culture multiple. Ainsi, le gouvernement devrait accroître les investissements dans les infrastructures de prévisions météorologiques afin de réduire l'écart entre la réalisation météorologique prévue et réelle et les institutions qui appuieront l'introduction de l'assurance-indice météorologique des cultures devraient être Établies.

Mots clés : Variabilité climatique, approvisionnement multicultures, zone soudano-sahélienne

Classification JEL: Q12, D81, D84

Introduction

Unpredictable and extreme weather induced by climate change and variability have led to land degradation, threatening about 35% of Nigeria's land mass mainly in the Sudano-Sahelian Zone (NISER, 2010). Several studies show that the climate of Sudano-Sahelian Zone of Nigeria have fluctuated substantially, affecting both intra-annual and inter-annual rainfall patterns (Abaje, Ati, & Iguisi, 2012; Ifabiyi & Ojoye, 2013) as well as key precipitation effectiveness indices (Sawa & Adebayo, 2011). This have impacted on crop yield and yield variability (Akinseye, Ajayi, & Oladitan, 2013; Omotosho, Agele, Balogun, & Adefisan, 2013) creating imbalances in local and regional food markets. These imbalances could worsen the already high level of vulnerability and low adaptive capacity faced by the rural populace (Adesina & Odekunle, 2011; Madu, 2012) due to rapid growth in population as well as high unemployment and poverty rates (Olojo, 2013). Findings from an anthropometric and retrospective mortality survey across the Sudano-Sahelian Zone show also that over 40% of children less than 5 years are suffering from stunting (UNICEF, 2012), highlighting the level of poverty and food insecurity in the study region.

Like in other parts of the country, rural livelihoods in the Sudano-Sahelian Zone of Nigeria are largely based on subsistence rain-fed mixed crop and livestock farming system (Ati, Stigter, Iguisi, & Afolayan, 2009). The cropping system[1] include mono crops, permanent intercrops and mixed farming as well as lands under temporary intercrops in rotation with fallows, all largely on a small scale (Bationo et al., 2012). However, intercropping is the most common cropping system in the Sudano-Sahelian zone (Bationo et al., 2012) and involves the growing of two or more crops in proximity to promote interaction between them (Ibeawuchi, 2007). The intercropping system provides the farmer with several options for returns from land and labor, often increasing efficiency with which scarce resources are used (Norman, 1974). It also reduces dependence upon a single crop that is susceptible to environmental and economic fluctuations (Bationo et al., 2012). This is largely because different crops or crop varieties have different water demands and phenology, especially in the event of adverse weather patterns (Callo-Concha et al., 2013).

[1] A cropping system is an aspect of agricultural production system which consists of one or more crops in which sets of resources and inputs are uniquely managed by the farmer in the production process to satisfy human needs for food, fibre, other products, monetary income and other objectives (Okigbo, 1984)

Given that climate change is unlikely to confront a static world, farmers are likely to respond to changes and variation in their natural and economic environment with the aim of making themselves better off (Burke & Lobell, 2010). The extent to which crop producers can adapt clearly raises empirical questions on their supply response to changing climatic conditions. Hence, this paper estimates the impact of climate variability on the supply of two most extensively grown crops (Millet and Sorghum) in the Sudano-Sahelian zone from 1994-2009. This paper fills an important gap in the body of relevant empirical literature (Blanc, 2013; Boussios & Barkley, 2012; Huang & Khanna, 2012; Traboulsi, 2013) because these studies have not taken into account the possibilities of farmers' adaptive response to climate variability and change. Adams et al. (2009) argued that there are several ways that farmers may be able to respond to adverse climatic conditions (for example, by changing crop mixes, cultivars and using fertilizer) to maintain or offset reductions in output levels. In general, studies that ignore these adjustment possibilities are likely to overstate the cost of climate variability and change[2].

1. Analytical Framework

The profit function approach to supply analysis provides a conceptual framework for evaluating interdependencies and trade-offs in the production decisions of farmers in mixed cropping system (Wall & Fisher, 1988). Therefore, following the Neumann & Morgenstern (1944) utility theory, the famer maximizes his expected utility of profits $E\left[U\left(®\right)\right]$. Thus, a duality model is developed under the following assumptions: (a) linear mean-variance risk preferences (which imply constant absolute risk aversion (CARA)), (b) quadratic indirect utility function and (c) price certainty. Although these assumptions are restrictive, they have been used in several empirical studies on agricultural producer behavior (Coyle, 1999; Zheng, 2010). More importantly, these assumptions imply that the farmer's objective function is almost linear in parameters, which simplifies empirical application. Consequently, the certainty equivalence of a production technology with multiple stochastic outputs based on the foregoing assumptions is specified as follows:

$$EU\left(®\right)=\overline{®}-\frac{\sim}{2}\pm_{®}^{2} \tag{1}$$

Where $\overline{®}$ and $\pm_{®}^{2}$ are the mean and variance of profit which is a random variable. Also, $\sim>0$ and measures the coefficient of absolute risk aversion. The randomness in profit is attributed to the revenue component of the profit function because input prices and quantities are assumed to be fixed. Therefore, given a multi-crop production system, the production technology can be specified generally as follows:

$$y=g\left(x,\mathrm{z},£\right)+u \tag{2}$$

[2] Solomon, S. et al. (2007) defines climate change as "a change in the state of the climate that can be identified (for example, by using statistical tests) by changes in the mean and/or the variability of its properties and which persists for an extended period typically decades or longer"

Where y is an (m rows) crop output vector, g represents a vector with terms $g_i\left(x, \mathrm{z}, \pounds\right)$ which are "well behaved" crop production functions, x is the ($n-m$ rows) variable input vector, z is the ($q-n$ rows) quasi-fixed input vector, $\pounds$ is a stochastic weather variable with mean $\overline{\pounds}$ and variance $\pm_{\pounds}^{2}$. Note that the weather variable is assumed to be exogenous and random. u is a vector of other random component of crop output with mean 0 and covariance matrix Ω . Taking the mathematical expectation of the second order Taylor Series expansion around $\overline{\pounds}$, the expected crop output level can be specified as:

$$\overline{y} = f\left(x, \mathrm{z}, \overline{\pounds}, \pm_{\pounds}^{2}\right) \tag{3}$$

Where $f\left(x, \mathrm{z}, \overline{\pounds}, \pm_{\pounds}^{2}\right)$ is a vector with terms $f_i\left(x, \mathrm{z}, \overline{\pounds}, \pm_{\pounds}^{2}\right)$. Here, it is assumed that $\pounds$ is unobservable and a producer makes his production plan conditional on mean and variance of past weather variables. The output covariance matrix is defined generally as:

$$\Omega_y = \Omega \tag{4}$$

Recall that the profit function which is stochastic can be fully specified as follows:

$$® = \sum_{i=1}^{m} p_i y_i - \sum_{j=1}^{n} w_j x_j \tag{5}$$

Hence, the mean and variance of profit can be expressed as:

$$\overline{®} = \sum_{i=1}^{m} p_i \overline{y}_i - \sum_{j=1}^{n} w_j x_j \tag{6}$$

$$\pm_{®}^{2} = p^{'}\Omega p = \sum_{i=1}^{m}\sum_{k=1}^{m} p_i p_k \pm_{ik} \tag{7}$$

Where p stands for output price vector, w for input price vector and $\pm_{ik}$ stands for the covariance between i^{th} and the k^{th} output. By substituting equations 3 in 6, we have

$$\overline{®} = \sum_{i=1}^{m} p_i f\left(x, z, \overline{\pounds}, \pm_{\pounds}^{2}\right) - \sum_{j=1}^{n} w_j x_j \tag{8}$$

If equation 7 and 8 are substituted in equation 1, the certainty equivalent of the profit function can be expressed as follows:

$$EU\left(®\right) = \sum_{i=1}^{m} p_i f_i\left(x, \mathrm{z}, \overline{\pounds}, \pm_{\pounds}^{2}\right) - \sum_{j=1}^{n} w_j x_j - \frac{\sim}{2} p^{'}\Omega p \tag{9}$$

From equation 9 above, the first order condition for certainty equivalent profit maximization will yield:

$$\frac{\partial EU(\circledR)}{\partial x_j} = \sum_{i=1}^{m} p_i \frac{\partial f_i\left(x, \mathrm{z}, \bar{\pounds}, \pm_{\pounds}^{2}\right)}{\partial x_j} - w_j = 0 \qquad \text{For all} \qquad j = 1\ldots.\mathrm{n} \tag{10}$$

Equations 10 provide the necessary condition to reach the optimal expected output and input levels: $\bar{y}_i\left(p, w, \mathrm{z}, \bar{\pounds}, \pm_{\pounds}^{2}\right)$ and $x_j\left(p, w, \mathrm{z}, \bar{\pounds}, \pm_{\pounds}^{2}\right)$. Substituting them into equation 7 and 9 will yield the dual indirect utility function of profit, that is, the relation between maximum feasible utility U and exogenous variables:

$$V\left(p, w, z, \bar{\pounds}, \pm_{\pounds}^{2}, \Omega\right) = \max_{x_j \geq 0} EU(\circledR)$$

$$= EU(\circledR)^{*} = \sum_{i=1}^{m} p_i \bar{y}_i\left(p, w, \mathrm{z}, \bar{\pounds}, \pm_{\pounds}^{2}\right) - \sum_{j=1}^{n} w_j x_j\left(p, w, \mathrm{z}, \bar{\pounds}, \pm_{\pounds}^{2}\right) - \frac{\sim}{2} p^{'}\Omega p \tag{11}$$

Where $(\circledR)^{*}$ is the maxim making use of the envelop theorem. The partial derivative of equation 11 with respect to input and output prices yields:

$$\frac{\partial V(.)}{\partial p_i} = \bar{y}\left(p, w, \mathrm{z}, \bar{\pounds}, \pm_{\pounds}^{2}\right) + \sum_{k=1}^{m} p_k \frac{\partial \bar{y}_k\left(p, w, \mathrm{z}, \bar{\pounds}, \pm_{\pounds}^{2}\right)}{\partial p_i} - \sum_{j=1}^{n} w_j \frac{\partial x_j\left(p, w, \mathrm{z}, \bar{\pounds}, \pm_{\pounds}^{2}\right)}{\partial p_i} - \frac{1}{2}\sim \frac{\partial\left(p^{'}\Omega p\right)}{\partial p_i}$$

$$= \bar{y}\left(p, w, \mathrm{z}, \bar{\pounds}, \pm_{\pounds}^{2}\right) + \sum_{j=1}^{m}\left[\left(\sum_{k=1}^{n} p_k \frac{\partial \bar{y}_k\left(p, w, \mathrm{z}, \bar{\pounds}, \pm_{\pounds}^{2}\right)}{\partial x_j} - w_j\right)\frac{\partial x_j}{\partial p_i}\right] - \sim \sum_{k=1}^{m} p_k \pm_{ik} \tag{12}$$

$$\frac{\partial V(.)}{\partial w_j} = -x_j\left(p, w, \mathrm{z}, \bar{\pounds}, \pm_{\pounds}^{2}\right) + \sum_{k=1}^{m} p_k \frac{\partial \bar{y}_k\left(\mathrm{p}, w, \mathrm{z}, \bar{\pounds}, \pm_{\pounds}^{2}\right)}{\partial w_j} - \sum_{j=1}^{n} w_j \frac{\partial x_j\left(p, w, \mathrm{z}, \bar{\pounds}, \pm_{\pounds}^{2}\right)}{\partial w_j}$$

$$= -x_j\left(p, w, \mathrm{z}, \bar{\pounds}, \pm_{\pounds}^{2}\right) + \sum_{j=1}^{n}\left[\left(\sum_{k=1}^{m} p_k \frac{\partial \bar{y}_k\left(p, w, \mathrm{z}, \bar{\pounds}, \pm_{\pounds}^{2}\right)}{\partial x_j} - w_j\right)\frac{\partial x_j}{\partial w_j}\right] \tag{13}$$

By re-arranging, the expected output and input equations can be re-presented thus:

$$\bar{y}_i\left(p, w, \mathrm{z}, \bar{\pounds}, \pm_{\pounds}^{2}\right) = \frac{\partial V(.)}{p_i} + \sim \sum_{k=1}^{m} p_k \pm_{ik} \quad \text{For all} \qquad i = 1, \ldots., m \tag{14}$$

$$x_j\left(p, w, z, \bar{\pounds}, \pm_{\pounds}^{2}\right) = -\frac{\partial V(.)}{\partial w_j} \qquad \text{For all} \qquad j = 1, \ldots, n \tag{15}$$

The system of expected crop(s) output supply equations (14) and input demand equations (15) are major derivations when uncertainty is accommodated in the production decision of risk non-neutral agricultural producers based on duality theory. All input quantity and prices as well as output prices are fixed, hence there is no effect of risk averseness behavior on the demand system. The proposition that establishes the properties of the system as obtained and its extensive proof can be found in the appendix of Coyle (1999).

2. Data Structure

The annual time series data sets on crop output quantities (millet and sorghum), variable inputs quantities (fertilizer and seeds) and their respective prices and quasi-fixed inputs (area harvested for each crop and family farm labour)[3] from 1994-2009 was collected from the National Bureau of Statistics (NBS) and the National Program on Food Security (NPFS). The aggregate seeds price and quantity variables are indexes for the four crops used in estimating the econometric model. A pooled time-series, cross-sectional (TSCS) panel data structure which generated 128 observations (that is $t = 128$ and $i = 8$).

Weather and technological change are assumed to be exogenous. It is widely accepted that the distribution of rain within the rainy season as well as the utilization of fixed and variable farm inputs has a significant impact on crop yields and output supply. This informed the use of average monthly rainfall data from April to October from Nigerian Meteorological Agency (NIMET)[4] as a measure of climate variability. The mean and variance of rainfall for each of the eight stations at time t was calculated using weights of past realizations. The formula is specified as follows:

$$\overline{\pounds}_t = 0.5\pounds_{t-1} + 0.33\pounds_{t-2} + 0.17\pounds_{t-3} \qquad (16)$$

$$\pm^2_{\pounds_t} = 0.5(\pounds_{t-1} - \overline{\pounds}_{t-1})^2 + 0.33(\pounds_{t-2} - \overline{\pounds}_{t-2})^2 + 0.17(\pounds_{t-3} - \overline{\pounds}_{t-3})^2 \qquad (17)$$

The mean rainfall expression in equation 16 fits adaptive expectation where belief at time t is a weighted average of past realizations. In equation 17, the current variance equals the sum of squares of prediction errors of the three previous years, with declining weights similar to other studies (Coyle, 1999). Also, means $\overline{y}$ and variances Ω_y of crop quantities are defined similar to equation 16 and 17 above respectively. Crop quantities' co-variances Ω_{ik} are defined as follows:

$$\begin{aligned}\Omega_{ik_t} &= 0.5(y_{it-1} - \overline{y}_{it-1})(y_{kt-1} - \overline{y}_{kt-1}) \\ &+ 0.33(y_{it-2} - \overline{y}_{it-2})(y_{kt-2} - \overline{y}_{kt-2}) \\ &+ 0.17(y_{it-3} - \overline{y}_{it-3})(y_{kt-3} - \overline{y}_{kt-3})\end{aligned} \qquad (18)$$

Trends, other descriptive summary statistics of crop output, monthly rainfall and other variables used are presented in the appendix below. Also in the appendix are the definition and lables of the variables used

[3] Due to the imperfect substitutability between family and hired labour, family farm labour is considered as a quasi-fixed allocable input in the short-run.

[4] The ground level rainfall data for Jigawa state was not available. Since Yobe state is close to Jigawa state and has two weather stations (in Potiskum and Nguru) whose data is available, the data for the weather station closer to Jigawa state (that is, Nguru) was used for Jigawa state.

3. Econometric Model

To apply econometrics methods in estimating the indirect utility function, it needs to take a specific functional form. The normalized quadratic specification has been used by several studies due to its appealing theoretical and empirical properties (Shumway, 1983). In addition, the normalized quadratic is attractive and unique for use in empirical applications as correct curvature can be imposed in a parsimonious way without losing the desirable property of flexibility (Diewert & Fox, 2009). Therefore, assuming a normalized quadratic function and using the price of cowpea as numeraire, the following equations reflecting the panel data structure of the system of expected crop(s) supply equations is specified:

$$\overline{y}_{1t} = a_1 + a_{11,t}\frac{p_{1t}}{p_{kt}} + a_{12,t}\frac{p_{2t}}{p_{kt}} + a_{13,t}\frac{w_{1t}}{p_{kt}} + a_{14,t}\frac{w_{2t}}{p_{kt}} + b_{11,t}z_{1t}$$

$$+b_{12,t}z_{2t} + c_{11,t}\pm^{2}_{\pounds_t}p_{kt} + c_{12,t}\overline{\pounds}_t + c_{13,t}p_{kt} + c_{14,t}tt_t + \sim\left(p_{1t}\Omega_{11} + p_{2t}\Omega_{12}\right)$$

$$\overline{y}_{2t} = a_2 + a_{21,t}\frac{p_{1t}}{p_{kt}} + a_{22,t}\frac{p_{2t}}{p_{kt}} + a_{23,t}\frac{w_{1t}}{p_{kt}} + a_{24,t}\frac{w_{2t}}{p_{kt}} + b_{21,t}z_{1t}$$

$$+b_{22,t}z_{1t} + c_{21,t}\pm^{2}_{\pounds_t}p_{kt} + c_{22,t}\overline{\pounds}_t + c_{23,t}p_{kt} + c_{24,t}tt_t + \sim\left(p_{2t}\Omega_{22} + p_{1t}\Omega_{12}\right)$$

$$x_{1t} = -\left(a_3 + a_{31,t}\frac{p_{1t}}{p_{kt}} + a_{32,t}\frac{p_{2t}}{p_{kt}} + a_{33,t}\frac{w_{1t}}{p_{kt}} + a_{34,t}\frac{w_{2t}}{p_{kt}} + b_{31,t}z_{1t} + b_{32,t}z_{2t}\right.$$

$$\left.+c_{31,t}\pm^{2}_{\pounds_t}p_{kt} + c_{32,t}\overline{\pounds}_t + c_{33,t}p_{kt} + c_{34,t}tt_t\right)$$

$$x_{2t} = -\left(a_4 + a_{41,t}\frac{p_{1t}}{p_{kt}} + a_{42,t}\frac{p_{2t}}{p_{kt}} + a_{43,t}\frac{w_{1t}}{p_{kt}} + a_{44,t}\frac{w_{2t}}{p_{kt}} + b_{41,t}z_{1t} + b_{42,t}z_{2t}\right.$$

$$\left.+c_{41,t}\pm^{2}_{\pounds_t}p_{kt} + c_{42,t}\overline{\pounds}_t + c_{43,t}p_{kt} + c_{44,t}tt_t\right)$$

$$\Omega_{11t} = -\left(\frac{2}{\sim}\right)\frac{\pm^{2}_{\pounds_t}}{\left(p_1 / p_{kt}\right)^2}\times\left(a_5 + a_{51,t}\frac{p_{1t}}{p_{kt}} + a_{52,t}\frac{p_{2t}}{p_{kt}} + a_{53,t}\frac{w_{1t}}{p_{kt}} + a_{54,t}\frac{w_{2t}}{p_{kt}}\right.$$

$$\left.+b_{51,t}z_{1t} + b_{52,t}z_{2t} + c_{51,t}\pm^{2}_{\pounds_t}p_{kt} + c_{52,t}\overline{\pounds}_t + c_{53,t}p_{kt} + c_{54,t}tt_t\right)$$

$$\Omega_{22t} = -\left(\frac{2}{\sim}\right)\frac{\pm^{2}_{\pounds_t}}{\left(p_2 / p_{kt}\right)^2}\times\left(a_6 + a_{61,t}\frac{p_{1t}}{p_{kt}} + a_{62,t}\frac{p_{2t}}{p_{kt}} + a_{63,t}\frac{w_{1t}}{p_{kt}} + a_{64,t}\frac{w_{2t}}{p_{kt}}\right.$$

$$\left.+b_{61,t}z_{1t} + b_{62,t}z_{2t} + c_{61,t}\pm^{2}_{\pounds_t}p_{kt} + c_{62,t}\overline{\pounds}_t + c_{63,t}p_{kt} + c_{64,t}tt_t\right)$$

$$\Omega_{12} = -\frac{1}{\sim}\frac{\pm_{\pounds}^{2}}{p_1 p_2 / p_{kt}^{2}} \times \Bigg(a_7 + a_{71,t}\frac{p_{1t}}{p_{kt}} + a_{72,t}\frac{p_{2t}}{p_{kt}} + a_{73,t}\frac{w_{1t}}{p_{kt}} + a_{74,t}\frac{w_{2t}}{p_{kt}}$$

$$+ b_{71,t} z_{1t} + b_{72,t} z_{2t} + c_{71,t} \pm_{\pounds_t}^{2} p_{kt} + c_{72,t} \overline{\pounds}_t + c_{73,t} p_{kt} + c_{74,t} tt_t \Bigg)$$

To achieve stochasticity in the equation, error terms which presumably represent errors in optimization were added to them. The added error terms were assumed to be inter temporarily independent and symmetrically distributed around zero with non-zero contemporaneous co-variances which satisfy the requirement for the Zellner's (1962) Seemingly Unrelated Regression (SUR) model. t is the time indicator in the panel data structure while k is the parameter indicator. In addition, tt is included as an explanatory variable to captures the effects of technological change over time. A system of two regional expected output supply and input demand equations are estimated.

4. Estimation and Discussion

Due to shared parameters, and because production decisions on one crop is likely to be associated with decisions on another crop, contemporaneous correlation among crop supply equation is likely. Zellner (1962) demonstrated that the Seemingly Unrelated Regression (SUR) method can be used to account for this correlation and give more efficient parameter estimates. In order to account for this correlation, the expected crop(s) supply equations in this study were estimated as a system of seemingly unrelated regression (SUR). The price of cowpea as the least important crop was used as numeric. All the estimates were done using STATA statistical software. Lastly, the logged variables enable the interpretation of the regression coefficients as marginal estimates measuring elasticity.

The results show that expected millet supply is decreasing in its own price which negates theoretical expectation, and the coefficient is statistically insignificant.

Table 1: SUR Estimates of Expected Crop Outputs Supply and Inputs Demand Functions in the Sudano-Sahelian Zone of Nigeria

Variable	**Millet**	**Sorghum**	**Fertilizer**	**Seed**
constant	Na	Na	-70.77 (-0.72)	-241.79 (-2.35)**
lnpmi	-0.02 (-0.06)	-0.66 (-1.74)*	0.33 (0.96)	-0.24 (-0.67)
lnpso	0.26 (0.96)	0.38 (1.27)	-0.29 (-.05)	0.88 (3.06)
lpco	0.86 (2.37)**	0.67 (1.84)*	-0.25 (-0.78)	-0.85 (-2.58)**
lnpfe	0.19 (0.43)	0.52 (1.13)	-0.40 (-0.98)	-0.81 (-1.88)*
lnspi	0.13 (1.20)	0.07 (0.58)	-0.07 (-0.62)	-0.01 (-0.07)
lahm	0.94 (14.98)***	1.17 (15.32)***	0.73 (9.23)***	0.37 (4.87)***
lmfem	-0.09 (-1.16)	0.06 (0.07)	0.23 (3.14)***	0.18 (2.26)**
lffem	0.01 (0.52)	-7.80 (-0.31)	-0.02 (-0.93)	0.04 (1.62)
legrap	-2.81 (-0.13)	0.02 (0.46)	0.08 (2.00)**	-0.02 (-0.63)
legrma	0.09 (1.69)*	0.07 (1.24)	-0.05 (-0.84)	0.11 (1.95)*
legrju	-0.07 (-0.77)	-0.13 (-1.34)	-0.02 (-0.21)	-0.11 (-1.24)
legrjl	0.06 (0.66)	0.08 (0.73)	0.17 (1.80)*	0.26 (2.51)**
legrau	0.35 (2.54)**	0.06 (0.37)	0.26 (2.12)**	0.22 (1.55)
legrse	-0.12 (-1.54)	7.10 (0.08)	-0.20 (2.53)**	-0.34 (-4.20)***

Note: ***P<0.01, **P<0.05, P<0.10. Values in bracket are t statistics

Source: Author's estimation

Table 2: SUR Estimates of Expected Crop Outputs Supply and Inputs Demand Functions in the Sudano-Sahelian Zone of Nigeria (cont.)

Variables	**Millet**	**Sorghum**	**Fertilizer**	**Seed**
legroc	-8.50 (-0.13)	0.01 (0.19)	0.03 (0.49)	-0.02 (-0.28)
lnvgrap	-0.12 (-0.62)	-0.03 (-0.25)	-0.02 (-0.85)	6.67 (0.23)
lnvgrma	-0.07 (-1.89)*	-0.05 (-1.19)	0.09 (2.25)**	5.63 (0.14)
lnvgrju	0.02 (0.84)	0.01 (0.48)	-0.03 (0.96)	-2.34 (-0.08)
lnvgrjl	-0.05 (-1.98)**	-0.04 (-1.49)	-0.06 (-2.56)**	-0.01 (-0.47)
lnvgrau	-0.03 (-0.89)	0.05 (1.40)	-0.01 (-0.40)	-0.09 (-2.59)**
lnvgrse	-0.04 (-1.62)	-0.03 (-1.00)	-0.05 (-2.27)**	0.03 (1.02)
lnvgroc	8.00 (0.23)	0.07 (1.84)*	-0.01 (-0.34)	0.02 (0.57)
Year	-0.06 (-1.01)	-0.07 (-1.17)	0.04 (0.75)	0.12 (2.34)**
α	0.01 (0.86)	-9.17 (-0.66)		
R^2	0.79	0.86	0.76	0.72
X^2	441.55***	611.77***	266.25***	226.45***
Breusch-Pagan test	51.06***			

Number of Observations	117	117	117	117

Note: ***P<0.01, **P<0.05, P<0.10. Values in bracket are t statistics

Source: Author's estimation

Cross price effect between millet and sorghum indicates that the expected millet supply is increasing in the price sorghum and statistically insignificant. Although price responsiveness of crops is not the focus of this study, it was expected that cross price effect should be negative, therefore giving an indication of substitutability of these crops in face of climate risk. However, the cross-price effect between millet and cowpea is positive and significant at 5% level. In general, a mismatch between actual and expected rainfall over the cropping season impacts negatively on the expected supply of millet. In particular however, regression estimates show that expected millet supply is increasing in the expected rainfall of May and August, with the coefficients statistically significant at 10% and 5% respectively.

The R-square of measure indicates that 79% of the observed variation in expected millets supply is explained by the variables in the model. Similarly, regression results for the expected supply of sorghum equation shows that sorghum supply is increasing and statistically insignificant in its own price which conforms to expectation based on economic theory. The cross-price effects coefficient with respect to millet is negative indicating that an increase in the price of millet impacts negatively on expected sorghum supply. Given that there is some measure of correlation of correlation between weather and price changes, the negative cross price effect could also indicate substitution effect in response to rainfall risk which is in conformity with expectation. In general, measures of monthly rainfall expectation are statistically insignificant but increasing in the supply of sorghum. Likewise, about 60% of the measures of seasonal rainfall risk impacts negatively on the supply of sorghum but most of the coefficients are statistically insignificant. The R-square measure suggests that 86% of the changes observed changes in expected sorghum supply is explained by the variables in the regression model.

5. Conclusion and Policy Implications

Accurate weather forecasts on the start of the rainy season when sowing is done will impact positively on the supply of these crops. As results also indicate that supply of all the crops considered are decreasing in measures of monthly rainfall risks, agricultural insurance programs will provide a hedge against weather risks that farmers face, therefore enabling farmers to be less risk averse. This will impact positively of the supply of these crops as well as the demand for farm inputs, including the utilization of family labour on family farms. Adaptation measures that involve the adjustment of crop calendars could also be useful in addition to providing farmers with climate related information that could help to ensure rational and time-efficient management of the agricultural calendar. Climate index crop insurance also presents opportunities to manage weather risk caused by variation in climatic conditions in a manner that addresses some short comings of the traditional crop insurance.

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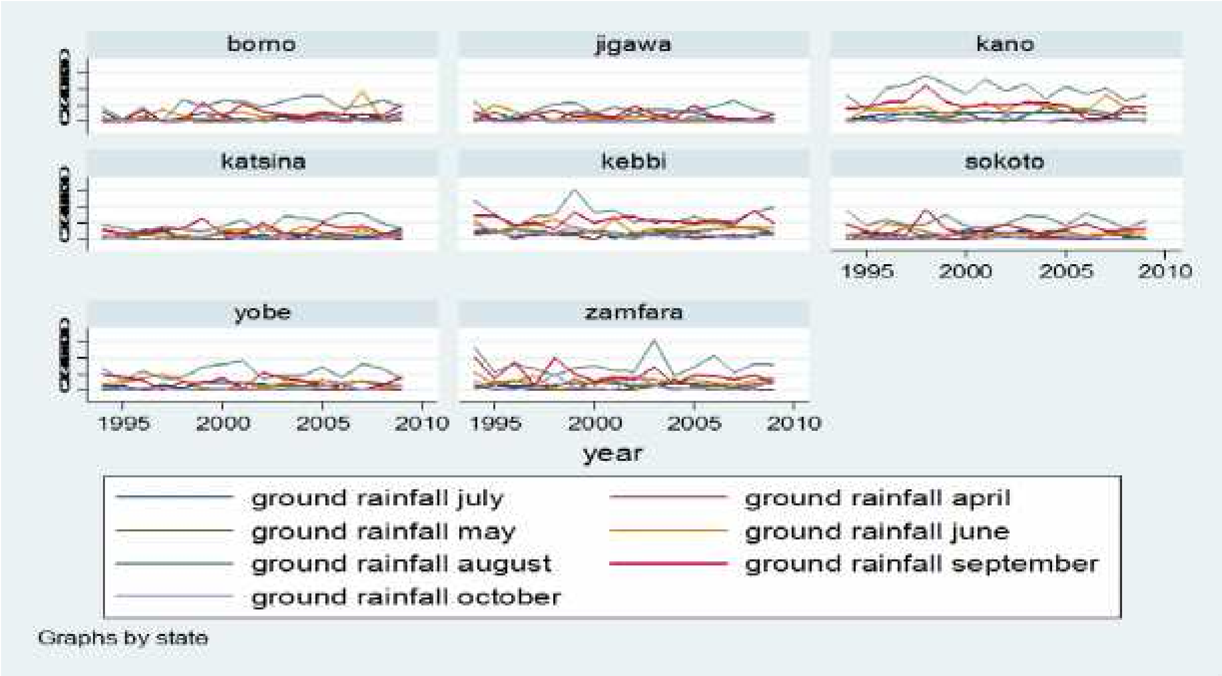
Appendix

Description of Variables and Labels Continued

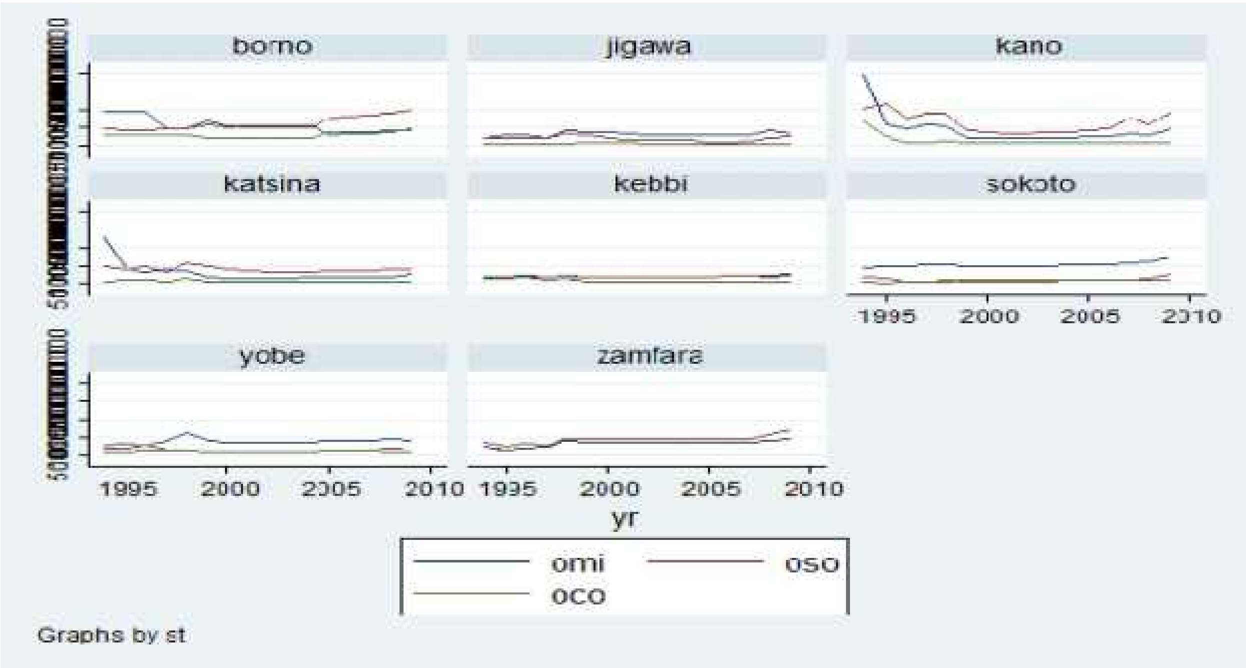
S/N0.	Variables	Measurement	Labels
1	pmi	Naira/kg	farm gate price millet
2	pso	Naira/kg	farm gate price sorghum
3	pco	Naira/kg	farm gate price cowpea
4	pfe	Naira/kg	average cost of fertilizer
5	qfe	Kilograms	quantity fertilizer
6	spi	Naira/kg	seed price index
7	sqi	Kilograms	seed quantity index
8	omi	Kilograms	output millet
9	oso	Kilograms	output sorghum
11	ahm	‘000 Hectares	area harvested millet
12	ahs	‘000 Hectares	area harvested sorghum
14	tfem	‘000 Workers	total family employment
15	mfem	‘000 Workers	male family employment
16	ffem	‘000 Workers	female family employment
24	grap	Millimeters	ground rainfall April
25	grma	Millimeters	ground rainfall May
26	grju	Millimeters	ground rainfall June
27	grjl	Millimeters	ground rainfall July
28	grau	Millimeters	ground rainfall August

29	grse	Millimeters	ground rainfall September
30	groc	Millimeters	ground rainfall October
31	tt		technological change

Trends in Monthly Seasonal Rainfall (NIMET) 1994-2009



Trend in Crop Output Quantity (millet, sorghum and cowpea) 1994-2009



Summary Statistics for pooled TSCS panel data

Variable		Mean	Std. Dev.	Min	Max	Observations
pmi	overall	18.64977	5.715762	6.62	33.67	N =128
	between		1.27865	17.05937	20.37437	n = 8
	within		5.58821	5.425391	31.94539	T=16
pso	overall	17.39789	5.547285	5.76	39.73	N =128
	between		1.540539	15.66813	20.5775	n = 8
	within		5.355317	4.25039	36.55039	T=16
pco	overall	19.62094	5.593341	7.68	29.12	N =128
	between		1.103276	18.555	22.035	n = 8
	within		5.496545	5.395937	29.49219	T=16
pfe	overall	34.48047	20.33977	8	78.75	N = 128
	between		0.960496	34.24625	34.52063	n = 8
	within		20.33779	7.959844	78.98422	T = 16
spi	overall	502.5833	251.0674	99.89	1438.6	N = 128
	between		181.0055	223.0987	783.4231	n = 8
	within		184.7741	-31.03233	1238.548	T = 16
omi	overall	379.0005	226.4111	145.7	1967.13	N = 128
	between		116.1583	202.685	549.585	n = 8
	within		198.4007	129.4155	1908.367	T = 16
oso	overall	336.7488	230.8605	55.05	1153.08	N = 128
	between		205.5531	105.7094	631.3787	n = 8
	within		126.6291	65.37008	858.45	T = 16
ahm	overall	368413.3	231997.2	126700	1747350	N = 128
	between		115238.4	188560.6	557858.1	n = 8
	within		205210.4	139185.2	1731802	T = 16
ahs	overall	321308.4	192024.3	126750	1033490	N = 128
	between		155393.5	158193.1	573016.9	n = 8
	within		124812.8	30851.52	851262.8	T = 16
qfe	overall	3976483	2308965	1455360	2188500	N = 128
	between		1420.216	2100.375	6044462	n = 8

within		1884.817	1216.020	1981702	T = 16
sqi overall	510.0591	303.468	100	2225.9	N = 128
between		188.3996	212.8519	800.7719	n = 8
within		246.5577	105.3472	1935.187	T = 16
tfem overall	713521.9	292656.7	215300	1710000	N = 128
between		294.0192	291.8313	1245.381	n = 8
within		97.0101	477.1406	1178.141	T = 16
mfem overall	456953.1	331053.6	118000	1249000	N = 128
between		349660.1	144875	1107438	n = 8
within		42128.02	284515.6	598515.6	T = 16
ffem overall	256568.8	187963.1	1000	689000	N = 128
between		185850.2	75687.5	626937.5	n = 8
within		69781.04	119625	626625	T = 16
grap overall	12.30313	21.27368	0	114.6	N = 128
between		15.28268	2.16875	48.30625	n = 8
within		15.70335	-33.40313	78.59687	T = 16
grma overall	47.25156	41.08203	0	175.74	N = 128
between		24.65053	18.5375	89.41875	n = 8
within		33.93897	-17.21094	157.4891	T = 16
grju overall	100.8621	67.21369	0	371.6	N = 128
between		39.43674	51.93125	160.8562	n = 8
within		56.09025	-53.49414	386.1434	T = 16
grjl overall	62.92969	36.65785	1	126	N = 128
between		14.61406	49.0625	93.875	n = 8
within		33.99194	-5.945313	137.1172	T = 16
grau overall	246.7705	116.9154	0	625	N = 128
between		77.9385	150.25	150.25	n = 8
within		91.17155	9.583048	9.583048	T = 16
grse overall	142.3105	92.88192	0	441.1	N = 128
between		57.59607	78.9625	233.5187	n = 8
within		75.50863	-22.58945	389.423	T = 16
groc overall	27.51523	36.23253	0	194.2	N = 128
between		19.64035	10.63125	62.45	n = 8
within		31.18674	-34.93477	167.7902	T = 16

tt	overall	8.5	4.627885	1	16	N = 128
	between		0	8.5	8.5	n = 8
	within		4.627885	1	16	T = 16

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