Modeling Efficient Resource Allocation Patterns for Food Crop Farmers in Nigeria: An Application of T- MOTAD Analysis

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Abstract: A single all encompassing objective of profit maximization has been conceived in models suggesting efficient resource allocation patterns for farmers in Nigeria. The results of such studies may be mis-specified if the farmers make production decisions in the face of risk that characterized Nigerian Agriculture. In this study, resource allocation behaviour among the farmers was modeled and efficient patterns were suggested. A two-stage random sampling procedure was used in the collection of primary data in Osun State. Data collected from 165 respondents were analyzed using descriptive statistics and Target Minimization of Total Absolute Deviation (T-MOTAD). Alternative efficient allocation plans suggested were of higher expected returns than the existing farmers' plan in the study area thus satisfying the increase income objective. The profit maximization model was associated with higher risk than the suggested efficient plans. It is concluded that farmers rather possess multiple objectives in their allocation behaviour other than single objective of profit maximization.

Keywords: Resource allocation, T-MOTAD, Food Crop

INTRODUCTION

Expenditure on food in Nigeria accounts for a substantial proportion of total households' expenditure (Amaza and Olayemi, 1999; Yusuf, 2006). Population pressure, especially urban population is a significant factor that exerts pressure on the increased demand for food. The disparity between population growth and increased population in Nigeria was described by NISER (2001); the population increases by 3.2 percent annually while food production increases by 2.5 percent. This therefore necessitates that the production of food crop be increased in order to meet the growing demands.

Food production decisions are made mainly by small scale farmers who represent 95 percent of the total food crop farming units in the country and produce about 90 percent of the total food output (Okuneye and Okuneye, 1988; as cited by Adejobi, 2004). These farmers use two principal resources, land and labour (Dipeolu and Akintola, 1999), others are owned and borrowed capital and purchased inputs; agro-chemical, fertilizer, etc and are often faced with severe price and yield variation (Isik, 2002). Viewing that efficient use of these resources stands paramount; studies have extensively investigated the allocative efficiencies among farmers. While some results have shown that farmers were efficient (Holden and Shifraw, 1997; Amaza and Olayemi, 1999) others showed that they were inefficient (Fafchamps, 1998; Adejobi, 2004). It is the concern of this study that these results may be mis-specified if these small farmers make production decisions in the face of risk that characterised Nigerian agriculture. Apprehension of risk induces certain behaviour into a farmer and this would grossly affect the resource use and allocation and consequently his investment.

The rural poor are risk averse as they are always skeptical of losing the little resources that they have at their disposal and thus specialize on low risk – low return activities (Collier and Gunning, 1999).These farmers are therefore more of risk minimisers contrary to the neo-classical principle of profit maximisation. In essence, the household tends to obey a safety – first principle that assumes the individual's objective is to minimise the probability of experiencing a short fall in income below a certain initial level (Sekar and Ramasamy, 2001). The practical implication is that fewer resources are devoted to risky or perceived risky activities given the fact that a single crop failure can threaten a household's livelihood. In line with this thought, the farmer should rightly be seen as trying to satisfice between goals rather than maximise particular economic magnitudes (Kooten *et al*, 1986). Satificing behaviour refers to a situation under which farmers allocate their available resources among competing production alternatives in such a way as to attain a satisfactory level of overall performance in terms of a defined set of aspiration levels of their pre-specified objectives of production (Aromolaran and Olayemi, 1997).

The concern of this study becomes more important in that most predictions, projections and farm planning for small farmers are carried out without adequate consideration and incorporation of farmers perception of risk and uncertainties inherent in farming. Land area devoted to any crop varies from farmer to farmer depending on expectations and subjective probability attached to each crop success. The degree of risk manifested by individual farmer can thus be derived from the observed behaviour. Thus, for a farmer with given production resources, the way those resources are allocated among enterprises shows his perception of risk inherent in each enterprise (Berbel, 1990). Therefore ignoring production and or output price uncertainty or risk preferences of farmers would lead to misleading estimates of the effectiveness of policies set at improving agricultural development in the country. The objective of the study is therefore to develop a risk- efficient resource allocation pattern for the farmers.

Hypothesis of the Study

There is no significant difference between the observed farm plan in the study area and the risk efficient farm plan

Research Methodology

The study was carried out in Osun State, Nigeria. The State was chosen because of its location in the rainforest region and the availability of food crops farmers. Also, available studies on food crops farmers in the study area were not well focused on risk in farm planning; an attempt to fill this void provides a basis for Osun State as the study area. A two-stage sampling procedure was used in the collection of primary data in Osun State. The first stage involved a random selection of 30 village/farming communities from the three agro-ecological zones of the state's Agricultural Development Programme. The second stage involved a random selection of food crop farmers from each of the villages with probability proportionate to size of each village/farming communities. Data from 165 respondents were used for the analysis. Using structured questionnaires, data used included resources employed and costs, food crop choices, yield and prices. Secondary data were also obtained from Central Bank of Nigeria and Food and Agriculture Organization.

Analytical Framework

Data were analyzed using descriptive statistics and Target Minimization of Total Absolute Deviation (T-MOTAD). The descriptive statistics include Tables, frequency counts and percentages. Summary statistics like mean, standard deviation, and coefficient of variation were also employed. Linear programming is widely recognized as a method for determining a profit maximizing combination of farm enterprises that is feasible with respect to linear fixed farm constraints. The conventional deterministic model ignores uncertainty, however, and may lead to a farm plan that is unacceptable to a farm operator on the basis of previous experience (Hazell, 1971). This thus informs suggestion of allocation plan for farmers while element of uncertainties are adequately taken care of. Alternative risk efficient resource allocation pattern is therefore predictable through the use of Target MOTAD (Minimization of Total Absolute Deviation) model. The model formulation becomes useful because decision makers often wish to maximize expected return but are concerned about net returns falling below a critical target. This approach is in accordance with safety- first principle.

Mathematically, the model, which was modified by Tauer (1983) after Hazell (1971), is stated below:

$$\text{Max } E(Z) = \sum_{j=1}^{n} C_j X_j \quad \text{------------ (1)}$$

Subject to

$$\sum_{j=1}^{m} a_{ij} X_j \leq bi \quad \text{----------- (2)}$$

$$\sum_{j=1}^{n} Crj\, X_j + y_r \geq T \quad \text{------------ (3)}$$

$$\sum_{j=r}^{n} P_r y_r = \uparrow, (\uparrow = M \text{ ----- } 0) \text{ --- (4)} \quad (r = 1 \ldots\ldots s)$$

$$X_j \text{ and } Y_r \geq 0$$

Where E (Z) = Expected return of the plan or solution to the plan in naira

C_j = expected return of activity in Naira, (Mean return from each activity)

X_j = level of activity j

a_{ij} = technical requirement of activity j for resource i

b_i = level of resource i

T = target level of return in Naira (using the daily consumption requirement recommended by FAO)

Crj = return of activity j for state of nature or observation r in Naira

P_r = probability that state of nature or observation r will occur

$\uparrow$ = a constant parameterized from M to 0

m = number of constraints or resource equations

s = number of state of nature or observation

M = Large number (represents the maximum total negative deviation of return of the model)

n= number of activities, or resource, or observation and their levels

y_r = deviation below T for state of nature or observation r.

$$y_r = \sum_{j=1}^{n} (Cr_j - C_j)X_j \qquad ....(5)$$

Equation (1) maximizes expected return of the solution set. Equation (2) fulfils the technical constraints; equation (3) measures the revenue of solution under state r. If that revenue is less than the Target T, the difference is transferred to equation (4) via variable y_r. Equation (5) sums the negative deviation after weighing them by their probability of occurring, P_r.

In order to incorporate risk variable into the model, time series data on input level, yield and price are usually needed for each production activity (Hazell, 1971; Adubi, 1998; Oni, 2000 and Isik, 2002). For the purpose of this study, prices and yield for only three (3) years 2002, 2003, and 2004 were considered due to constraint in the information/data availability. Average prices, costs and yield data for 2002 and 2003 were collected from ADP in the study area while the study relied on farmers' memory for similar data for year 2004. The gross margins estimates for the three-year period for the respective crop production activities were then adjusted to their 2003 price values, using the consumer price index (CPI). The model is superior to other programming models for farm planning under risk because it is computationally efficient and it generates solutions that are not in conflict with second degree stochastic dominance (SSD) (Berbel, 1990). The model is a risk programming technique solved with a linear programme algorithm since it has a linear objective function and linear constraints. The computational procedure involved two steps; a conventional linear programming maximization problem was first formulated and solved. This gave the maximum return since safety first or risk constraints were not included. This represented the highest point on the risk- return efficiency frontier. The safety first element was then formulated in the second step as a matrix of deflated gross margins and the sum of negative deviations from the expected returns for each state of nature. This served as risk measure while a target level of return, T (an average amount required to provide for households' minimum financial needs) was set as risk constraints. As the total absolute deviation (TAD) was parameterized, selection of a set of risk efficient farm plan from the available possible points on the frontier becomes possible through the comparison of the standard deviation, coefficient of variation (measures of associated level of risk) and returns of activities or enterprises and farm plans generated by the programme.

The standard deviation (SD) was derived thus:

$$SD = D\,[\pi s / 2\,(s-1)]^{1/2} \qquad ----------- (6)$$

Where D = Mean negative deviation

s = number of observations or states of nature

π = 22/7

(Hazell, 1971)

The programming technique was based on the following assumed objectives of the farmers:

i. to provide adequate food in order to ensure at least minimum household food requirement,

ii. to earn adequate monetary income so as to meet minimum household financial needs,

iii. to maximize the return to the allocated resources

RESULTS AND DISCUSSIONS

Efficient Farm Plans and Models Comparison

The farmers' existing plan in the study area, risk minimized or efficient farm plans and the profit maximization farm plan are shown in Table 1. Plan I represents the farmers' existing plan, Plans II and III represent the modeled risk minimized or efficient farm plans while plan IV represents the profit maximization plan. The profit maximization plan IV has the highest return of N98, 861.24 and allowed the cultivation of only Maize/ yam and maize/vegetable enterprise combinations. However, this plan is associated with maximum variability of 33.06 percent in Table 2 and it is likely to be selected by a risk neutral or risk indifferent farmer.

Table 1. Cropped Area Distribution (Ha) Among Enterprises for the Various Farm Plans

	Farmers' Plan	Risk Minimized Farm Plans		Profit Maximization Plan
	I	II	III	IV
Returns in Naira per/ha	31,959.81	36,776.05	54,919.73	98,861.24
Maize	0.048 (2.21)			
Cassava	0.133 (6.20)			
Sorghum	0.04 (1.87)	0.018 (0.84)	0.15 (7.00)	
Yam	0.168 (7.80)	0.52 (24.18)		
Cowpea	0.005 (0.26)			
Maize/ Cassava	0.774 (35.90)	1.00 (46.51)	1.67 (77.70)	
Maize/ Yam	0.107 (5.00)	0.20 (9.30)	0.18 (8.40)	0.83 (38.60)
Yam/ Vegetable	0.011 (0.52)			
Maize/ Vegetable	0.131 (6.09)	0.26 (12.09)	0.09 (4.20)	1.32 (61.40)
Cassava/ vegetable	0.134 (6.24)			
Maize/Cassava/yam	0.318 (14.77)			
Cowpea/cocoyam	0.154 (7.14)		0.06 (2.80)	
Maize/cowpea/cocoyam	0.130 (6.02)	0.15 (7.00)		
Total Cropped Area	2.15 (100)	2.15 (100)	2.15 (100)	2.15 (100)
Percentage sole Cropping	18.34	25.02	7.00	0.00
Percentage Cropped Mixtures	81.68	74.90	93.00	100.00

Source: Computed from Linear Programming Results and T-MOTAD Model

Figures in Parentheses are the percentage cropped area

A return of N31, 959.81 per hectare was the actual level of the farmers' income as shown in the farmers' plan I (Table 1), while the return was N98, 861.24 when the farmers were assumed to possess only profit maximization objective. This shows that there is a pronounced difference between the farmers observed farm plan and profit maximization plan. The result is similar to the report of Osuji, (1978) and Adubi (1998); however, Osuji (1978) attributed this discrepancy in the optimal and actual farm income to the fact that linear programming model aims at profit maximization alone whereas traditional farmers have additional objectives such as the maintenance of a minimum level of family self –sufficiency in food supply asides maximum farm income or gross margin. Given preference to these objectives; a set of feasible risk efficient farm plans were generated as Total absolute deviation (TAD) was parameterized. These are plans (II and III) which cover a wide range of available choices for the farmer on the basis of enterprise combinations and resource allocation.

In the risk minimized farm plans II and III, more enterprises entered the plans unlike plan IV, six of the 13 enterprises entered plan II while five of the 13 enterprises were allowed in plan III. Thus, the critical objective of household food security is achieved. Since the farmer and his household also consumed parts of what is produced, the programming was therefore constrained so as to satisfy the household minimum food requirements. The enterprises are as shown in Table 1. From the Table, the average farmer should allocate his resources in such a way that the six enterprises in Plan II are produced according to their hectrage allocations. The recommended allocation pattern depicts the most important enterprises as maize/cassava (1.00ha), yam (0.52ha), maize/vegetable (0.26ha), maize/yam (0.20ha), maize/cowpea/cocoyam (0.15ha), and sorghum (0.018ha). In plan III, the recommended allocation pattern is maize/cassava (1.67ha), maize/yam (0.18ha), sorghum (0.15ha), maize/vegetable (0.09ha), and cowpea/cocoyam (0.06). It could be observed that maize/cassava enterprise had the highest land allocation in the two risk minimized plans II and III (46.51percent and 77.70percent respectively). While sorghum had the least land allocation (0.84percent) in plan II, cowpea/cocoyam was the least (0.06) in plan III. In all the plans percentage crop mixtures were above 70 percent implying a mitigation strategy towards reducing the possible risk among the enterprises.

Trade-Off between Expected Return and Risk

The result shows that the returns in the risk minimized plans II and III (N36, 776.05 and N54, 919.73 respectively) were higher than the return in existing situation in plan I (Table 2); thus satisfying the increased income or limited out of pocket cash expenses objective. The risk (measured by coefficient of variation) and return levels of the four farm plans are as shown in Table 2. The trade-off between the expected income and the variance of income determines the suitability of any of these plans. The average farmer would be operating at a high-risk level of 33.06 percent if he adopts the profit maximization plan IV. The risk level would also be 26.53 percent if he maintains the existing plan I. However, these high risks levels can be averted if the average farmer shifts to enterprise mixes with less variability in returns to farm resources. These are plans II and III with minimized risk of 18.20 percent and 6.12 percent respectively.

Table 2. Risk and Return levels of Different Farm Plans

	Farmers' Plan	Risk Minimized Plans		Profit Maximization Plan
	I	II	III	IV
Expected Returns to the allocated Resources/ha	31,959.81	36,776.05	54,919.73	98,861.24
Minimized standard Deviation of Returns	8478.34	6695.78	3358.70	32688
Coefficient of Variation of Returns (%)	26.53	18.20	6.12	33.06

Source: Computed from Linear Programming Results and T-MOTAD Model

Test of Hypothesis Using the t –Test Statistics

The t-test was employed to test the significant differences in the expected returns to the allocated resources between the farmers' plan I and the other plans II, III and IV. The mathematical notation of the t statistics is given below following Sirkin (1995):

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\frac{S_1}{n_1^{(1/2)}} + \frac{S_2}{n_2^{(1/2)}}}$$

Where X_i = mean or expected return to the allocated resources

S_i = Standard Deviation

n_i = number of observation

Table 3 shows that the t- value was 1.15 for plan I and Plan II and was not significant while the t-value was 7.01 for plan I and plan III and was significant at $P < 0.01$. This shows that there exists no significant difference in the returns of plans I and II but a significant difference exists in the returns of plans I and III. However, the t-value was 5.87 for plans I and IV at a significant level of $P < 0.01$ implying a significant difference in the returns of plans I and IV. The interpretation of the result is that the allocation behaviour of the farmers in the study area was not really targeted at profit maximization only but to also minimize the probability risk occurrence. This is because the returns in the farmers' plan I had no significance difference with that of risk minimized plan II. Though a significant difference was observed between the returns of plan I and risk minimized plan III, it could still be observed on aggregate that the distribution of returns among the four plans shows that the return in plan I is closer to those of plans II and III than that of plan IV. The necessary deduction from the result is that the current allocation of the resources among the farmers is towards being risk efficient and farther from pursuing the profit maximization objective alone; hence the null hypothesis is accepted. This is in line with the study of Aromolaran and Olayemi (1997). In their study, the farmers were found to behave more like goals satisficers than single magnitude maximizers (profit maximization) in the process of making their resource allocation and production decisions.

Resource Use Patterns Across Models

The resource use status across the plans is presented in Table 4. A striking feature in the result is that land and cash on material inputs (fertilizers, agrochemicals, seeds and cuttings etc) were fully utilized in all the plans implying additional returns to the farmers (as given by the shadow prices) as more units of these resources are utilized. It would also be observed that on a general note that the labour resource was not fully utilized in the plans. This implies an excessive use of family and hired labour (as shown by the slack variables).This invariably would have increased the production cost. Though it has been shown that labour resource is a major resource in crop production (Dipeolu and Akintola, 1999), however; this cost could be reduced using agrochemical options for operations like weeding and an increased yield through fertilizer options as suggested in the plans.

Table 3. t- Test Results

Different Farm Plans	**t-value**
Farmers' Plan I & Risk Efficient Plan II	1.15
Farmers' Plan I & Risk Efficient Plan III	7.01*
Farmers' Plan I & Profit Maximization Plan IV	5.87*

Source: Field Survey; 2005
*: indicates significant at P < 0.01

CONCLUSIONS, POLICY IMPLICATIONS AND RECOMMENDATIONS

The alternative resource allocation plans modeled for the farmers in the study area using T-MOTAD allowed more enterprises combination for production than the profit maximization plan. These plans also allowed the farmers to operate at a relatively reduced risk. The resource allocation behaviour of the farmers in the study area was closer to the modeled risk efficient plans than the profit maximization plan. Hence, the resource use and allocation pattern of food crop farmers is in consonance with the behavioural theory of a firm rather than the neo-classical principle of the economists. The results of the study indicated that in spite of prevailing risk sources; the food crop farmers have the potential to increase their crop yields and gross margin. This implies an important policy implication for strategies towards increased food production in the country. The sustainability of the farmers in this respect lies in resource availability. Farm management research and smallholder development programmes initiations through extension education on efficient allocation of resources by the government should be built.

Table 4. Resource Use Patterns Across Models

Resource	Plan1
Land (hectare)	2.15
Family Labour 1[1]	102
Hired Labour 1[1]	148
Family Labour 2[2]	102
Hired Labour	148
Cash on Material (N)	32,690.95
Borrowed Capital (N)	25,988.75

Plan II

Resource Use Status	Slack	Shadow Price
Fully utilized	-	10039.68
Not Fully utilized	12.30	-
Not Fully utilized	6.50	-
Not Fully utilized	21.22	-
Not Fully utilized	30.53	-
Fully utilized	-	19.0
Not Fully utilized	8,618.09	-

Plan III Resource Use Status	Slack	Shadow Price
Fully utilized	-	1866.8
Fully utilized	-	44.6
Not Fully utilized	8.00	-
Not Fully utilized	11.8	-
Not Fully utilized	43.9	-
Fully utilized	-	19.0
Not Fully utilized	4,459.89	-

Plan IV Resource Use Status	Slack	Shadow Price
Fully utilized	-	2839.72
Not Fully utilized	11.39	-
Not Fully utilized	22.24	-
Fully utilized	-	44.60
Not Fully utilized	35.90	-
Fully utilized	-	3.40
Not Fully utilized	10223.6	-

Source: Field Survey, 2005
[1] Labour required in wet season (mandays)
[2] Labour required in dry season (mandays)

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