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## **A Risk Responsive Acreage Response Function for Millet in Niger**

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### **Abstract**

*Adesina, A.A. and Brorsen, B.W., 1987. A risk responsive acreage response function for millet in Niger. Agric. Econ., 1: 229–239.*

*In this paper the impact of price risk on millet production in Niger is investigated. The hypothesis that farmers respond to output price risk is tested. The results indicate that millet acreage planted decreased when millet price risk increased or when price risk of the competing crop decreased and therefore farmers do respond to changes in risk.*

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### **Introduction**

The role of risk and uncertainty in agricultural production has received attention in empirical studies in recent years. The neoclassical theory of modelling farmers' production behavior within the profit maximization framework has been well tested and accepted in the literature (Welsch, 1965; Chen-nareddy, 1967; Sahota, 1968; Wise and Yotopoulos, 1969). However, the neoclassical framework has been criticized for not considering risk (Officer and Halter, 1968; Dillon and Anderson, 1971; Lin et al., 1974; Wolgin, 1975; Moscardi and DeJanvry, 1977).

Supporting earlier work of Porter (1959), Dillon and Anderson (1971) argue that farmers in traditional agriculture (and indeed everywhere) have non-linear utility functions, implying risk is important. Wolgin (1975) argues that farmers in Kenya are risk averse. Other research has demonstrated that due to risk aversion, increases in income or price variability tend to decrease aggregate supply (Just, 1974; Lin, 1977; Hurt and Garcia, 1982) and increase marketing margins (Brorsen et al., 1985, 1987). Sandmo (1971) and Iishii (1977)

have also demonstrated theoretically that increases in price uncertainty lead to a decline in the optimal output of a competitive firm.

Most of these studies on the impact of risk in agricultural production have not analyzed production decisions in developing countries, except a few (e.g. Behrman, 1968 (Thailand); Wolgin, 1975 (Kenya); Moscardi and DeJanvry, 1977 (Mexico); Narayana and Shah, 1984 (Kenya). Also, very few studies have considered risk for a multiproduct firm. The majority of supply response studies in traditional agriculture have used non-risk models (e.g. Welsch, 1965; Oni, 1969a,b, 1984; Adesimi, 1970; Maina, 1982; Bond, 1983). The understanding of the effects of farmers' attitudes toward risk on production decisions is important for formulation of more effective development policies in many developing countries. Agricultural technology development programs from agricultural experiment stations are more likely to be successful if farmers risk preferences are understood and incorporated. Also, if price risk is important in acreage decisions, the use of domestic commodity programs to stabilize prices and farm incomes may be beneficial.

Niger experiences substantial output price variabilities and thus risk is likely to be important to producers in Niger. Maina (1982) estimated an econometric model of production responses using official market prices and concluded that Niger farmers do not respond to official market prices. The government of Niger sets uniform nation-wide grain prices, which are usually much lower than corresponding prices on the open market. The bulk of grain marketing is carried out on the open market (Cullen and Waldstein, 1983; Adesina, 1985), and open market prices have been shown to be more important than official prices in driving production decisions (Adesina and Brorsen, 1986). No acreage response study on Niger has considered the impact of price risk (e.g. Becker, 1974; Maina, 1982; Adesina, 1985; Adesina and Brorsen, 1986). Becker (1974) used weather indexes to measure yield risk, but no consideration was given to the role of prices in the study. The specific objective of this study is to determine the effect of price risk on millet acreage in Niger. The hypothesis tested is that millet acreage will decrease when output price risk increases. Policy makers in Niger need information on farmers risk responsiveness to evaluate benefits of price stabilization schemes as well as in evaluating farmers' adoption of new technology.

The rest of this paper is divided into three sections. The first contains the theoretical framework used in deriving the demand equation for millet land under output price uncertainty. The next section gives the results and a discussion of the empirical model, and in the last section a summary of the study and policy implications of the findings are presented.

### **Theoretical model**

This section presents a theoretical model of the farmer's acreage demand decisions. Although farm production has been viewed as a multi-product pro-

duction decision (Just et al., 1983), these models have not included risk. In this section, an original theoretical formulation of production decision under uncertainty using a multi-product approach is presented. A millet acreage demand function is derived under output price uncertainty. This function is then used in the empirical section to specify the empirical model.

Millet is the major crop in Niger, accounting for 60% of the cultivated area in 1976–1983. The other crops — sorghum, cowpeas, and peanuts — represent a smaller portion of total production. Sorghum and cowpea acreage constitute 17% and 22% of the total acreage cultivated in 1976–1983. Peanuts have become a minor crop in production, representing less than 1% of the total crop area in the same period (Ministry of Rural Development, 1976–1983). Only the millet acreage demand is considered in this study, since it is the major cultivated crop. None of these crops are economically complementary in production. They are assumed to compete for land based on market prices (millet competes more directly with cowpea, since sorghum and peanuts are usually grown on land of higher quality). As it is an arid crop, millet is produced on the dryland area, the very little irrigated areas in Niger being used mainly for rice cultivation. In 1980, the total contribution of dryland production systems to total crop production was 84% (Enger, 1980).

Let  $Y_j, j=1, 2, \dots, N$  represent the output of the crops produced on the farm.

$X_{jk}, k=1, \dots, K$  represent the quantity of input  $k$  used in production of crop  $j$ .

Let  $\bar{X}_1$  be the fixed quantity of land available for production. This assumption of fixed land amount is appropriate for Niger, where most land is too sandy and thus the amount of cultivatable land is limited.

The production technology on the farm can be represented as

$$Y(X) = [X, Y: F(X) \geq Y; X_1 = \bar{X}_1] \quad (1)$$

where  $Y(X)$  represents the restricted production possibility set with fixed amount of land input available for production;  $X$  and  $Y$  are the input and output vectors respectively. Following Just et al. (1983, p. 772), inputs are assumed allocable among production activities and production is assumed to be non-joint (i.e. unique output determination). Also there exists resource constraints (i.e. fixed land input). The production technology derivable from eqn. (1) can be written as

$$\begin{aligned} Y_j &= F_j(X_{1j}, \dots, X_{Kj}) \quad j=1, \dots, N \\ X_k &= \sum_{j=1}^N X_{kj} \quad k=1, \dots, K \\ X_1 &= \bar{X}_1 \end{aligned} \quad (2)$$

Equation (2) is the multi-equation representation of non-joint production with

allocable factors. Outputs are linked only through allocable resource constraints and the allocable factor is explicitly distributed to output  $j$ . The derived production function in eqn. (2) will display decreasing returns to scale, since the amount of land input is fixed (Varian, 1982, p. 20).

Dillon and Anderson (1971) have argued that traditional farmers maximize the expected utility of profit. Following Sandmo (1971) and Iishii (1977), let the farmer maximize expected utility of profit ( $EU(\Pi)$ ), where  $\Pi$  is profit and  $E$  is the expectation operator. Further, assume that the farmer's utility function is a Von-Neumann Morgenstern utility function (concave, continuous and differentiable function of profits), so that  $U'(\Pi) > 0$  and  $U''(\Pi) < 0$ . The absolute risk aversion index  $R_A(\Pi) = -U''(\Pi)/U'(\Pi)$  is assumed a decreasing function of profit, implying that  $\partial R_A(\Pi)/\partial \Pi < 0$ . The output prices are assumed to be stochastic. This assumption is a simplification, since output is also variable. An alternative is to consider revenue as a random variable (see Winter and Whittaker, 1979). The problem with this assumption is in the empirical applications. First, there is the problem of aggregation. National yield is certainly less variable than yield for individual producers. Thus it is impossible to measure yield risk appropriately with aggregate data. Secondly, the variability of yield depends on the variability of weather. Weather innovations are likely to be independent and thus producers' perceptions of yield variability may remain unchanged over time. For an individual producer the correlation between yield and prices is likely to be quite low. Since perceptions of yield variability may change little over time, and the correlation between prices and yields for an individual producer can be assumed zero, concentrating on price uncertainty seems appropriate. This argument is supported by empirical work. Winter and Whittaker (1979) and Brorsen et al. (1985b) considered income risk and found their measure of risk was relatively unimportant in acreage decisions, but Hurt and Garcia (1982) considered price risk and found their measure of risk was important in their study of sow farrowings. The data used in this paper also support this argument, since income variability is not significant, but price variability is. Let  $P_j$  (the output price for crop  $j$ ,  $j=1, \dots, N$ ) be a random variable with subjective probability density function  $f(P_j)$  reflecting farmer's price expectations (Sandmo, 1971).

The farmer's decision can then be written as

$$\text{Max } EU(\Pi) = EU \left( \sum_{j=1}^N P_j Y_j - \sum_{k=2}^K W_k X_k \right) \quad (3)$$

subject to eqn. (2), where  $\sum_{j=1}^N P_j Y_j$  represents the total revenue from the  $N$  crops produced on the farm and  $\sum_{k=2}^K W_k X_k$  represents the total variable cost of production. Maximization of eqn. (3) under appropriate regularity conditions

yields the conditional optimal risk responsive output and input demand functions:

$$X_{kj} = F_{kj}(P_1^*, \dots, P_N^*, W_2, \dots, W_K; \Omega, \bar{X}_1) \quad j=1, \dots, N; k=2, \dots, K \quad (4)$$

$$Y_j^* = F_j(P_1^*, \dots, P_N^*, W_2, \dots, W_K; \Omega, \bar{X}_1) \quad j=1, \dots, N \quad (5)$$

where  $P_j^*$  are the expected output price of crop  $j$  (i.e.,  $P_j^* = E(P_j)$ );  $\Omega$  is the second-order and possibly higher moments of the subjective multivariate probability distribution of the output prices and measures output price uncertainty (risk).  $\Omega$  is assumed to be a multiplicative mean preserving spread of output price distribution satisfying:

$$P = P^* + \Omega e, \quad e \sim N(0, I) \quad (6)$$

where  $I$  is an identity matrix and  $P$  is the vector of output prices. Equation (4) is the risk responsive input demand function and is the theoretical framework for specification of millet acreage demand under price risk; eqns. (4) and (5) are short-run partial equilibrium risk responsive choice functions.

Sandmo (1971) and Iishi (1977) have demonstrated that under decreasing absolute risk aversion, the expected sign for the effects of risk in eqns. (4) and (5) can be obtained for a single product firm ( $N=1$ ). The comparative statics results for a multiproduct firm for a change in an element of  $\Omega$  are in general ambiguous. Only under quite restrictive conditions can expected signs be obtained. In the special case considered in the empirical section when  $N=2$ , the covariance is zero, and producers follow Freund's risk averse expected utility function (Freund, 1956), expectations about the effects of risk can be obtained. This gives the intuitively appealing result that millet acreage increases when millet price risk decreases or cowpea price risk increases, which agrees with the empirical findings. Thus, the effects of risk for a multiproduct firm are best determined empirically. In the next section the empirical procedure used to determine the effects of output price risk on millet acreage is explained.

## Data and empirical model

Sorghum and peanut prices and risks are not included in the empirical model. Sorghum is grown mainly as a subsistence crop and the marketed volume is small (Adesina, 1985). Therefore variation in sorghum prices can be expected not to affect millet acreage demand. Peanuts are an insignificant part of production in Niger. In all agricultural zones in Niger, the average peanut crop area was 0.31 ha (Adesina, 1985). Therefore, only cowpeas need to be considered as a substitute for millet. The total available cultivatable land area used for millet and cowpea production is assumed fixed over time, and hence  $\bar{X}_1$  need not appear in the empirical model. Millet production in Niger is done with family labor, with little or no use of hired labor. Therefore the wage rate does not enter the empirical model and the only purchased input is fertilizer.

How to measure risk is a difficult question. A 3-year moving average standard deviation of prices has been used by Behrman (1968). Just (1974) and Traill (1978) define risk as a deviation from an expected output (i.e. price). In this case the producer is assumed to form an expected price with some subjective probability distribution around the expectation. The expected price and the price risk variable can be estimated using distributed lags (Traill, 1978; Hurt and Garcia, 1982). Other researchers have assumed naive expectations and thus the expected price is the last period's price (Lin, 1977; Brorsen et al., 1987).

Price risk is defined here as a weighted moving average of squared deviations of expected price and actual price, and the deviations used are percentage deviations. Expected prices are assumed to be last period's price. Risk perceptions are assumed to be based on price variability from the last 3 years.

Thus the measure of price risk in supply is given as

$$R_{it} = \left[ \sum_{j=1}^3 \alpha_j \left( \frac{P_{it-j} - P_{it-j-1}}{P_{it-j-1}} \right)^2 \right]^{1/2}; i=1,2 \quad (7)$$

where  $R_{it}$  is the price risk for crop  $i$  at time  $t$  and  $\alpha_j$  are the weighting factors.

Assuming naive expectations, the risk responsive millet acreage demand, eqn. (4), is written as

$$\begin{aligned} AM_t = & B_0 + B_1 MP_{t-1} + B_2 CP_{t-1} \\ & + B_{11} \left[ \sum_{k=1}^3 \theta_k \left( \frac{MP_{t-k} - MP_{t-k-1}}{MP_{t-k-1}} \right)^2 \right]^{1/2} \\ & + B_{12} \left[ \sum_{m=1}^3 \psi_m \left( \frac{CP_{t-1} - CP_{t-m-1}}{CP_{t-m-1}} \right)^2 \right]^{1/2} \\ & + B_{13} \left[ \sum_{j=1}^3 \rho_j \left( \frac{CP_{t-j} - CP_{t-j-1}}{CP_{t-j-1}} \right) \left( \frac{MP_{t-j} - MP_{t-j-1}}{MP_{t-j-1}} \right) \right] \\ & + B_3 FP_t + e_t \end{aligned} \quad (8)$$

where:  $AM$ =millet acreage (in thousand ha) at time  $t$ ;  $MP$ =millet price (CFA/kg);  $CP$ =cowpea price (CFA/kg);  $MR$ =millet price risk;  $CR$ =cowpea price risk;  $FP_t$ =fertilizer price (CFA/kg) at time  $t$ .

The coefficients  $\theta_k$ ,  $\psi_m$ , and  $\rho_i$  are the weighting coefficients for the millet price risk, cowpea price risk, and cross-product price risk in the respective periods;  $B_{ij}$  are the coefficients on the price risk variables; and  $e_t$  is the error term. Researchers often assume equal or declining weights on the prices (Brorsen et al., 1985, 1987). Brorsen et al. (1987) used weights ( $\theta_k, \psi_m, \rho_i (k, m, i=1, 3)$ ) of 0.6, 0.3, and 0.1, while Nieuwoudt et al. (1985) used similar weights of 0.5, 0.33,

TABLE 1

Estimated non-risk and risk-responsive millet acreage response equations<sup>a</sup>

Independent variable	Non-risk model <sup>b</sup>	Price-risk <sup>b</sup>
Intercept	2885.32 (3.17)**	230.336 (0.36)
Lagged millet price	2562.81 (1.88)*	5988.507 (8.94)**
Lagged cowpea price	-1188.68 (-2.34)*	-1468.899 (-7.82)**
Millet risk	—	-3881.225 (-7.21)**
Cowpea risk	—	2886.661 (3.17)**
Fertilizer price	-3749.416 (-1.51)	2373.47 (1.74)
$R^2$	0.81	0.98

<sup>a</sup>The results were corrected for autocorrelation.<sup>b</sup>The figures in parentheses are *t*-values; \*, significant at the 5% level; \*\*, significant at 1% level.

and 0.17 based on a Fisher lag. The weights used here are the weights used by Brorsen et al. (1987). No other weights were considered to avoid any biases from pretesting. In accordance with Hurt and Garcia (1982), the covariance term is assumed equal to zero.

The data used in the estimation are for 1963–1983. Open market prices are used rather than official market prices for all prices except fertilizer, since only official fertilizer prices are available. Thus, the fertilizer price data may not be as relevant as the other price data. Output prices are yearly averages, measured at the national central market in Niamey. Regular and reliable Niamey prices are collected in Niger. Prices in the other minor markets derive from Niamey base prices, and there is high correlation between Niamey market prices and prices in other minor markets (JPAR, 1983). Crop area (1000 ha) and price data (CFA/kg) are taken from Borsdorf (1979), Joint Programme Assessment Report (JPAR, 1983) and various issues of the yearly statistical report (Ministry of Rural Development, 1976–1983). The retail price index used in deflating prices is taken from World Bank Tables (1984).

## Model results

The empirical model results are presented in Table 1. Based on correctness of coefficient signs, statistical significance of explanatory variables and explanatory power ( $R^2$ ), the risk model outperforms the non-risk model. In both the non-risk and risk models, lagged millet and cowpea prices have the



TABLE 2

Estimated mean response millet acreage elasticities, 1963–1983

Millet acreage	Millet price	Cowpea price	Millet risk	Cowpea risk
Risk model	0.98	–0.32	–0.32	0.31
Non-risk model	0.42	–0.26	—	—

expected coefficient signs and are significant at the 5% and 1% probability levels, respectively. The negative coefficient sign on the cowpea price implies that cowpeas and millet are competing crops in production, reflecting actual production patterns in Niger. The farmer shifts more crop land into millet production as the relative price of cowpeas decline. Such crop substitutability has been advanced to explain the declining peanut acreages in Niger (Borsdorf, 1979; Adesina, 1985). Cowpeas are the major competing crop for millet in production. As pointed out by Borsdorff (1979), farmers tend to devote increasingly more land to cowpeas because it can be used as a food crop, as well as for cash purposes, so as to protect themselves from another severe food shortage. The positive sign on the millet price implies that an increase in the millet price (expected price) leads to an increase in land used for millet production.

The coefficients on the price risk variables are statistically significant at the 1% probability level and have intuitively appealing signs. The negative sign on millet price risk shows that, as millet output price risk increases, farmers divert acreage away from millet production. The coefficient sign on cowpea price risk implies that increasing cowpea price risk leads to an increase in the demand for millet land. Hence, output price risk is an important decision variable in millet production. The results suggest that farmers' risk perceptions are appropriately measured in terms of output price variability and that farmers are risk responsive (presumably risk averse). The fertilizer price is not significant in either model. The fertilizer price data are official prices and thus may not represent the price paid in the open market. Also, the use of mineral fertilizer is a recent agronomic practice in Niger.

The computed acreage elasticities are presented in Table 2. The omission of price risk biases the estimates of the own-price elasticities. In the risk model, the millet own-price elasticity is 0.98, compared to 0.42 in the non-risk model. Also the cross-price elasticity with respect to cowpea is –0.32 in the risk model compared to –0.26 in the non-risk model. Millet production response to price changes, although inelastic, is masked by omission of price risk variables, a result similar to that found by Hurt and Garcia (1982). The price risk elasticity for millet is 0.32, while the price risk elasticity for cowpeas is 0.31.

Farmers respond to price risk. Hence both consumers and producers might

benefit from more stable prices. Domestic policy instruments that can be used to stabilize grain prices include price supports and buffer stock policies. The government of Niger might consider a price support program that requires the official marketing agencies to purchase substantial volumes of grains whenever open market prices fall below official market prices. The OPVN and SONARA, the official marketing agencies for millet and cowpeas, respectively, would have to be given the financial leverage needed to effectively perform this function, as procurement by these commodity boards has been low. The operation of a buffer stock policy can be used to stabilize prices and farm incomes during production shortfalls, but the benefits from this type of program would have to be weighed against its high cost before making a decision about whether to adopt such a program.

## Summary and conclusions

This study investigated the role of risk in millet production in Niger. Most applied risk studies have focussed on developed agriculture and most supply response studies in developing countries have been non-risk models. Most earlier risk analyses have not considered a multi-product approach to risk. This study presents the relevance of risk in production in a developing agriculture, i.e. Niger, using a multi-product framework. The results showed that Niger millet farmers are risk responsive. Output price risk is important in empirical modelling of acreage decisions of millet producers and can greatly influence the magnitude of estimated output price elasticities. The study presents evidence that farmers in traditional agriculture maximize expected utility of profit rather than profit maximization (non-risk model) and respond to risk.

The results are relevant for price-stabilization and technological development in Niger. While new technological development is important to increasing crop yields, price uncertainties and risk aversion may present constraints on technology adoption. To stimulate increased millet production, market price uncertainties could be reduced with price supports or buffer stock programs. The strengthening of the financial capacity of existing official commodity agencies to perform these programs could reduce price variabilities. The successful operation of such programs would also provide producers with a stable price structure, on which rational production decisions could be made. Stability in farm incomes provided through such programs may stimulate adoption of new agricultural technologies and expansion of millet production. The benefits from reducing risk would have to be weighted against the substantial costs of stabilizing prices in order to determine if a price stabilization program would be desirable. However, the results of this paper certainly suggest that risk should be considered in designing and implementing agricultural policies in Niger.

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