STOCHASTIC TECHNOLOGY IN A PROGRAMMING FRAMEWORK: A GENERALISED MEAN-VARIANCE FARM MODEL

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Production uncertainty is important in studying behaviour of risk-averse firms and developing successful agricultural policies. A model that extends the standard Mean-Variance (E-V) method to incorporate stochastic technology in a proscriptive programming framework is developed, and risk effects of factor inputs are measured for the irrigated multi-crop farming system in the Sudan. Hired labour is found to be risk increasing in cotton and sorghum but risk reducing in groundnuts. Operator labour is found to be risk reducing in cotton and sorghum but risk increasing in groundnuts. Supply responses are derived from a nonlinear programming model of agricultural producer decisions and it is found that supply responses are more elastic when labour choices are allowed to influence production risks.

Introduction

Uncertain decision environments have several implications on the behaviour of the competitive firm and associated policy issues. Random prices (market risks) and stochastic production processes are commonly identified as the main sources of producer uncertainty. The economics literature has devoted much space to studying the impact of market risks on output supply and factor demands (Sandmo, 1971; Batra and Ullah, 1974; Traill, 1978), and various policies and institutions have been developed in the face of market risks, e.g., insurance, hedging, future contracts etc.

Less attention has been given to production uncertainty in spite of its behavioural and policy implications (Just and Pope, 1979; Pope and Kramer, 1979). Although market risks are essentially exogenous, producers can affect yield variability and the distribution of returns by the choice of inputs in a given enterprise and by the combination of enterprises undertaken. There is empirical evidence, particularly in agriculture, that moments higher than the mean (variance and skewness) of the distribution of output are functions of input levels and thereby can be changed by producer choices (Fuller, 1965; Griffiths and Anderson, 1982; Antle, 1983). Consequently, instruments and production strategies used for risk management in agriculture such as fertilisation, crop rotations, pest control, etc., often have stochastic effects on farm output. Although diversification of enterprises may reduce market risks, its impact on individual crop-yield variability could be unfavourable.

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Moreover, most of the policies and innovations prescribed for developing countries to enhance productivity and promote agricultural development, such as the green-revolution packages of high-yielding varieties, fertilisation and mechanisation, were based on their favourable yield effects, whereas their risk effects were not often considered. If farmers respond to risk, then the rate of adoption and diffusion of such farming methods and technologies is dependent on their risk effects as well as their yield effects. It is therefore essential for better understanding of producers' behaviour and making of sound and successful agricultural policies to adequately investigate and quantify the relationship between factors of production and the upper moments of the distribution of crop yields.

The Mean-Variance (E-V) model is commonly used as a conditionally normative tool to study the behaviour of farm firms under uncertainty. Whereas the E-V method accounts for the variance of the firm's portfolio of enterprises, the individual variances of the production activities in the mix are assumed to be constants (Freund, 1956). Though the second moment of the distribution enters the objective function in the E-V formulation, factor use cannot have both risk-increasing and risk-decreasing effects. To provide for risk effects of factor inputs, Antle (1983) proposed a flexible moment-based (FMB) econometric approach to characterise the decision problem of risk-averse producers under production uncertainty. Because of some limitations of econometric methods in handling multi-output supply structures, the FMB method has been applied only in a single-output framework (Antle, 1983, 1987).

This paper proposes an alternative method for analysing the supply behaviour of the multi-product firm under production uncertainty and risk aversion. The method extends the standard E-V programming model to incorporate stochastic technology in its structure. In this case, the variances of the individual enterprises and, hence, the variance-covariance matrix of the portfolio of expected returns are no longer constants but functions of the levels of factor inputs. The model is used to study the supply behaviour of farmers in the irrigated multi-crop sector of Sudan (Rahad Scheme) under production uncertainty. Stochastic production functions are specified to allow for risk-increasing as well as risk-decreasing input effects. This production technology is then used in a conditional, normative analysis of the firm's utility maximisation process by assuming mean-variance preferences. The model is an extension of the standard E-V model and allows for normative supply response estimation.

The next section discusses the characteristics of the study region and the crops considered, followed by a discussion of the stochastic specification of production technology and the programming model. The empirical model and the results are discussed in section three. Section four summarises the findings and concludes the study.

The Farming System of the Rahad Scheme in Sudan

The Rahad Scheme is the second largest irrigated scheme in Sudan. Three thousand feddans (one feddan ≈ one acre) of cotton, groundnuts and sorghum are grown under regular irrigation and mechanical power. A fixed cropping pattern is imposed on the 22-feddan tenancies allotted to each farmer. Half the land is planted to cotton, while groundnuts and sorghum equally share the other half of the tenancy.

The Scheme is managed by the Rahad Agricultural Corporation, a parastatal organisation that acts as the owner of the land and irrigation network. The major agricultural operations such as ploughing, ridging, planting, spraying of pesticides, and application of fertilisers and herbicides are directly performed by the Corporation employees or contracted for with other companies. Levels of chemical inputs, seed rates and number and timing of irrigations, recommended by the Scheme's research station, are equally applied to all tenancies. Although farmers control few inputs in this arrangement, labour hiring and family labour allocations across crops and production operations are important activities controlled by tenant farmers.

The cotton crop is delivered to the Rahad Corporation for ginning and marketing. Sorghum, on the other hand, being the main food staple, is usually retained for home consumption, and the surplus is sold together with groundnuts to private traders by the individual tenant. The Corporation collects land and water rents, together with charges for materials and services provided by the Scheme, from proceeds of the farmer's cotton crop. Cotton (the government crop) is the major foreign-exchange earner for the country, whereas most of the sorghum and groundnuts production is absorbed in domestic uses (food and processing). Government policy makers are interested in the effects of pricing programmes on the supply response of crops and the implications for export earnings, food supply and employment. If production risk can be controlled by changing own or hired labour allocations across crops, then supply response will be affected by risk considerations. In particular, supply response estimates ignoring risk effects may over- or under-estimate the true response estimates. Whereas area allocations and non-labour inputs are fixed by the scheme administration, preliminary analysis suggested that crop yields were responsive to the quantity and quality of hired and family labour and managerial resources under the farmer's control.

A long time-series of data on the scheme is not available, and prices have been under government control for some time. Thus, a positive approach to supply estimation is not applicable and a normative technique is appropriate.

A Mean-Variance Model with Stochastic Technology

An average-farm programming model is developed in this section to characterise the decision problem of agricultural producers under production uncertainty. Crop yields are stochastic and assumed to be the only source of risk in the model. Prices are non-random and independent of the individual farmer's actions. This is consistent with the environment in many developing countries where prices are set by the government and is the case for Sudan. The model could be generalised to handle price uncertainty with a joint density function formulation (Antle, 1987). The (average farm) model assumes identical preferences and risk aversion parameters as opposed to a distribution of risk preferences (Antle, 1987). The farmers' objective criterion is to maximise the expected utility of net returns to the fixed resources of the farm firm. The two moment (E-V) model postulates the objective function:

$$EU(\pi) = E[\pi] - \tfrac{1}{2}\lambda V(\pi) \tag{1}$$

where expected utility (EU) is a weighted function of the mean $E[\pi]$ and variance $V(\pi)$ of the random returns (π). The weight λ is the coefficient of absolute risk aversion (ARA). Constant ARA and normality of (π) are maintained by the structural nature of the model (Freund, 1956). Net farm

returns (π) is defined to be the sum of the net returns to individual enterprises:

$$\pi = a'r \tag{2}$$

where a and r are respectively (nx1) vectors of crop areas and net returns per unit area. And:

$$r = Py \tag{3}$$

where P is an (nxn) diagonal matrix of net returns per unit of output and y is an (nx1) vector of output per unit area. The vector y represents the random yield function given by:

$$y = f(x, \beta, \epsilon) \tag{4}$$

where x represents input levels, β, is the technology parameter vector, and ϵ is an error term. Alternative specifications of the stochastic component (ϵ) lead to different production function representations and behavioural implications.

In relation to the risk effects of factor inputs, Just and Pope (1979) showed that several popular formulations of stochastic production functions are restrictive. The main deficiency of common forms is the implication that all factors are risk-increasing, and thus, all are used less under risk aversion. They propose a more flexible form:

$$y = f(x, \beta) + h(x, \alpha)\epsilon \tag{5}$$

which defines separate effects of the decision variables (x) on the deterministic (f) and random (h) components of production respectively measured by the parameter vectors β and α. This heteroscedastic, additive-error form allows for risk-increasing and risk-reducing, as well as zero-risk effects of factor inputs $\left(\frac{\partial h}{\partial x_i} \gtreqless 0\right)$. Given that ϵ is an independently distributed random vector with zero mean and variance Σ, model (5) has the moments:

$$E[y] = f(x, \beta) \tag{6}$$

$$V(y) = h'\Sigma h = h_i \sigma_{ij} h_j \qquad \forall\, i, j = 1, \ldots, n \tag{7}$$

where V (y) is the (nxn) variance-covariance matrix of crop yields, and n indexes crop enterprises.

Combining equations (6 and 7) with equation (3) gives:

$$E[r] = P f(x, \beta) = r(x, \beta, P) \tag{8}$$

$$V(r) = P\,V(y)\,P = V(x, \alpha, P) \tag{9}$$

Then, according to (2), expected returns are given by:

$$E[\pi] = a'r(x, \beta, P) \tag{10}$$

while returns variance is given by:

$$V(\pi) = a'V(x, \alpha, P)\,a \tag{11}$$

The farmers' decision problem can be defined as the maximisation of the expected utility function in (1) subject to the stochastic technology constraints in (10) and (11), plus the other institutional and resource constraints of the system:

$$\Sigma_i g_{ij} y_i \leq g_j \qquad j = 1, \ldots, m \tag{12}$$

where g_{ij} is the amount of resource j used in the production of one unit of crop i, and g_j represents the upper limit of the total amount of resource j available. In this formulation of the E-V model, it is clear that the mean and variance of net farm returns are functions of factor inputs as shown in (10) and (11), e.g., the variance-covariance matrix of net returns is no longer constant. In a compact form, the decision problem is written as:

$$\max_{x,a} U = a'r - \tfrac{1}{2}\lambda\, a'V a \tag{13}$$

subject to:

$$r = P\,f(x, \beta)$$
$$V = P\,V(y)\,P$$
$$V(y) = h'(x, \alpha)\,\Sigma\,h(x, \alpha)$$
$$\Sigma_i g_{ij} y_i \leq g_j$$
$$x, a \geq 0 \qquad j = 1, \ldots, m$$

where variables are defined as in (1-12) above.

The model can be solved for alternative price scenarios to trace out supply and demand curves. This allows for estimation of normative supply and demand response when price variation is not present in historical data.

Model Estimation and Results

Parameter Estimation

Although production function and supply response parameters could be obtained by econometric estimation of the first-order conditions for profit (utility) maximisation using price and quantity data, the approach taken here is to directly estimate the production function and then use optimisation

techniques in a normative approach to supply analysis. This is because only cross-sectional data were available, with almost no variation in prices (across the scheme) to allow econometric estimation of the dual functions.

The Just-Pope specification of stochastic technology given in (5) is employed to represent the multi-crop production technology of the Rahad tenants. Three yield equations were specified for cotton, groundnuts and sorghum following model (5). Jointness in production holds for the multi-product firm when there are technical interdependencies among outputs or in the presence of allocable fixed resources (Pfouts, 1961). Though the present study assumes no technological externalities, jointness due to allocable fixed resources is provided for by assuming cross-equation correlations in the econometric estimation of parameters of (5). The programming model imposes the physical constraints and the estimated covariance structure of residuals on the model's solutions to further account for jointness in production.

The three-yield-equations model is fitted to data collected from a sample of 54 farmers surveyed during the 1984/85 season. Rather than to fit an arbitrary functional form to the data, the generalised power production function (GPPF) of de Janvry (1972) was estimated for the three crops. The GPPF contains several functional forms (e.g., Cobb-Douglas) as special cases depending on the structure of f and g. The general form of the GPPF is:

$$y_k = a_k \prod_{i=1}^{n} x_{ik}^{f_{ik}(x)}\, g_k(x) \qquad k = 1, \ldots, 3 \tag{14}$$

where y_k is the kth output and x_{ik} is the ith factor in the production of crop k, and f and g are real-valued functions of x.

Six variable factors were considered: man-days of family labour in weeding (WF) and harvesting (HF), man-days of hired labour in weeding (WH) and harvesting (HH), sowing dates (SD) and years in farming the crop (FR). Other inputs are assumed fixed across farmers, and farm firms are assumed to use the same production technology across the Scheme. Selection of functional form was based on the statistical performance of individual coefficients and their joint effects (the t-statistic and log-likelihood ratio). The Cobb-Douglas structure was accepted for groundnuts, where $g(x) = 1$ and $f_i(x_i) = \alpha_i$. The transcendental form ($g(x) = \Sigma_i \beta_i x_i$ and $f_i(x_i) = \alpha_i$) was accepted for cotton, and the variable elasticity of substitution function ($g(x) = 1$ and f_{ik} not a constant) was the best for sorghum.

An instrumental variable multi-stage non-linear systems estimation procedure (IVMNS) and a multi-stage non-linear systems estimation (MNS) were employed to estimate the parameters of the mean and variance of the yield functions of the system (14). The first method allows for heteroscedasticity, possible endogeneity of factor inputs and across-equations correlations from jointness in production. Sets of instrumental variables include age, sex, farming years, education, distances between tenancies, and homesteads, family size, average wage rates, sowing, and weeding and harvesting date overlap indices which represent competitive pressures among crops.

To test for mis-specification due to endogeneity of factor inputs, a Hausman (1978) test was performed on the system estimaters with and without endogeneity (MNS vs. IVMNS). A Hausman statistic of 0.173 was calculated, which fails to reject exogeneity for any tabled level of significance. This result tends to support the theoretical finding that the endogeneity problem (Marshak and Andrews, 1944) associated with production function estimation does not occur if producers maximise expected profit (Zellner, Kmenta and Dreze, 1966) or expected utility of profit (Blair and Lusky, 1975). Results from both estimation procedures are presented in Table 1.

Table 1 System Estimates of the Accepted GPPF Forms for Cotton, Sorghum[a] and Groundnuts[b]

	Cotton			*Sorghum*			*Groundnuts*		
	1st Moment		*2nd Moment*	*1st Moment*		*2nd Moment*	*1st Moment*		*2nd Moment*
	MNS	*IVMNS*	*IVMNS*	*MNS*	*IVMNS*	*IVMNS*	*MNS*	*IVMNS*	*IVMNS*
A[c]	.62 (1.4)	.74 (2.06)†	191.21 (.578)	.831 (4.02)‡	.784 (2.71)‡	108.74 (.721)	.68 (9.82)‡	.82 (9.89)‡	117.42 (1.62)
	.19 (2.23)†	.205 (1.958)*	-2.8 (-2.31)†	.262 (1.53)	.293 (2.14)†	-.85 (-2.25)†	.167 (3.03)‡	.137 (2.83)‡	-.41 (-2.3)†
FR	.188 (1.38)	.134 (2.378)†	-1.62 (-1.67)*	.413 (2.06)†	.345 (2.76)‡	-.271 (-1.15)	.056 (3.676)‡	.034 (12.35)‡	-.082 (-.89)
FL	.215 (2.17)†	.221 (1.22)	-.68 (-1.4)	2.43 (7.66)‡	.238 (7.87)‡	-.43 (-1.36)			
HL	.172 (1.69)*	.185 (8.09)‡	.23 (1.81)*	.136 (6.59)‡	.124 (2.94)‡	.15 (2.23)†			
γ	.007 (1.92)*	.01 (4.24)‡							
δ				-.0003 (-6.38)‡	-.0003 (-6.65)‡				
FL*HL			-.0003 (-.62)			-.001 (-1.94)*			
WF							.164 (1.724)*	.112 (2.975)‡	.26 (1.24)
WH							.132 (1.11)	.214 (1.84)*	-.23 (-1.62)*
HF							.067 (1.34)	.121 (1.95)*	.31 (1.67)*
HH							.415 (4.32)‡	.352 (6.54)‡	-.29 (-1.73)*
Log Likelihood Ratio	-176.42	-304.03		-99.953	-298.03	-62.4	-147.32	-304.03	-74.32

* significant at 10%
† significant at 5%
‡ significant at 1%

[a] The following forms were estimated for yield per feddan of cotton (Y_L) and sorghum (Y_S):

$$y_c = A_c \cdot SD^{\beta_1} \cdot FR^{\beta_2} \cdot FL^{\beta_3} \cdot HL^{\beta_4} \cdot \exp(\gamma(\frac{FL}{HL}))$$

$$y_s = A_s \cdot SD^{\alpha_1} \cdot FR^{\alpha_2} \cdot FL^{(\alpha_3 + \delta \cdot HL)} \cdot HL^{\alpha_4}$$

[b] The Cobb-Douglas form was used for groundnuts.

[c] SD sowing date; FR years in farming the crop; FL family labour; HL hired labour; WF weeding family labour; WH weeding hired labour; HF harvesting family labour; HH harvesting hired labour; A, A_s, β_k, α_j, γ and δ are parameters.

The residual covariances of the econometric estimation of (5) are used as consistent estimates of the yield covariances (V_{ij}). The covariances of the yield functions (the off-diagonals of V(y) in (7) e.g. $V_{ij} = h_i \sigma_{ij} h_j$, $\forall i \neq j$) are non-zero but assumed to be constants and independent of the x's as given in Table 2. However, the diagonal elements of V(y) (e.g., $V_{ii} = h_i^2 \sigma_{ii}$) are functions of input levels (x) as measured by h in (5).

Important results about risk attributes of the production technology in the Rahad Scheme were obtained. The risk effects of factor inputs were evaluated at the mean by using parameter estimates of the second moment of yield functions given in Table 1. Optimal sowing date (SD) and farming experience (FR) were found to reduce yield variability in the three crops. Hired labour is found to increase production risks in cotton and sorghum where cash wages are paid, whereas it is risk decreasing in groundnuts production where share cropping prevails. This result implies a relationship between the form of the labour contract and its risk effects. Though other factors such as the relative difficulty in monitoring and enforcing labour-hiring contracts may have led to share-cropping arrangements in groundnuts production, the negative risk effects of share tenancy arrangements provides one more reason for this choice. Family labour on the other hand, is found to be risk reducing in cotton and sorghum production and risk increasing in groundnuts.

Model Solution

Constraints on land and on family (F) and hired (H) labour are specified in the programming model as shown in Table 2. Total number of family man days available are calculated on the basis of the average effective family size (4 adults and 120 days a year). The highest level of hired hours observed is considered the average upper limit of hired labour per feddan (80 man days/feddan). Labour hiring is allowed at the average wage rates shown in Table 2 part C. The General Interactive Optimiser (GINO) was used to solve the programming model. Different solutions to the model were generated by varying the coefficient of risk aversion (λ). Simulated solutions were compared with the actual average farm plan (Hazell, 1971). The value of λ that best simulated observed choices of the farmers was 0.01.

Discrete supply responses were generated by varying the output and input price vectors. Continuous partial supply and demand equations were then obtained from the step response functions by regression analysis. This facilitates the comparison of alternative specifications and also provide elasticity estimates useful to policy makers. The following log-linear form was estimated to study own and cross-price effects

$$Q = aP^bW^d \qquad (15)$$

where Q refers to quantities of outputs and inputs, P represents output prices, W is the appropriate wage rate, and a, b and d are parameters of the response function. Equation (15) was estimated for output supply and labour input demands (Table 3). Output responses are generated by varying crop prices simultaneously while maintaining the wage rate fixed. Input demands, on the other hand, are conversely derived.

Although equation (15) is not a long-run equilibrium supply (demand) equation (because some prices are fixed), it measures partial supply

… Parameters of the Programming Model

A) *Covariances* (v_{ij} of equation 5):

	Cotton (C)	Sorghum (D)	Groundnuts (G)
C	v_{cc}	158	330.5
D		v_{dd}	215
G			v_{gg}

B) *Net returns per unit of output:*

	Cotton	Sorghum	Groundnuts
in Sudanese Pounds	30/kantar	7.5/kantar	6/kantar

C) *Resources:*

	Area	Family Labour	Hired Labour
i. constraints levels	22 fed.	22 manday/fed.	80 manday/fed.
ii. input prices			
PH	1.45	Sudanese Pound/day*	
PGWH	1.7	Sudanese Pound/day	
PGHH	1.85	Sudanese Pound/day	

* The wage rate for hired labour in cotton and sorghum production is given by PH, whereas PGWH and PGHH give the wage rate for weeding and harvesting hired labour in groundnuts. Sudanese Pound was equivalent to US $0.40 in 1984.

adjustments when risk effects of factor inputs are taken into consideration (Pope, Chavas and Just, 1983). The estimated elasticities are not directly nterpretable, owing to the variance component of the risk-averse firm supply esponse structure, but represent elasticities along a risk-adjusted supply curve.

The response functions in (15) were estimated for different behavioural and structural specifications to analyse the risk effects of factor inputs and the changes in the supply function when risk behaviour is included. Three scenarios were employed to represent different specifications of the model.

1. *Risk neutrality (RN):* $\lambda = 0$ and thus effects of factor inputs on the second moment of the return distribution do not affect farmers decisions.
2. *Risk aversion and zero input-risk effects (RA1):* λ is positive, but farmers' actions cannot influence production risks. In other words, the diagonal elements as well as the off-diagonals in the covariance matrix (V) are constants. This is the standard E-V analysis case.
3. *Risk-aversion and non-zero risk effects (RA2):* λ is positive, and factor inputs have non-zero risk effects. In this scenario, farmers are allowed to alter production risks by optimally choosing input levels, e.g., the diagonal elements of the (V) matrix are functions of input levels (x). This is the proposed extension to E-V analysis offered by this paper.

Optimal production plans obtained by solving the model under the scenarios mentioned are compared in Table 3. As compared with the standard E-V solution (RA1) the risk-averse firm is found to use more of marginally risk-reducing factors (e.g., labour in cotton and sorghum and hired labour in groundnuts) when factor inputs are allowed to influence risk (RA2). The reverse is true for risk-increasing factors: e.g., family labour in groundnuts and hired labour in cotton and sorghum (Table 3). Risk neutral firms on the other hand produce more of the more remunerative crops irrespective of their riskiness (e.g., cotton and groundnuts) and use more of the more productive inputs regardless of their risk effects (family labour in cotton and hired labour in cotton and groundnuts) than risk-averters do. The different factor demand and output supply responses obtained from different model specifications have significant implications for employment of factor resources and composition of output in agriculture. Production strategies and farm programs designed to promote a desired shift in cropping patterns to enhance productivity, employment, export earnings or food supply may lead to perverse results if the farm firm decision problem ignores the risk effects of factor inputs. Moreover, incorporating risk effects may help explain differential adoption rates of new farming methods and production technologies among farmers and contribute to diagnosing barriers to technological change in agriculture.

Table 3 Model Solutions and Derived Supply Response Elasticities

	Cotton				Sorghum				Groundnuts			
	(Actual Sample Average	*Risk Neutral (RN)*	*Standard E-V (RA1)*	*Risk Averse I (RA2)*	*Actual*	*RN*	*RA1*	*RA2*	*Actual*	*RN*	*RA1*	*RA2*
1. *Family Labour*												
level (man-day/fed)	6.8	7.88	6.88	7.74	7.1	5.32	5.84	6.23	5.0	5.86	5.33	5.02
wage elasticity	—	.11	.12	.14	—	.07	.07	.09	—	.15	.15	.17
2. *Hired Labour*												
level (man-day/fed)	20.0	23.2	23.18	18.86	14.0	13.16	14.59	12.91	28.0	31.4	29.02	32.28
wage elasticity	—	−.13	−.15	−.20	—	−.09	−.10	−.12	—	−.18	−.20	−.23
3. *Yield*												
level (kantar/fed)	5.6	6.31	6.21	5.94	12.0	11.36	13.48	12.73	21.3	17.24	16.97	18.42
output price elast.												
*PC	—	.18	.19	.24	—	−.10	−.11	−.16	—	−.14	−.14	−.16
PG	—	−.15	−.17	−.20	—	−.04	−.07	−.11	—	.16	.16	.19
PD	—	−.25	−.25	−.31	—	.44	.45	.48	—	−.06	−.06	−.07

*PC is price of cotton, PG is price of groundnuts and PD is price of sorghum.

The estimated partial demand and supply elasticities are summarised in Table 3. Farmers' supply responses are more elastic when risk effects of factor inputs are taken into consideration (RA2). According to Table 3, supply responsiveness increased significantly under RA2, particularly for cotton (more than 30%) and sorghum (between 60% and 70% for cross price effects) over the risk-neutrality case. The elasticity of demand for hired labour is also higher by 30% to 50% under the RA2 scenario. This indicates the magnitude of under-estimating supply responses to changing policies and economic conditions when the risk effects of factor inputs are ignored. It also shows that labour allocations across crop enterprises and, hence, crop yields and composition of agricultural output in the public irrigation schemes are responsive to changing economic incentives and riskiness in spite of the high government control over crop areas, prices and input allocations. Accordingly, policy packages derived from analytical models that do not incorporate factor risk stimuli may lead to lesser control over agricultural production and generate perverse results. Such reduced control of agricultural output may have substantial implications for employment, food production and export earnings in this important sector of Sudanese agriculture.

Summary and Conclusions

The treatment of production uncertainty is important in studying the behaviour of risk-averse producers and essential to successful agricultural policies. A normative supply-response model is developed to analyse the supply behaviour of farmers in the irrigated multicrop sector of Sudan. The model extends the two-moment (E-V) method to incorporate stochastic technology in the programming framework. Stochastic production functions are specified for three crops. Risk-increasing as well as risk-decreasing input effects are allowed. The estimation procedure used corrects for heteroscedasticity and cross-equation correlation in estimating the parameters of the mean and variance of yield functions.

Farmers' supply responses are simulated under different behavioural and structural specifications of the model. The results show that supply responses are more elastic when the risk effects of factor inputs are taken into consideration. Less (more) of the marginally risk-increasing (decreasing) factors are demanded under risk aversion. It follows that, if yield variability is dependent on levels of input use and if risk matters (e.g., farmers have risk preferences), it is important to adequately investigate the risk effects of the policy instruments to be employed in order to influence farmers' responses and to promote the desired adjustments in agricultural supply.

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CEREAL SUPPLY POLICY INSTRUMENTS: AN ATTITUDINAL SURVEY AMONG FARMERS IN ENGLAND

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Against a background of steadily mounting cereal surpluses in the European Community and a recognition that the cereals sector is a major contributor to the Community's budgetary problems, a survey was carried out of English farmers' attitudes and preferences concerning a range of alternative cereal supply policy instruments. Personal interviews were held with 102 farmers in two contrasting agricultural districts — one an intensive cereal-growing district in eastern England, the other an area of mixed livestock and arable farming in western England. Amongst cereal producers in both areas a quota was the preferred policy instrument; in the east because of the security it offered, but in the west because it was perceived to be the least damaging instrument for the industry as a whole. A price reduction was the preferred option of small livestock farmers in the western area. None of the other instruments — co-responsibility levy, set-aside, nitrogen use restrictions — received much support. Farmers were particularly negative about schemes involving the withdrawal of land from agricultural use.

Introduction

The sustained increases in output of many commodities which have characterised agriculture in the developed world during recent years pose an unprecedented problem for those nations directly responsible and have a distorting effect on world trade. Moreover, the continued pace of technological progress is likely to aggravate the problem of agricultural surpluses still further in the future. Within the European Community, cereal surpluses currently present a particular problem which has yet to be effectively tackled. The European Commission has repeatedly emphasised the importance of constraints on spending in the cereals sector as a key to alleviating budgetary problems and has considered a range of measures for this purpose. Adjustments in price have failed to alter the production trend, and in 1988 a major policy initiative was introduced in the form of a voluntary set-aside scheme. Under this scheme, which is clearly targeted at the cereal sector, arable farmers are financially compensated for withdrawing a proportion of their land from crop production

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