THE DEMAND FOR COMMODITY INSURANCE BY DEVELOPING COUNTRY AGRICULTURAL PRODUCERS: THEORY AND AN APPLICATION OF COCOA IN GHANA

Alexander Sarris

Commodities and Trade Division, Food and Agriculture Organization of the United Nations
Viale Delle Terme di Caracalla, Rome 00100 Italy
Tel: (+39-06) 5705 4201. Fax: (+39-06) 57054495. Mobile: (+39) 3488705340
E-mail: alexander.sarris@fao.org

ABSTRACT

The paper considers the benefit to agricultural producers from commodity price insurance that provides in every year, but in advance of the resolution of production and price uncertainty, a minimum price for a fixed or variable portion of production. Under the assumption that producers do not change their long term production and income diversification pattern, the theoretical framework suggested leads to explicit formulas for the benefit from providing this type of insurance. The theoretical framework is implemented for Ghana, using the GLSS data to specify various classes of cocoa producing households, and monthly price data for both domestic and international prices to formulate appropriate models for ascertaining price risks faced by producers. Empirical estimates of the actuarially fair premium are given, and it is shown that they are smaller than market based put option prices from organized exchanges. The overall benefit to households, however, turns out to be substantially higher than the actuarially fair premiums, as well as the market based put option prices, due both to the magnitudes of the uncertainties facing the households, as well as their risk and consumption smoothing behavior.

Keywords: Commodity price insurance, cocoa, Ghana.

INTRODUCTION

Agricultural producers around the world are exposed to a variety of income uncertainties, both market related, such as price variations, as well as non-market related, such as unstable weather patterns. These induce substantial income risks, which can be detrimental to small and/or poor producers in developing countries. Farmers have developed risk management and risk coping strategies to deal with these risks (Dercon, 2000), but these are not sufficient, and proposals have been made for the adoption of various additional safety nets (World Bank, 2001), as well as market based insurance systems (International Task Force, 1999). The various proposals, however, have not considered the demand for such safety nets, by the beneficiaries. The purpose of this paper is to analyze the demand for commodity price insurance theoretically as well as empirically in the context of a poor agrarian economy, with rural households significantly dependent on agricultural commodity risks. The theory developed is applied to Ghana, and for the case of price insurance for cocoa. Ghana is a poor country, with a large rural population that depends substantially on agriculture Cocoa is the most important cash crop for farmers in the south and it accounts for 13 percent of national agricultural GDP. There are about 500 000 cocoa producing households (11 percent of all Ghana households or 16 percent of all households producing some agricultural output). Section 2 outlines the methodology. Section 3 explains the empirical implementation, section 4 presents the empirical results, while section 5 summarizes the conclusions and implications.

METHODOLOGY

Assume that for a farm household time is measured in crop years, indexed by an integer T. Each crop year is divided into two, not necessarily equal, periods 1 and 2, indexed by j.

The first period within each crop year is meant to represent the period after planting, but before the resolution of production and price uncertainty, while the second period is meant to represent the resolution of production and price uncertainty, and the realization of annual crop income. In the first period the household income consists of sources other than agriculture, while all agricultural income is assumed to be realized in the second period (in addition to other possible sources of income). Time is indexed by an integer variable t=2T+j, where j=1 or 2. Denote the vector of consumed goods of the farm household in period t by C_t , the vector of quantities of assets in the beginning of period t by A_t , the vector of decision variables that are determined in period t by x_t , the information available to the decision maker at the beginning of period t by I_t, and the state of nature that is revealed in the beginning of period t by S_t. Also denote by p_{At} , p_{Ct} and p_t , the vectors of prices of assets, consumption goods, and income earning activities (including labor) respectively at time t. Denote by $U(C_t)$ the instantaneous household utility in period t. The household will be postulated to maximize the ex-ante expected value of the discounted sum of instantaneous utilities, over n crop years.

$$W = E\{\left[\sum_{t=1}^{2n} \delta^t U(C_t)\right] / I_1\} \tag{1}$$

where δ denotes an appropriate discount factor. The restrictions relating the various variables are the following.

$$p_{At} A_{t+1} = p_{At} A_t + p_t y_j(A_t, x_t, S_t) - p_{Ct} C_t \equiv R_t - p_{Ct} C_t \tag{2}$$

The variable R_t denotes the value of resources available to the household at the beginning of period t, namely previous period assets valued at current period prices, plus current income from these assets. The decision variable x_t belongs to some constraint set, and y_j (.) denotes the vector of quantity of netput activities affecting the income of the household in period t. Note that the nature of the income function y is time invariant. The solution, while theoretically well known, is not analytically tractable, and can be written as follows.

$$C_t = f(I_t) = f(A_t, y_j(A_t, S_t), p_t, p_{At}, p_{Ct}) \tag{3}$$

If an equation like (4) is the solution to the overall optimization problem (1)-(3), then the utility function in (1) can be rewritten as follows.

$$W = E\left\{\{\sum_{T=0}^{n} \delta^{2T}\left[U(C_{2T+1}) + \delta E\left(C_{2T+2} \middle| I_{2T+1}\right)\right]\} \middle| I_0\right\} \equiv E\left\{\sum_{T=0}^{n} \delta_1^T V(C_{2T+1}, I_{2T+1}) \middle| I_0\right\} \tag{4}$$

In (5) $\delta_1 = \delta^2$, the consumption within the various parentheses and brackets has a form like (4), and the function V just defines the quantity inside the bracket in the left had side of (4). The expectation inside the brackets are taken conditional on information available in the first period of a given crop year T.

Consider the provision of an insurance contract to the farmer in the first period of the crop year, whose outcome depends on events of the second period. The contract considered is in the form of an option to sell all or a portion of a produced crop at a minimum "strike" price. Denote the amount of the crop that is insured as q (can be fixed or variable), and the return to the insurance contract per unit of the insured crop as r. If we assume that the nature of the function f in (4) is not affected by the provision of this contract, then we can define the benefit of this contract as the amount that must be subtracted from income of the first period in the crop year, so that the two-period utility with the contract is equal to the utility without it. Analytically we define the benefit in year T to be the solution B to the following implicit equation.

$$U(C_{2T+1}(y_1 - B)) + \delta E\left[U(C_{2T+2}(y_2 + rq)) \middle| I_{2T+1}\right] = U(C_{2T+1}(y_1)) + \delta E\left[U(C_{2T+2}(y_2)) \middle| I_{2T+1}\right] \tag{5}$$

To utilize (6) for empirical analysis we first assume for convenience that total household consumption is composed of one aggregate commodity. Then we approximate (4) by the following aggregate consumption function.

$$\hat{C}_t = C_t^* + \beta \frac{(R_t - R_t^*)}{p_{Ct}} = C_t^* + \beta(R_t - R_t^*) \tag{6}$$

where R_t has been defined in (2), and where we have normalized all nominal values by the price of aggregate consumption (namely a suitable consumer price index). The formulation in (7) is the one that has been utilized as an approximation to the optimal rule (4) in the literature of the general lifetime optimization problem under uncertainty as well as under liquidity constraints (for a survey see Morduch, 1995). The starred value of R is the trend or expected value of these resources (income and assets). The parameter β denotes the amount of smoothing that the household does in each period, and is a function of household characteristics. If β is equal to 0, then there is perfect smoothing, and current consumption is independent of current income, or the value of current assets. If β is equal to 1, there is no smoothing at all, and current consumption moves exactly as current resources.

Define $z = rq$, where by r we now denote the return to the insurance contact, deflated by the CPI in the relevant period. We can then write the consumption with the insurance in each of the two periods of crop year T as follows (the year specific variable T is suppressed for ease of notation).

$$\hat{C}_1 = C_1^* + \beta(R_1 - B - R_1^*) = C_1^* + \beta(R_1 - R_1^*) - \beta B \equiv C_1^* + \beta \Delta R_1 - \beta B = C_1 - \beta B \tag{7}$$

$$\hat{C}_2 = C_2^* + \beta(R_2 + z - R_2^*) = C_2^* + \beta(R_2 - R_2^*) + \beta z \equiv C_2^* + \beta \Delta R_2 + \beta z = C_2 + \beta z \tag{8}$$

In (7) and (8) the consumption variables with hats denote consumption with the insurance contract, while the ones without hats denote consumption without insurance.

We can now expand the utilities in both the left and right hand sides of (5) about C_t^* using Taylor's theorem. Neglecting the Taylor expansion terms higher than second order, canceling similar terms from the left and right hand sides of (5), and normalizing all return and quantity variables by trend prices and C* (the normalized variables will have superscripts r) results in the following quadratic equation in B^r.

$$\frac{1}{2}\theta(B^r)^2 + (B^r)(1 - \theta \Delta R_1^r) + \delta\left[-E(z^r) + \frac{1}{2}\theta\left\{E(z^r)^2 + 2E(z^r \Delta R_2^r)\right\}\right] = 0 \tag{9}$$

where θ is the product of the coefficient of relative risk aversion ρ and the consumption smoothing parameter β.

Solving the quadratic equation (9) we find the following expression for the WTP for commodity insurance.

$$B^r = \delta E(z^r) + \frac{1}{2}\theta\left[(\Delta R_1^r)^2 - \delta\left\{E(z^r)^2 + 2E(z^r \Delta R_2^r)\right\}\right] \tag{10}$$

If the consumption smoothing parameter β is equal to zero, or if risk aversion is zero, then the value of B^r is equal to the (discounted) expected value of the return to the (normalized) insurance contract. $\delta E(r^r q^r)$ .This value is the actuarially fair premium for the insurance, and as such it has appeared in analyses of crop insurance in developed countries (Fraser, 1992).

To estimate the average benefit we take the expectation of the expression in (10) over all realizations of the first period variables.

$$\overline{B}^r = \underset{y_1}{E}\left\{\delta E(z^r | y_1) + \frac{1}{2}\theta\left[(\Delta R_1^r)^2 - \delta\left\{E(z^r | y_1)^2 + 2E(z^r \Delta R_2^r | y_1)\right\}\right]\right\} \tag{11}$$

where the vector y_1 denotes all the random variables that are known in period 1, and conditioned on which the expectations of period 2 are taken. Equation (11) will form the basis of the empirical estimates of the demand for commodity price insurance.

EMPIRICAL IMPLEMENTATION OF THE MODEL

There are four variables that need to be specified empirically, apart from the parameters β and ρ, in order to estimate the benefit of insurance. These are $E\left(r^r q^r\right)$, $Var(r^r q^r)$, $Cov(r^r q^r, R_2^r)$ and $Var(\Delta R_1^r)$. These can be estimated under the reasonable assumption that the return to the price insurance contract is independent from the quantity insured, and under the further assumptions that the price of the insured crop is independent of the domestic prices of all other agricultural products, as well as the quantities produced. These assumptions are justified if the insured crop is an internationally traded one, and the insurance contract is priced in an organized international commodity exchange, as is the case for cocoa in Ghana. Assume furthermore that the insurance contract covers a share γ of the produced crop. Then the above expressions can be estimated by using formulas for truncated normal distributions. The distributions involved are those of domestic and world prices and domestic yields.

The empirical implementation of the methodology involves specifying the structure of income of various types of households producing the commodity under investigation, as well as analysis of the stochastic nature of the uncertainties facing these households. To implement the model for Ghana, the 1998/99 Ghana Living Standards Survey (GLSS) was used to specify the various types of cocoa producing households. Official time series annual data on yields of the major agricultural products were obtained from FAO, and domestic monthly national wholesale prices for the major products of interest to the study are compiled by the Ministry of Agriculture in Ghana. World monthly prices of cocoa, as well as several other products were obtained from the World Bank.

In 1998/99 there were 501.8 thousand households that had some income from cocoa. Of these, 30.5 percent were poor, 82 percent lived in the main cocoa producing region, the rural forest region. These households were classified further according to their share of income deriving from cocoa (less than 20 percent, between 20 and 40 percent and over 40 percent). Each one of these groups was further subdivided according to the share of income from all agricultural activities (smaller and larger than 60 percent), and finally each group was further subdivided among those that are poor and those that are not. For each of these groups the average profile of income was estimated. The shares of income deriving from cocoa vary considerably among producers, ranging from 5.8 to over 70 percent. To analyze the uncertainty presented by the various agricultural income sources, the product accounting for the largest share of income among all agricultural households in each agricultural product group was selected. With these assumptions time series of annual national yields of the relevant crops plus cocoa were regressed on time trends, and the residuals were utilized to compute both the coefficients of variation of the yields of the relevant products (and product groups they represent) as well as the correlation matrix of yields.

Concerning world prices, the monthly deflated world prices for cocoa prices and other traded products that are substitutes for Ghana's products (maize, groundnuts, and banana) were used. For each product a time series model for the log of monthly price was estimated, using data for 1983-2002, in order to obtain equations for estimating conditional price expectations and variances. The same procedure was followed for domestic deflated wholesale prices. It turns out that there is no transmission of international prices to domestic markets.

EMPIRICAL RESULTS

Table 1 presents the actuarially fair premiums (as a share of the expected price at expiration), estimated by the model, for a minimum price insurance contract for cocoa written for a fixed amount of the commodity and for various strike prices (all expressed as percent of difference from the expected future price), and three months to maturity. The premiums are per unit quantity insured, and the annual interest rate assumed is 5 percent (adjusted to monthly basis). The indicated values are computed using formulas for censored distributions as discussed earlier, with conditional variances for n periods before expiration computed from the estimated world price models. Comparisons with actual put option prices are indicted.

Table 1. Comparison of actual cocoa put option prices at the New York Board of Trade and actuarially fair insurance premiums from model for three months ahead. All prices expressed as shares of future prices).

Futures price ($/mt)	Strike price ($/mt)	Strike Price Relative to futures price (% deviation from future price)	Actual put option price as share of futures price	Model computed actuarially fair insurance price (% of futures price)	Difference Actual put option-Model (% of futures price)	Difference: Actual put option-Model (% of actual put option price)
Cocoa put option prices NYBOT on June 5, 2002 for three months ahead (September 2002)						
1552	1450	-6.51	2.58	2.52	0.06	2.34
	1500	-3.32	3.80	3.64	0.16	4.27
	1550	-0.13	5.15	5.07	0.09	1.73
	1600	3.07	7.22	6.81	0.41	5.68
	1650	6.26	9.34	8.85	0.49	5.23
Cocoa option prices NYBOT on Feb 2, 2001 for three months ahead (May 2001)						
1058	950	-10.21	2.65	1.56	1.08	40.98
	1000	-5.48	4.44	2.85	1.59	35.90
	1050	-0.76	6.81	4.76	2.05	30.05
	1100	3.97	9.83	7.36	2.47	25.16
	1150	8.70	13.04	10.61	2.44	18.68

Source: Computed from data in Wall Street Journal, various issues.

It can be seen that these premiums are substantial. The large values of these premiums are due to the fact that, while the estimated cocoa price model is stationary, it is not too far from a unit root. Hence the variances of conditional predictions of prices n months ahead, tend to increase considerably. The estimated actuarially fair premiums are generally smaller than the market determined put option prices. This suggests that risk neutral and/or perfect consumption smoothing households, would not be interested in market based commodity price insurance.

Consider now the full values of WTP computed by the earlier formula. Table 2 presents the model estimated WTP for cocoa price insurance for coverage of 100% of the expected production, three months ahead, and for different strike prices, and compares them with the actually observed put option prices in NYBOT in June 5, 2002 for different values of the combined household "insurance" parameters θ. The table considers the various types of households in the main cocoa producing region of Ghana (the rural forest region).

In the estimates presented in the table, the value of the consumption smoothing parameter is set at either 0.5 or 0.8, for all households, and this represents mild and low consumption smoothing respectively. As for the coefficient of relative risk aversion ρ, perusal of the literature revealed that there is a range of empirical estimates between 0.2 and 3.5. For the estimates reported here three values of the relative risk aversion were adopted, namely 0.4, 2 and 3. Only three experiments are reported for lack of space, namely one with $\beta=0.5$, and $\rho=0.4$ (hence $\theta=0.2$), one with $\beta=0.5$, and $\rho=2$ (hence $\theta=1$), and one with $\beta=0.8$, and $\rho=3$ (hence $\theta=2.4$).

The various WTP estimates differ considerably for different types of households. Households with large dependence on cocoa exhibit, as expected, considerably larger WTP estimates. The second observation is that the estimated WTP measures differ considerably, and are generally larger, than the actuarially fair values of table 1, especially for cases with large values of theta. These results suggest that potential benefits from commodity price insurance are heavily underestimated if one applies the techniques for computing actuarially fair premiums, that have been utilized in developed countries. It also suggests that high risk aversion and the lack of appropriate consumption smoothing for covariate risks may make the benefits from providing safety nets in the form of commodity price insurance quite large. Comparison with actual put option prices indicates that for the lowest θ , all the estimated WTP figures are not much different than the market based put option prices. However, for the two higher θ cases, all estimates of WTP are higher, and in some cases considerably so, than the market based put option prices. This suggests, that commodity price insurance for such households based on buying put options in organized exchanges is a viable proposition.

Table 2. Comparison of WTP and actual cocoa put option prices in the NYBOT for a fixed 100% of total production and three months in advance, for the producers in the rural forest region of Ghana.

			Share of cocoa in household income											
			0-20%				20-40%				>40%			
			Share of agriculture in household income				Share of agriculture in household income				Share of agriculture in household income			
			<60%		>60%		<60%		>60%		<60%		>60%	
			Poor	Non-Poor	Poor	Non-Poor	Poor	Non-Poor	Poor	Non-Poor	Poor	Non-Poor	Poor	Non-Poor
Number of households			18668	50048	47133	106948	3983	11068	23540	64912	979	2855	23017	58395
Share of total income from cocoa (%)			6.8	6.1	8.6	8.9	26.4	26.1	31.7	28.6	42.2	46.8	53.5	56.6
Date of observation	Strike price in relation to future price (%)	Actual put option price (% of future price)	WTP with theta=0.2 and 3 months in advance											
5-Jun-02	-6.51	2.58	3.0	2.8	4.1	3.9	3.2	3.2	3.5	3.5	3.7	3.8	4.0	4.1
	-3.32	3.80	4.1	4.0	5.2	5.1	4.4	4.4	4.7	4.7	4.8	4.9	5.2	5.3
	-0.13	5.15	5.5	5.3	6.6	6.4	5.8	5.8	6.1	6.1	6.2	6.3	6.5	6.6
	3.07	7.22	7.2	7.0	8.3	8.1	7.5	7.5	7.8	7.8	7.9	8.0	8.3	8.4
	6.26	9.34	9.2	9.1	10.3	10.2	9.5	9.5	9.8	9.8	9.9	10.1	10.3	10.4
Date			WTP with theta=1 and 3 months in advance											
5-Jun-02	-6.51	2.58	4.9	4.0	10.4	9.5	6.2	6.2	7.8	7.8	8.3	9.0	10.1	10.5
	-3.32	3.80	6.0	5.2	11.6	10.7	7.4	7.4	8.9	9.0	9.5	10.2	11.3	11.7
	-0.13	5.15	7.4	6.6	13.0	12.1	8.8	8.8	10.3	10.4	10.9	11.6	12.7	13.1
	3.07	7.22	9.1	8.3	14.7	13.8	10.5	10.5	12.1	12.1	12.7	13.3	14.5	14.9
	6.26	9.34	11.2	10.3	16.7	15.8	12.6	12.6	14.1	14.1	14.7	15.4	16.5	17.0
Date			WTP with theta=2.4 and 3 months in advance											
5-Jun-02	-6.51	2.58	7.0	5.4	17.4	15.7	9.6	9.5	12.4	12.5	13.5	14.7	16.8	17.7
	-3.32	3.80	8.1	6.6	18.6	16.9	10.8	10.8	13.7	13.7	14.8	16.0	18.1	19.0
	-0.13	5.15	9.5	7.9	20.0	18.3	12.2	12.2	15.1	15.1	16.2	17.4	19.6	20.4
	3.07	7.22	11.3	9.7	21.7	20.0	14.0	13.9	16.9	16.9	18.0	19.3	21.4	22.2
	6.26	9.34	13.3	11.7	23.7	22.0	16.0	16.0	18.9	19.0	20.1	21.3	23.5	24.4

Source. Author's computations and Wall street Journal for put option quotes.

CONCLUDING REMARKS

Estimates of actuarially fair values of the premiums for commodity price insurance suggested that they are not only large, and increasing with the distance from contract expiration, but also smaller than the actually observed prices of put-options traded in internationally organized commodity exchanges, such as the NYBOT. This suggests that risk neutral households, or perfectly consumption smoothing households would not have any demand for market based commodity price insurance. When, however, the total WTP is computed, namely including the terms that the theory suggests are important for developing country producers, then the resulting WTP estimates are larger than the actuarially fair values. They differ considerably among households, with the estimates for households with large cocoa dependence much larger than those for households with low cocoa dependence. Hence farmers with larger dependence on cocoa, as well as those that are more risk averse and do not manage to smooth consumption (and these are more likely to be the poorer farmers), would obtain larger benefit from commodity price insurance.

ACKNOWLEDGEMENTS

The author would like to thank Hua Di for excellent research assistance, Awudu Abdulai, Yiannis Baffes, Patience Mensah, and Gerald Shively for help with data acquisition, and Yiannis Baffes, Gershon Feder, Don

Larson, and Panos Varangis for helpful discussions at various stages of the work. Comments received at two seminars presented at the World Bank are also acknowledged.

REFERENCES

Dercon, S., 2000. Income Risk, Coping Strategies and Safety Nets. World Bank, background paper for the World Development Report 2000/01, WPS/2000.26, September.

Fraser, R. W., 1992. An Analysis of Willingness-To-Pay for Crop Insurance. The Australian Journal of Agricultural Economics 36(1), 83 – 95.

International Task Force on Commodity Risk Management in Developing Countries, 1999. Dealing with Commodity Price Volatility in Developing Countries: A Proposal for a Market Based Approach", Discussion Paper for the Roundtable on Commodity Risk Management in Developing Countries. World Bank, Washington DC., September 24, processed.

Morduch, J., 1995. Income Smoothing and Consumption Smoothing. Journal of Economic Perspectives (9), 103-114.

Townsend, R.M., 1995. Consumption Insurance: An Evaluation of Risk-bearing Systems in Low-income Economies. Journal of Economic Perspectives (9) 83-102.

World Bank, 2001. World Development Report 2000/2001: Attacking Poverty. Washington DC.