The Demand for Commodity Insurance by Developing Country Agricultural Producers: Theory and an Application to Cocoa in Ghana

By

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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, a theoretical framework is suggested that leads to explicit formulas for the benefit from providing this type of insurance. It is shown that this benefit depends not only on the actuarially fair insurance premium, but also on household specific factors, that depend on the attitudes to risk, the consumption smoothing parameters, and the household specific exposures to income risks. 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, from providing minimum price insurance 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, risk management, cocoa, Ghana.

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1. 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. It is well known that such uncertainties induce substantial income risks, and these can be particularly detrimental to small and/or poor producers in developing countries. It is also well known that farmers have developed several ways for dealing with the various risks they face. These involve risk management strategies, namely actions taken ahead of the resolution of any uncertainty to improve the ex-ante exposure of the producer's household to various risks, as well as risk coping strategies, namely rules adopted ex-ante to help the household to deal ex-post with any undesirable consequences. Risk management strategies include among others crop diversification, income diversification through off-farm work, sharecropping, etc. Such ex-ante strategies are usually designed to sacrifice higher expected income for a more stable income stream Risk coping strategies may include the availability of short term consumption credit, mutual family or village based reciprocal giving arrangements, etc. For a recent survey of these practices see Dercon (2000).

The acknowledged precarious situation of many poor rural residents in developing countries has led to calls for the adoption of various additional safety nets (World Bank, 2001). Apart from publicly based such safety nets for rural residents, some proposals have advocated market based insurance systems. For instance, the recent initiative of the International Task Force (ITF) on Commodity Risk Management, has proposed using market based derivative instruments to provide price insurance for internationally traded commodities (ITF, 1999), while other proposals have suggested using market based weather insurance to cover yield risks (Skees, Hazell and Miranda, 1999). Varangis, Larson and Anderson (2002) have suggested using combinations of the above instruments to manage agricultural market risks in developing countries.

The various proposals, however, have not considered the demand for such safety nets, by the beneficiaries. The issue in the context of agricultural income insurance is the following. Under the structural conditions, exposure to risk, and risk mitigations strategies agricultural producers have adopted, how much yield and price insurance for the commodities produced would they wish to obtain, and how much would they be willing to pay for it? These are crucial questions that must be answered if a system of providing rural safety nets and in particular various types of commodity insurance (quantity or price based) are to be promoted in developing countries. The purpose of this paper is to explore the issue of the demand for commodity insurance theoretically as well as empirically for the case of price insurance, and in the context of a poor agrarian economy, with rural households significantly dependent on agricultural commodity risks.

A significant share of the income variations of rural producers in developing countries seem to be due to idiosyncratic shocks, namely shocks particular to a household (such as sickness) (Morduch, 1995, Townsend, 1995, Carter, 1997). Such risks can be insured through formal or informal pooling of a large number of such shocks, such as through village reciprocity relations, that exist in many developing countries, or formal private or public insurance schemes that exist in many developed countries. Covariate shocks, however, namely those that affect all households in a given community or region, such as weather or price shocks, cannot be insured by pooling them within a small region, and can be insured only if pooled over a much wider range of potentially affected households. It is the need to insure farmers, against such covariate shocks that have induced the governments of most developed countries to institute various price or income support schemes, under the perception that the private insurance industry would not be able to provide adequate coverage at reasonable cost.

The non-existence of such arrangements in developing countries is what induces rural households to develop self insurance, or what has been termed "consumption smoothing strategies" to deal with covariate shocks. These strategies basically involve building "precautionary savings", in the form of liquid or near liquid assets (cash, grain stocks, livestock, jewelry, etc.) in good years, and depleting them in years of adverse covariate shocks (Deaton, 1991). There is conflicting evidence, however, on whether such strategies are effective at smoothing consumption (Rosenzweig and Binswanger (1993), Rosenzweig and Wolpin, 1993, Fafchamps, et. al, 1998, Dercon, 2000). The consensus, nevertheless, appears to be that despite the variety of smoothing strategies adopted by poor households in developing countries there is substantial residual consumption risk (Jalan and Ravallion, 1999). There is also evidence that these practices are costly at the micro level in terms of current income and consumption foregone, as well as the types of investments undertaken (Fafchamps and Pender, 1997). Finally there is evidence that commodity price instability is detrimental to overall macroeconomic growth (Collier and Dehn, 2001). For all these reasons the additional provisions of safety nets or insurance mechanisms in rural areas is crucial to poverty alleviation, as well as growth.

Under the above circumstances, how is one to assess the benefit, and hence the potential Willingness of Producers to Pay (WTP), namely their underlying demand, for additional income insurance, and in particular insurance against downward commodity price risks? The question cannot be judged in abstract, but only in the context of the already existing self or community based insurance systems available to households, and after taking into account the degree to which they have altered their economic behavior to take into account such possibilities. If, for instance, households are already using precautionary savings to smooth out covariate price and quantity variations to income, they are already paying for such insurance through the opportunity cost of any consumption that is put into saving. Unless the provision of additional income insurance in such circumstances costs less, or provides for more reliable insurance at similar cost, households may not be willing to pay for it.

There are two consequences of providing in every period some type of income insurance to a household, including special types, such as commodity price insurance. The first involves a ceteris paribus increase in overall welfare, assuming that nothing else in the household structure changes. This will be the object of this paper, and can be considered as the minimum possible benefit from the insurance. The second consequence involves changes in the overall income and production pattern. These changes will occur if the household believes that the insurance provided is permanent, namely will be provided in every period. Both common sense as well as theory suggest that if a household is covered through adequate safety nets, then it may adopt a production and income pattern that is more risky, in the sense that it includes larger amounts of activities that have uncertain returns (Newberry and Stiglitz, 1981, Fraser, 1988, Finkelshtain and Chalfant, 1991, Moschini and Lapan, 1995, Gollier, 1995). Empirical verification of these theoretical predictions, however, is difficult (for a review of relevant studies and problems see Moschini and Hennessy, 2001).

This paper outlines a theory of the benefit from commodity insurance, under fixed production structure, and a methodology for empirical assessment of this benefit. The theory developed is applied to Ghana, and for the case of price insurance for cocoa. Ghana is a poor country (per capita income around 400 USD), with a large rural population (68 percent of the 18.9 million inhabitants) that depends substantially on agriculture (35 percent of GDP). About 42.6 percent of the total population and 51.6 percent of the rural population live below the poverty line. Ghana is heavily dependent on three commodities (gold, timber and cocoa) for its exports. In year 2000 cocoa accounted for 20 percent of export earnings, down from about 40 percent in 1990 and more in the 1980s. Cocoa is the most important cash crop for farmers in the southern "Rural Forest" agroecological zone, 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).

Cocoa is mostly exported, and a government parastatal marketing agency "Cocobod" has monopolized cocoa trade until recently when liberalization allowed the participation of private marketing agents. Domestic cocoa prices have been stable and under government control, and the government through Cocobod has absorbed most of the international price fluctuations, in effect through variations in its export tax revenue from exports. Cocoa export tax revenues have fluctuated widely and have averaged between 4 and 15 percent of total tax revenues during the decade of the 1990s (for a review of the history and consequences of the various cocoa related policies of the government of Ghana (GOG) see Varangis and Schreiber, 2001). A more open trading regime, however, will expose domestic producers directly to international price fluctuations. Even if, however, Cocobod maintains its price guarantee function, it may consider insuring its minimum price offered to farmers in international markets, and charge farmers an insurance premium for it (which could be implicit in the prices offered). Thus the estimation of the WTP of farmers for insurance is relevant to this case as well. The availability of organized international futures and options markets, make the study of the demand for commodity price insurance for cocoa in Ghana particularly interesting, as the possibility arises of providing insurance through commercially available derivative instruments like options

The plan of the paper is the following. In section 2 a review of previous relevant studies is presented. Section 3 outlines the theoretical framework. Section 4 explains the application of the theory to an empirical setting. Section 5 presents the data and estimations of the various model parameters for Ghana. Section 6 presents the empirical results concerning WTP, while section 8 compares the WTP with actual market based put option prices. The final section summarizes the conclusions and implications.

2. Previous literature related to commodity insurance

There are three ways that have been utilized to assess the WTP of farmers for price or income insurance. The first involves direct questioning of producers, and is related to the literature on contingent valuation (we shall term this the CV method). The second method involves the use of theory along with the combination of microeconomic household information, and market information to estimate indirectly the appropriate premiums (this will be termed the indirect method). The third involves inference of the willingness to pay from analysis of the patterns of production and other behavior of producers (we shall term this the revealed preference method).

The CV methods are based on direct questioning of agents (producers, households, etc.) on how much they are willing to pay for avoiding an undesirable event, or for a given amount of an insurance contract. The major problems with this approach have largely to do with the specification of the "scenario" or the "benchmark" against which the agent is supposed to compare the current situation, and express a monetary value for what it is worth to him/her to move to the new situation, or avoid a bad one. It is not always easy to specify well this scenario, especially if it involves a rather improbable event, and this lies at the heart of most criticisms of this approach (see e.g. the papers in Hausman (1993)). However, in the case of well specified risks, such as price or yield variations, it is likely that farm households are familiar not only with their normal values, but also with their variability over time, and hence the above criticism may not be valid.

Another problem with direct WTP studies involves the fact that reported values are likely to be influenced by recent experiences, For instance farmers are more likely to express high demand for price insurance if prices in recent periods have been low. There are also several issues concerning the method of deriving the WTP from either direct expression of values, or contingent rankings of alternative choices, but these seem to have been largely resolved. The literature on CV based methods has recently been surveyed by McCarthy (2002), who provides more discussion on both conceptual as well as estimation issues, and more references.

There are very few studies relevant to agricultural insurance, that use the CV approach. Patrick (1988) analyses producers' demand for a multiple peril crop insurance (MPCI) program with indemnities based on actual yields, and a rainfall insurance program with indemnities based on area rainfall, and uses tobit procedures to analyze factors influencing farmers' WTP for the alternative programs. Vandeveer and Loehman (1994) applied both dichotomous choice and ranking of activities in a study of farmer response to modifications in crop insurance. The ranked responses were used in a ranked logit model to derive WTP.

The indirect methods of estimating WTP involve first the specification of a model of the random income or other variable of direct relevance to the farmer's welfare (e.g. consumption), and expressing the WTP as the amount of money that would equate the expected utilities of the relevant variable with and without the insurance. This amount of money (the premium) is then estimated for objectively estimated values of the risks with and without the insurance, and for a range of relevant utilities, or relevant parameters (such as degrees of risk aversion) from a given class of utilities.

There are also very few studies attempting to estimate WTP for agricultural insurance by the indirect approach. Hazell, Bassoco and Arcia (1986) applied a programming model to infer the demand for crop yield insurance by the representative farmer in Mexico. Fraser (1992) uses an indirect method to estimate WTP for crop insurance. He does this by estimating and comparing certainty equivalents, in the presence and absence of insurance, of expected utility, based on the mean-variance framework and constant relative risk aversion. Bardsley, Abey and Davenport (1984), use a simulation model to estimate the amount of insurance at a given minimum price that will be purchased, per unit of insured quantity.

All the indirect methods have to use market data to infer the various parameters of the models, such as price and yield variabilities, as well as estimates of risk aversion parameters. While estimates of market parameters can be estimated readily if the appropriate data is available, risk parameters are not easy to estimate (for available empirical methodologies see Moscardi and deJanvry 1977, Binswanger 1980, Antle (1987,89), and Bardsley and Harris 1987). This suggests that the relevant measures of the WTP must be estimated using a set of risk aversion parameters that are considered as spanning the appropriate true values in the relevant region. An additional restriction of these methods is that they must assume some parametric form of utility that can subsequently be simulated. Nevertheless, the methods avoid many of the subjectivity issues, as well as the scenario design problems that plague the CV based approaches.

The revealed preference (RP) method relies on the idea that the producers are behaving with respect to their production and saving-investment decisions in a way that is compatible with their attitudes toward risk. Their desire and WTP for insurance is expressed implicitly in these decisions. If a model can be constructed that takes all these decisions into account, then observable behavioral patterns can be deduced, from which risk attitudes as well as WTP measures can be estimated. The problem, of course, if to specify a general enough model that allows for the derivation of risk attitudes and WTP measures.

An early paper by Binswanger and Sillers (1983) utilized this methodology to estimate the implied risk attitude parameters of farmers, but did not consider explicitly insurance. The first paper using a methodology of this type to estimate risk premiums for insurance is the one by Gautam, Hazell and Alderman (1994). In that paper the farm household's behavior is assumed to be described by the maximization of the expected value of an intertemporal utility function. The production, saving, labor allocation, diversification, borrowing, and insurance decisions are assumed to be endogenous. The equilibrium conditions of the optimization problem are manipulated to infer the production and diversification decisions of the household as functions of both standard variables as well as a variable that measures the relative preference of the household for risky versus non-risky income.

Under the assumption that the household is already well diversified and insured, implying that there is no unmet need for further insurance, the value of this parameter should take a value that can be inferred from non-experimental data. The authors use panel data to estimate the value of this parameter implied by the actual behavior of farmers, and deduce that there seems to be considerable latent demand for crop insurance, and furthermore, that the implied WTP is in the neighborhood of 13-17 percent of the indemnity value. These numbers (supplemented by estimated transactions cost) suggested in that case, that the WTP of farmers for drought insurance is above the cost of actuarially fair drought insurance, and hence that the provision of such insurance would be commercially viable.

The strength of this methodology lies in the fact that it can estimate the "latent demand" for drought insurance, namely the additional and as yet unmet demand for insurance, given that the households already have some self insurance mechanism. The underlying assumption is that the way the households have adjusted to the recurring weather risks is by diversifying, as well as adopting different production patterns than what would be dictated through simple expected income calculations. As such, the empirical estimates involve the long run or steady state production pattern of the farm household, given the household's perceptions of drought risks.

This approach seems suitable for the issue of assessing how farm households who are exposed to price risk adjust their long term production structures (for instance through diversification), and what implicit risk attitudes dictate the observed production patterns. The method may also be suitable for assessing the WTP for price insurance, but, the data requirements are quite heavy, as they invariably involve panel survey data.

The same approach is essentially followed by Sakurai and Reardon (1997) who utilized panel data for Burkina Faso. The additional feature of this study is that the researchers regress their estimates of farm level demands for drought insurance on a set of variables, so as to identify variables that increase or decrease such demand. They find, as expected, that the demand for drought insurance depends on the perceived probabilities of droughts, and is higher for regions with higher such probabilities. They also find that variables such as the size of cultivated area, and the age of household significantly affect positively the demand for insurance, while the amount of off-farm income, the availability of public aid and private gifts, and the size of household significantly affect negatively the demand for insurance. These are reasonable and expected findings.

There are finally few studies who utilize panel data to infer simultaneously the risk attitudes and consumption smoothing parameters of rural households. All of these studies use the RP methodology to assess risk attitudes and consumption smoothing as well as diversifications patterns and savings parameters for rural households, using panel data, but do not consider the demand for insurance. Examples of such studies are the ones by Kurosaki (1998), Kurosaki and Fafchamps (2002), Fafchamps, Udry and Czukas (1998), and Dercon (1996, 1998).

3. A model for the demand for commodity price insurance

Commodity price insurance for an agricultural producer is like a put option, or a minimum price guarantee. In other words it guarantees for the amount of contracts purchased or quantity covered, and over a period stated in the contract, a minimum price (the strike price of the option like contract), but allows the producer to obtain a higher price. This similarity is the basic reason that renders price insurance schemes based on derivative instruments traded in organized markets possible (Duncan, 1997, Sarris, 1997, 2000, 2002, Varangis, Larson and Anderson, 2002). Commodity yield insurance is similar to price insurance except that the role of price and quantity are reversed. In other words rather than guaranteeing a minimum price for a given quantity, yield insurance guarantees to farmers a given price for a minimum insured quantity. Thus the put-like option is on quantity produced rather than price. In the sequel the discussion will refer to price insurance, with the understanding that all theoretical analysis can be easily transposed to the yield insurance problem.

There are several points of clarification worth mentioning in the context of commodity price insurance. First, the price insurance may not affect all of the production of a producer, but only the amount of production covered, and hence it is not strictly similar to a minimum price guarantee scheme for whatever output is produced, of the type that have been adopted by many governments. Nevertheless, an agricultural producer is probably more interested in a minimum price guarantee for whatever amount of product he/she[2] decides to sell.

The second issue concerns the type of price and market that is relevant for a producer, and the ones that must be considered in estimating WTP for price insurance. It is clear that a producer is mainly interested in the price he receives for his commodity locally. If this price happens to be the same or partially correlated with some international price or price in some organized exchange, then such price offers good signals to the producer. However, as far as his WTP is concerned, price information must relate to local prices.

Third, the WTP for commodity price insurance depends at what point in the production cycle the producer is faced with the possibility to buy insurance. For instance, the insurance can be provided at a point in the year, after all production inputs are committed, and the only uncertainties facing the producer are environment related and price related. Alternatively, the insurance can be offered before the annual production decision is made. The WTP under each of these alternatives should be different, and in fact is expected to be larger on average in the

[2] In the sequel the male gender is used to refer to a producer, without implying any prejudice concerning the type of agricultural household head.

second situation above, as in that case the producer has larger flexibility to adjust, and hence can achieve larger expected utility with the insurance.

Fourth, it makes a difference whether insurance, under either of the two types indicated above (before or after annual production decisions) is temporary, namely a one shot affair, or is offered every year. In the former case, the producer is not expected to alter long term behavior, while in the latter case he is.

The theory outlined below pertains to the case of insurance offered within one crop year, and after the major short term production decisions, such as land and fertilizer allocations, have been made. It thus assumes that the long term diversification pattern of the producer stays unaffected. In this sense, the estimated benefit, and WTP can be considered as the minimum demand for price insurance. Any changes in production structure will provide an additional benefit, but will not be considered here.

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. Hence, odd values of t denote the first part of any crop year, while even values the second part.

Denote the vector of consumed goods (it may include leisure) 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 (such as inputs, land allocation, amount of insurance instruments to buy, savings and investment decisions, etc.) 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 (such as values of all realized economic variables as well as states of nature in previous years), and the state of nature that is revealed in the beginning of period t by S_t (this may include uncertainty about income affecting variables such as weather, prices, sickness, etc.). 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.

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

where δ denotes an appropriate discount factor. The expectation in (1) is taken over all states of nature S_t (t=1,2,,.,2n), based on information at the beginning of the relevant horizon for the household. The maximization will be assumed to be over all sets of decision vectors x_t

The restrictions relating the various variables are the following.

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

$$x_t \in X_t \qquad (3)$$

The equation in (2) defines the value of end of period assets at period t prices. 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. X_t is an appropriate constraint set for the decision variables, and y_j (.) denotes the vector of quantity of netput activities (positive if outputs, negative if inputs) affecting the income of the household in period t[3]. The subscript j in the income function denotes the possibility that income sources may be different in the two periods of each crop year. However, note that the nature of the income function y is time invariant. In other words it is assumed that during the planning horizon of the household, the nature of the income generating activities, stays unchanged. This implies, for instance, that unknown future technological improvements are not taken into account in the household's planning problem. Notice that the budget constraint (2) takes into account appreciation of assets, through the revaluation of assets carried over from last period (A_t) at current period asset prices. Notice that no restriction is placed on the sign of assets. Hence negative assets (namely liabilities such as borrowing) are allowed in this general formulation. If the household is liquidity constrained, then the restriction that some or all assets should be non-negative must be imposed (Deaton, 1991).

The nature of the solution to such a problem is theoretically well known, and involves the application of Kuhn-Tucker first order conditions (if there are non-negativity constraints) to the standard Bellman equation (for illustrations see Deaton, 1992a, Zeldes, 1989). If the utility and income generating functions are time invariant, as has been assumed here, and if the stochastic processes determining prices as well as the other uncertainties affecting household incomes are stationary, the general solution for the consumption in each period is a time invariant function of the "state variables" in period t, namely variables that summarize the information available to the household in the beginning of period t. Such information generally include the volumes of assets at the start of period t, the state of nature in period t (such as uncertain types of income), and the prices of the various assets and products that enter production and consumption. Under some restrictive assumptions such as equality of all prices, and simple linear income generating rules, the solution can be obtained numerically (e.g. Deaton, 1991). In general the solution is not analytically tractable, and can be written as follows.

$$C_t = f(I_t) = f(A_t, y_j(A_t, S_t), p_t, p_{At}, p_{Ct}) \qquad (4)$$

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.

$$W = E\left\{ \{\sum_{T=0}^{n} d^{2T} \left[U(C_{2T+1}) + dE\left(C_{2T+2} \middle| I_{2T+1}\right)\right]\} \middle| I_0 \right\} \equiv E\left\{ \sum_{T=0}^{n} d_1^T V(C_{2T+1}, I_{2T+1}) \middle| I_0 \right\} \qquad (5)$$

In (5) $d_1 = d^2$, 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

[3] The returns to any financial assets, such as interest on deposits or loans, are included in the income terms. Similarly the depreciation of physical assets can also be considered as included in y in this general notation.

of a given crop year T, while the unconditional expectations outside the brackets are taken with information available in the beginning of the planning horizon, namely year 0[4].

Consider now 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. The insurance contract is similar to the minimum price guarantee schemes that have been popular in developed countries (such as the loan rate system for cereals in the US), and hence the theory applies to these settings as well.

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.

$$U(C_{2T+1}(y_1 - B)) + dE\left[U(C_{2T+2}(y_2 + rq))\middle| I_{2T+1}\right] = U(C_{2T+1}(y_1)) + dE\left[U(C_{2T+2}(y_2))\middle| I_{2T+1}\right] \quad (6)$$

The key assumption that allows the definition in (6) is that the nature of the income generating function $y_j(.)$ as well as the consumption function (4) are not altered by the provision of insurance. This, of course, is not strictly correct, as the household may adjust its long term exposure to risk as is implied by theory, but as the nature of the changes in the income functions as well as the consumption function under insurance are quite intractable, the assumption can be considered as a first approximation, and one that can facilitate the estimation of the "minimum value" of WTP, for such insurance contracts.

To utilize (6) for empirical analysis we first assume that total household consumption is composed of one aggregate commodity. This is done for convenience, so as to neglect commodity composition consumption effects. Then we approximate (4) by the following aggregate consumption function.

$$\hat{C}_t = C_t^* + b\,\frac{(R_t - R_t^*)}{p_{Ct}} = C_t^* + b\,(R_t - R_t^*) \quad (7)$$

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 (there is a large literature on consumption under uncertainty and liquidity constraints, and consumption smoothing. For useful surveys see Deaton, 1992b, Browning and Lusardi, 1996, and Morduch, 1995).

In (7) the value of "trend" real consumption C_t^* is assumed not to depend on current period random variables, albeit it may include time varying components due to seasonal or lifetime effects. The current (real) value of resources R_t includes the current real income of the household, as well as the current valuation (deflated by the consumer price index) of the

[4] If the two periods within the crop year are different in duration, the discount rate within the bracket in the left hand side of (5) will be different than the discount rate outside the same bracket.

household assets. As such it includes both covariate risks, such as price variations, as well as idiosyncratic risks. 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. Notice that perfect smoothing may involve negative values of assets in some periods (namely debts). If this is impossible due to liquidity constraints, then consumption smoothing will not be perfect and the relevant value for β will be larger than zero.

Denote by z the term that include the total (real) return to the insurance contract.

$$z = rq \tag{8}$$

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, and because it does not affect the subsequent analysis which depends only on the seasonal variables).

$$\hat{C}_1 = C_1^* + b\,(R_1 - B - R_1^*) = C_1^* + b\,(R_1 - R_1^*) - bB \equiv C_1^* + b\Delta R_1 - bB = C_1 - bB \tag{9}$$

$$\hat{C}_2 = C_2^* + b\,(R_2 + z - R_2^*) = C_2^* + b\,(R_2 - R_2^*) + bz \equiv C_2^* + b\Delta R_2 + bz = C_2 + bz \tag{10}$$

In (9) and (10) 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 (6) about C_t^* using Taylor's theorem. Neglecting the Taylor expansion terms higher than second order, and canceling similar terms from the left and right hand sides of (6), results in the following equation (primes denote differentiation).

$$0 = -U'(C_1^*)B + \frac{1}{2}bU''(C_1^*)\cdot(B^2 - 2B\cdot\Delta R_1) + d\left[U'(C_2^*)E(z) + \frac{1}{2}bU''(C_2^*)\cdot\{E(z^2) + 2E(z\Delta R_2)\}\right] \tag{11}$$

In (11) E(.) denotes conditional expectation, given information in period 1 of the crop year. To proceed, assume that the trend real consumption is the same in each of the two sub-periods of the crop year. Denote this common value (which may be different in each crop year) by C*. Furthermore, define the following normalized variables.

$$r^r \equiv \frac{r}{p_{i2}^e} \tag{12}$$

$$B^r \equiv \frac{B}{C^*} \tag{13}$$

$$q^r \equiv \frac{p_{i2}^e q}{C^*} \tag{14}$$

$$z^r \equiv r^r q^r = \frac{z}{C^*} \tag{15}$$

$$R_j^r \equiv \frac{R_j}{C^*} \qquad \text{(j=1,2)} \tag{16}$$

$$R_j^{*r} \equiv \frac{R_j^*}{C^*} \qquad \text{(j=1,2)} \tag{17}$$

$$r = -\frac{U''}{C^* \cdot U'} \tag{18}$$

In (12) the price in the denominator is the expected or normal price of the insured commodity in period 2. In (13)-(17) all variables are defined as shares of trend real expenditures, and (18) just defines the coefficient of relative risk aversion.

With these definitions, equation (11) can be rewritten as a quadratic equation in the normalized benefit, as follows.

$$\frac{1}{2}q(B^r)^2 + (B^r)(1 - q\Delta R_1^r) + d\left[-E(z^r) + \frac{1}{2}q\left\{E(z^r)^2 + 2E(z^r\Delta R_2^r)\right\}\right] = 0 \tag{19}$$

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

$$q = rb \tag{20}$$

Solving the quadratic equation (19) and using the approximation $(1+e)^{1/2} \approx 1 + \frac{1}{2}e$ we find the following expression for the WTP for commodity insurance.

$$B^r = dE(z^r) + \frac{1}{2}q\left[(\Delta R_1^r)^2 - d\left\{E(z^r)^2 + 2E(z^r\Delta R_2^r)\right\}\right] \tag{21}$$

From (21) it can be readily seen that if the consumption smoothing parameter β is equal to zero, or if risk aversion is zero, then the value of B is equal to the (discounted) expected value of the return to the (normalized) insurance contract, namely

$$B_0^r = dE(z^r) = dE(r^r q^r) \tag{22}$$

This value then can be taken as the benchmark value, or the value of the benefit from provision of the insurance under risk neutrality and/or perfect consumption smoothing. In fact ł is the actuarially fair premium for the insurance, and as such it has appeared in analyses of crop insurance in developed countries (Turvey, 1992, Fraser, 1992). The contribution of the theory expounded here can be considered as the inclusion of terms additional to those in (22), that reflect the joint risk aversion and consumption smoothing behavior of the farm household. The formula in (22) bears some similarity to the formula derived for the benefit of a consumer from price or income stabilization in chapter 9 of Newberry and Stiglitz (1981).

Notice that the benefit defined in equation (21) includes the (square of) realization of the deviation of real normalized resources in period 1 from their trend values. This means that the benefit of the one period ahead insurance, is state contingent, namely depends on the household resources realized in the same period. Hence, if, for instance, survey techniques are utilized to ask producers about their WTP for a specific insurance contract, as is done in CV studies, then the answers will depend on current realizations of uncertain income related variables, and cannot be considered as representative of WTP over a longer period. This is a limitation of CV studies that was pointed out earlier. The same holds about the conditional expectations in the terms multiplying θ, as they are also conditioned by realizations of period 1.

Expression (22) leads to several conclusions that are compatible with intuition. First, the larger is the degree of risk aversion (larger value of ρ), and the smaller is the degree of consumption smoothing (larger values of β), the larger is the benefit of insurance. Second, the larger is the degree of (unpredictable) deviation of current resources from normal (positive or negative), the larger is the WTP for insurance. Third, the larger is the variance of the return of the insurance contract, the lower the WTP for it. Finally the WTP for an insurance contract is larger with a more negative correlation between the return to insurance and the second period resource uncertainty.

To estimate the average benefit we take the expectation of the expression in (21) over all realizations of the first period variables.

$$\overline{B}^r = \underset{y_1}{E}\{dE(z^r|y_1)+\frac{1}{2}q\left[(\Delta R_1^r)^2 - d\left\{E(z^r|y_1)^2 + 2E(z^r\Delta R_2^r|y_1)\right\}\right]\} \quad (23)$$

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. If, of course, the conditional expectations in (23) do not depend on the vector y_1, then the unconditional and conditional expectations will be the same. Equation (23) will form the basis of the empirical estimates of the demand for commodity price insurance.

4. Empirical implementation of the model

According to (23) and under the assumption that the expected values of the deviations of household resources from their trend values in each period are zero, 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 the following.

$$E(r^r q^r),\ Var(r^r q^r),\ Cov(r^r q^r, R_2^r) \text{ and } Var(\Delta R_1^r) \quad (24)$$

The first three of these expressions are the expectations with respect to the conditioning variables, of the one period ahead conditional expectations. If, of course, the conditional expectations do not depend on any first period variables, then the unconditional and the conditional expectations are the same. The last term is an unconditional variance.

To proceed, the reasonable assumption is made that the return to the price insurance contract is independent from the quantity insured. Hence.

$$E(r^r q^r) = E(r^r)E(q^r) \quad (25)$$

$$Var(r^r q^r) = Var(r^r)Var(q^r) + \left[E(r^r)\right]^2 Var(q^r) + \left[E(q^r)\right]^2 Var(r^r) \quad (26)$$

Thus to estimate these variables all we need are the expected values and variances of the insurance contract return, and the insured quantity. If the latter is fixed, as would be the case for a put option for a specific quantity, then (26) is further simplified by the omission of the quantity variance terms. If the quantity is not fixed, as would be the case with a price floor for whatever quantity is produced, then the variance of the (normalized) insured production can be obtained by the residuals of time series regressions on local yield data.

Consider the return to a unit of the put-option like contract. Suppose that the underlying probability distribution for the price of the commodity in the next period is normal, and has a conditional mean equal to p^e and a conditional variance equal to s^2. Assume that the option like contract has a strike price equal to p_S. This means that if the eventual market price p is below p_S, namely if $p_S - p > 0$, the payoff is equal to $p_S - p$, while if the market price is below or equal to p_S, namely if $p_S - p <$ or $=0$ the payoff is zero. This implies that the distribution of r will be a censored one that derives from censoring above the point zero the distribution of the variable $y = p_S - p$ which is similar to the one for the price, but with mean equal to $m = p_S - p^e$ and variance equal to s^2. The distribution of the normalized variable r^r will also be truncated (above zero) normal but relative to a distribution similar to y above, but with normalized (by p^e) mean and variance.

The expressions for the mean and the variance of a censored normal distribution can be found, for instance, in Greene (2000, p. 907), and are not repeated here for economy of exposition. The mean and the variance of the return to the insurance contract will then depend on the mean and variance of the underlying conditional price distribution, namely the values of p^e and s^2.

To analyze the third term in (24) consider the normalized resource deviation variable for period 2, ΔR_2^r. The terms that will contribute to the covariance with the insurance contract return are those that will be correlated with the quantity produced of the insured crop and its price. Among the several income sources of the household, the ones that are likely to be so correlated are the components of household income that derive from agriculture. Hence we consider only these terms. With this assumption we can write the second period normalized resource deviation as follows.

$$\Delta R_2^r = \sum_i s_i (\Delta p_i^r \Delta y_i^r + \Delta p_i^r + \Delta y_i^r) \tag{27}$$

Where i denotes the i'th agricultural product produced by the household, s_i is the share of household income derived from the i'th product, and the other terms denote the normalized deviations of prices and quantities from their expected values.

Denote the expected value of the insured production of the crop by q^{re}. Then given (27), the covariance term in (24) can be written as follows

$$\begin{aligned} Cov(r^r q^r, R_2^r) &= E\left[(r^r q^r - E(r^r) q^{re}) (\sum_i s_i (\Delta p_i^r \Delta y_i^r + \Delta p_i^r + \Delta y_i^r) \right] = \\ & E\left[\left[(r^r - E(r^r))(q^r - q^{re}) + E(r^r)(q^r - q^{re}) + q^{re}(r^r - E(r^r)) \right] (\sum_i s_i (\Delta p_i^r \Delta y_i^r + \Delta p_i^r + \Delta y_i^r) \right] \end{aligned} \tag{28}$$

This is a complicated expression. To simplify, it will be assumed 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. This will be the case for any market based commodity price insurance scheme, such as the ones proposed by the ITF. Assume furthermore that the insurance contract covers a share γ of the produced crop. If γ=1, then all production is insured, irrespective of outcome. Under the above assumptions (28) can be written as follows.

$$Cov(r^r q^r, \Delta R_2^r) =$$
$$gs_c E(r^r)\sum_i s_i k_{ci}\sqrt{Var(y_c^r)Var(y_i^r)} + gs_c^2 E\left[(r^r - E(r^r))\Delta p_c^r\right]Var(y_c^r) + gs_c^2 E\left[(r^r - E(r^r))\Delta p_c^r\right] \quad (29)$$

In (29) the subscript c denotes the cash crop that is insured (in this application it will be cocoa) and k_{ci} denotes the correlation coefficient between the production of the insured crop and the i'th other crop produced by the household. The only term that is nontrivial to compute in (29) is the covariance between the return to the insurance contract and the price of the insured crop. An expression for this expectation is derived in the appendix. If the contract covers only a fixed portion of the crop, namely if q is fixed and not a function of the actual random production, then the only term that remains in (29) is the last one.

Consider now the final term in (24), namely the unconditional variance of the first period deviation of normalized real resources from trend. Recall that this period within the year is the period at or right after planting, or making production plans that will be realized in period 2. The assumption is that there is no agricultural production during this period. Given, however, the rule for consumption in (7), the dynamic equation for resources available in (2) can be written as a first order recursive equation in the volume of assets. Under the simplifying assumptions that the same value of the consumption smoothing parameter β applies to both periods within the crop year, that in the long term the value of total consumption is equal to the value of total resources, and that the real prices of produced products and assets are equal, it can be shown that the unconditional variance of first period assets can be written as follows[5].

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[5] This can be shown by writing, under the simplifying assumptions mentioned in the text, the resource restriction equation (2) and the consumption smoothing equation (7) as follows.

$A_{t+1} = A_t + y_t - C_t \equiv R_t - C_t$ and $C_t = C_t^* + b(R_t - R_t^*)$

These imply a recursion equation for assets as follows

$$A_{t+1} = (1-b)(A_t - A_t^* + y_t - y_t^*) - (C_t^* - R_t^*)$$

If it is assumed that the household starts with a given amount of resources A_0, that the trend value of consumption is equal to the expected value of income in the same period, and that the only income uncertainty involves the agricultural income of the second period within the crop year, then it can be easily shown, if there are no inequality constraints, that the expected value of assets in every period is equal to A_0 and that the variance of assets follows the recursion equation

$$Var(A_{t+1}) = (1-b)^2 Var(A_t) + (1-b)^2 Var(y_2)$$

Since the variance of the resources in period t is just the sum of the variance of the assets in period t, plus the variance of period t uncertain income, then, if the income process is stationary, the equation (30) in the text follows.

$$Var(\Delta R_1^r) = \frac{Var(y_2)}{1-(1-\beta)^2} \qquad (30)$$

In (30) the variance term in the numerator is the unconditional variance of second period (and hence for the crop year) agricultural income. If there is no smoothing and hence β=1, then the variance of resources is equal to the variance of income, as there is no accumulation and decumulation of assets. If, on the other hand, there is perfect smoothing, namely β=0, then the unconditional variance of first period resources will be infinite, as assets must vary by large amounts to ensure the complete smoothing of income. In fact it can be easily shown in this case that, as the dynamic asset equation is a random walk, the variance of the resources in period t is just the sum of the variance of income realizations of every period, and hence grows without bound as t increases. For any non-zero value of the consumption smoothing parameter β, the unconditional variance of first period resources will be larger than the variance of agricultural income.

The variance of agricultural income in turn can be written as follows:

$$Var[y_2] = Var\left[\sum_i s_i(\Delta p_i \Delta y_i + \Delta p_i + \Delta y)\right] = \sum_i \sum_j s_i s_j E\left[(\Delta p_i \Delta y_i + \Delta p_i + \Delta y_i)(\Delta p_j \Delta y_j + \Delta p_j + \Delta y_j)\right] \qquad (31)$$

If we assume normality of the various price and quantity terms, the only terms that will contribute to the variance in (31) are those that include even number of terms in the products of the price and quantity terms. Hence (31) can be rewritten as follows.

$$Var(R_1^r) = \sum_i \sum_j s_i s_j E\left[\Delta p_i \Delta p_j \Delta y_i \Delta y_j + \Delta p_i \Delta p_j + \Delta p_i \Delta y_j + \Delta p_j \Delta y_i + \Delta y_i \Delta y_j\right] \qquad (32)$$

We postulate models of domestic price formation that assume partial international tradability of the various products, as follows.

$$\log p_{it}^r = \alpha_i + \zeta_i \log p_{it}^{rw} + \eta_i \log y_{it}^r \qquad (33)$$

In the above equation the domestic price is made a function of the world price and the domestic production. Parameter ζ_i denotes the elasticity of transmission of world price to domestic price, and is a measure of tradability. An elasticity equal to 1 implies that the domestic price of the product is determined basically in the international market. In an actual econometric specification appropriate lags should be entered to account for stock adjustment effects. The parameter η_i denotes the reduced form elasticity of domestic price to domestic production. It will depend on the domestic supply and demand price elasticities for the i'th product.

Denote by σ_i the coefficient of variation of yield of the i'th crop produced by the household, by v_i^w the coefficient of variation of the world price of the i'th product, by ρ_{ij} the correlation coefficient of world prices of the i'th and j'th products (if they are tradable), by v_i the coefficient of variation of the domestic price of the i'th product, and by ψ_{ij} the correlation coefficient between the domestic price of the i'th and j'th products.

Given (33) the various terms in (32) can be evaluated as follows

$$E(\Delta p_i \Delta p_j \Delta y_i \Delta y_j) = h_i h_j (1+2k_{ij}^2) s_i^2 s_j^2 + z_i z_j r_{ij} n_i^w n_j^w k_{ij} s_i s_j + y_{ij} n_i n_j k_{ij} s_i s_j \quad (34)$$

$$E(\Delta p_i \Delta p_j) = h_i h_j k_{ij} s_i s_j + z_i z_j r_{ij} n_i^w n_j^w + y_{ij} n_i n_j \quad (35)$$

$$E(\Delta p_i \Delta y_j) = h_i k_{ij} s_i s_j \quad (36)$$

$$E(\Delta y_i \Delta y_j) = k_{ij} s_i s_j \quad (37)$$

The variances and correlations in the above equations are unconditional ones. This implies that if one, for instance, estimates a stationary time series model of the price of commodity j of the AR form

$$a_j(L) p_{jt} = e_{jt} \quad (38)$$

where $a_j(L)$ denotes a polynomial of the lag operator L, and e_{jt} is an iid error term with variance s_j^2 and covariance with the price of product i equal to s_{ij}, then the unconditional variance of the price, as well as the covariances between prices, can be estimated with the help of the Yule-Walker equations for stationary time series (Greene, 2000, p. 756).

5. Specification of the model and data for Ghana cocoa producers

It is clear from the above theory that the benefit from commodity price insurance by a household depends both on exogenous sources of covariate uncertainty, such as the price and yield variations of various products, as well as the allocation of income sources of a household among different activities subject to these uncertainties. Thus 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 Ghana Living Standards Survey (GLSS) carried out by the Ghana Statistical Service in collaboration with the World Bank was used to specify the various types of cocoa producing households. These large surveys are representative of the whole country, and there have been two such surveys in Ghana, one in 1991/92 and another in 1998/99. For the present analysis the 1998/99 GLSS was utilized. Furthermore, official time series annual data on yields of the major agricultural products were obtained from FAO. Domestic monthly national wholesale prices for the major products of interest to the study are compiled by the Ministry of Agriculture in Ghana, and were obtained with the help of the World Bank office in Accra. These are market prices and hence are not expected to be influenced by government pricing policies which were prevalent for a considerable part of the 1970s and 1980s. World monthly prices of cocoa, as well as several other products were obtained from the Economic Policy and Development Prospects group of the World Bank, and represent the major indicator market for each product.

The cocoa producing households in Ghana were first divided according to their residence. The major region of cocoa production in Ghana is the rural forest region in the south. However, a substantial number of cocoa producing households live in other rural areas near the rural forest regions, as well as in urban areas. Thus three major regions were specified for the classification, namely rural forest, other rural areas, and all urban areas. According to the GLSS in 1998/99, and the projections to the national total based on the sampling methodology used, there were 501.8 thousand households that had some income from cocoa. Of these, 411.5 thousand or 82 percent lived in the rural forest region, 50.3 thousand or 10 percent lived in other rural areas, and 39.9 thousand or 8 percent lived in urban areas. These households were classified further according to their share of income deriving from cocoa (three groups were distinguished, namely those with cocoa income share 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 (those with such share smaller and larger than 60 percent), and finally each group thus defined was further subdivided among those that are poor and those that are not.

The results of these classifications and the relevant shares of income from all the major and relevant income sources as well as cocoa are exhibited in tables 1-3. It can be seen that the shares of income deriving from cocoa vary considerably among producers, ranging from 5.8 to over 70 percent. However, it can also be seen that there are large disparities between reported income and expenditure, with the latter almost invariably considerably larger than the former. This is a well known problem of all household income and budget surveys. Of course, it is not known whether there are different degrees of under or overestimation of various types of income, and it is difficult to correct for this discrepancy. If we assume that the degree of under or overestimation is similar across the various income sources, then the estimated income shares can be considered as approximations to first order of the actual true income shares[6]. This is what is assumed in the empirical specification of the model.

Among all cocoa producing households in Ghana 30.5 percent are poor according to the classification of the GLSS. In the rural forest the proportion of poor cocoa producers is 28.5 percent, in other rural areas it is 38 percent, and among those living in urban areas it is 41.2 percent. These proportions are lower than the poverty incidence among non-cocoa households that have some income from agriculture (41 percent in the aggregate), but much higher than the poverty incidence among non-agriculture producing households (7.9 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 the GLSS in each agricultural product group was selected. Thus maize was selected to represent the cereals group, cassava was chosen for the roots group, groundnuts for the other cash crops group, onions for the vegetables group, and plantains for the fruit group. The processed crop group as well as the group of other agricultural income were assumed not to present uncertainties, and the same was assumed about the non-agricultural sources of income. This was done because of lack of relevant data, and also because the emphasis is on agricultural income. The assumption would tend to bias the WTP measure downwards, as, under the assumption of independence between the variations in agricultural and other sources of income, the estimated unconditional variance of first period resources in (23) would be smaller than the correct value. Hence the calculated WTP would be smaller than the true WTP. The group of own consumed production does contribute to real income uncertainty, because of yield variability. It was assumed to consist of maize and cassava in equal shares (there is no data in the GLSS to infer more precise shares).

With these assumptions time series of annual national yields of the above crops plus cocoa were regressed on time trends, and the residuals were utilized to compute both the coefficients of

[6] An occasional small negative agricultural income share is due to the fact that agricultural production expenditures are subtracted from gross receipts, and these may some times be larger than the receipts.

variation of the yields of the relevant products (and product groups they represent) as well as the correlation matrix of yields. Table 4 indicates the results (only correlation coefficients significant at 10 percent or better were retained and reported).

Concerning world prices, the monthly world cocoa prices[7] and the monthly prices of other traded products that are presumably substitutes for Ghana's products (maize, groundnuts, and banana) were first deflated by the US monthly consumer price index to express them in real terms. Then for each product j the following econometric equation was estimated (the subscript j for a product is omitted for notational simplicity), where ln is the natural logarithm[8].

$$\Delta \ln p_t = a_0 + a_1 t + b_1 \Delta \ln p_{t-1} + b_2 \ln p_{t-2} + \sum_{k=1}^{11} g_k month_k + e_t \qquad (39)$$

In (39) the variables $month_k$ are monthly dummies, in order to take account of any seasonality at the world level. This equation is similar to what was estimated by Dehn (2000) in his analysis of commodity price uncertainty. It is based on the principle proposed by Ramey and Ramey (1995), namely that the predictable component of a price series can be modeled using a selection of explanatory variables. The variance of the residuals can then be thought of as uncertainty, namely the unpredictable component of the series. Here, as in Dehn (2000) we adopt a time series model with seasonal dummies for the predictable component of the price series

The equation was estimated with data from the period 1983 to 2002, except for cocoa, where a longer time series was available (1970-2002) and was utilized. The results for the OLS estimation of (39) are reported in table 5. It can be seen that the coefficients of the lagged price terms are all significant. The coefficients of all the linear trends are negative and significant, implying a negative long term decline in real world prices. The monthly dummies are for the most part not-significant, and this may be expected, as world prices are influenced by production in many countries, that have different producing seasons. The magnitudes of the estimated price coefficients imply stable (namely stationary) price processes[9].

Concerning domestic prices, the monthly wholesale prices were deflated by the Ghana consumer price index. Then the following regressions were estimated[10].

$$\Delta \ln p_t = a_0 + a_1 t + b_1 \Delta \ln p_{t-1} + b_2 \ln p_{t-2} + z_0 \Delta \ln p_t^w + z_1 \Delta \ln p_{t-1}^w + z_2 \Delta \ln p_{t-2}^w + h \Delta \ln PROD_t + \sum_{k=1}^{11} g_k month_k + e_t \qquad (40)$$

In (40) the prices with superscript w denote the (real) world price of the commodity in question, and PROD denotes the domestic production of the commodity in the crop year that includes the month of the price in the left hand side. Since the production data is annual, the assumption was

[7] The prices obtained were the International Cocoa Organization (ICCO) prices, which are regarded as representative of the world market.

[8] Augmented Dickey-Fuller tests for unit roots of the world price series were borderline in rejecting the hypothesis of a unit root for all of the commodities considered except for banana , where the test strongly rejected the hypothesis of a unit root

[9] If we define $\delta_1 = 1 + \beta_1$, and $\delta_2 = \beta_2 - \beta_1$ then stationarity of the AR(2) price process in (41) is implied by the following conditions ABS(δ_2)<1, $\delta_1 + \delta_2 < 1$ and $\delta_2 - \delta_1 < 1$ (see Greene, 2000, p. 753).

[10] Augmented Dickey-Fuller tests for unit roots of the real domestic prices strongly rejected the hypothesis of a unit root for all commodities considered.

made that the same value of this annual variable pertains to the prices of all months within the relevant crop year[11]. The coefficients ζ_k are meant to represent the different degrees of "transmission" of world prices to domestic prices. If, for instance, domestic prices were strictly determined by world prices in the same month, then the coefficient ζ_0 should be equal to 1, and all other coefficients should be equal to zero. The additional lags in world prices are designed to capture the possibility of lagged transmission.

Equation (40) was estimated with data for the period 1983-1999, which is the period of overlap between our domestic price data and our world price data, and for the three products for which we had corresponding world price data (maize, groundnuts, and plantain (for which banana data was used)). Table 6 presents the results of these regressions. There are two notable observations. First in none of the equations estimated is the world price significant for either same month transmission or for lagged transmission. This implies that domestic prices for the major agricultural food crops in Ghana are largely determined locally, and hence the products can be considered as nontradable.

Second, in none of the equations is the domestic production variable significant with the correct sign, and in the one case (groundnut) where it is significant it has the wrong (positive) sign. This non-significance was also found in (not-reported) regressions where the crop year was adjusted by few months backwards and forward, to capture the possibility that the crop years might be slightly different than those adopted for the regressions in table 6. This finding could be because of the poor quality of production data. However, it may also be due to the fact that the estimated regressions include seasonal dummies and these capture the seasonal pattern of production. In fact, contrary to what was obtained for world prices, there are marked seasonal price patterns, as evidenced by the significant coefficients of several seasonal dummies in the relevant regressions in table 6. For instance, in the maize regressions, the negative coefficients for the July, August and September dummies may reflect the fact that the bulk of the harvest period in the south occurs in these months, while the negative dummy for November coincides with the peak production period in the north of Ghana. The positive value for the April dummy may reflect the peak of the "dry" season, namely the end of the previous year supplies, before the new harvest starts.

Given that world prices do not appear to matter for domestic price formation, and that we have longer price series for domestic prices than international ones, equations similar to (40) but without the world price terms were estimated for the period 1970-1999. The results are exhibited in table 7 for the five commodities that have been taken as representative of the various agricultural income components. It can be seen that the production terms are still non-significant, that there are even more marked seasonal patterns, and that the two lagged price terms are significant in all equations and with magnitudes that are compatible with stationarity of the price process.

Given the lack of transmission of world prices to domestic markets for all food products, the correlations between the residuals of the estimated regressions of different world prices are not relevant for the calculations of the WTP and are not shown. For the domestic prices, the correlation matrix of the residuals of the monthly prices is exhibited in table 8.

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[11] The crop years differ among products in Ghana, depending on the region of major production and the rainfall pattern. They were specified after considering the timing of production in the major producing regions, as reported by the Ghana ministry of agriculture. There is no officially recognized crop year for any product.

6. Empirical estimates for the willingness to pay for commodity price insurance

Table 9 presents the actuarially fair premiums (as a share of the expected price at expiration) 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 various months to maturity. The premiums are per unit quantity insured, and the annual interest rate assumed is 5 percent (adjusted to monthly basis). The price series utilized is the international ICCO one, and the 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 model for cocoa exhibited in table 5. As that price model is stationary, the conditional variances do not depend on current prices, and hence these premiums can be considered as the unconditional average values for the actuarially fair levels.

It can be seen that these premiums are substantial. They also increase considerably with duration of the insurance contract. For instance for six months to maturity, they range from 3.3 percent of the expected future price if the strike price is 10 percent below expected future price, to 13 percent if the insurance provides for minimum price at 10 percent above the expected price at maturity. For 12 months to maturity they range from 5.4 percent to 14.9 percent for the same type of contract. 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. As discussed earlier these figures indicate the minimum benefit to producers, and hence their theoretical WTP, under a perfect market, and no risk aversion.

The expected prices at maturity that are underlying the calculations in table 9 can be either actual future market prices, if such markets exist, or current best forecasts of prices at maturity if futures markets do not exist. This does not imply that futures prices, if they exist, are necessarily the market determined expectations of subsequent prices. If we assume, for instance that the producer has a different forecasting model of prices, and consistently forecasts prices to be within a constant differential from observed futures prices (higher or lower), then his actuarially fair WTP exhibited in table 9 would be the same, but as a share of his own expected prices and not the observed futures prices.

The estimated actuarially fair premiums are generally smaller than the market determined put option prices. Table 10 compares for illustration the prices of cocoa put options in the New York Board of Trade (NYBOT) in June 5, 2002, February 2, 2001, and April 4, 2000, for three month maturities, and different strike prices and compares them with the actuarially fair insurance premiums calculated with the formulas here, for the exact same deviations of strike prices from future prices as the ones actually observed in the market. Table 11 does the same for two and five month put options and for different dates[12].

Note that with only one exception, namely the July 5, 2000 prices, in all other cases the market determined put option prices are higher than the ones predicted by the actuarially fair insurance premiums computed here. This suggests that risk neutral and/or perfect consumption smoothing households, would not be interested in market based commodity price insurance.

Consider now the adjustments to this actuarially fair WTP that are induced by the portfolio structure of income. As indicated in formula (23) there are two terms that multiply the combined

[12] These comparisons were done for several other dates and maturities, and the results are similar.

risk aversion cum consumption smoothing parameter θ. The first is the unconditional variance of period 1 resources, while the second is a term that depends on the conditional variance of the contract return, as well as the conditional covariance between the contract return and the deviation of period 2 household resources from trend. Both of these terms were elaborated in section 4. The formulas of section (4) along with the domestic price series models indicated in table 7, and the structure of incomes indicated in tables 1-3 were utilized to estimate these formulas for the case of Ghanaian cocoa producers.

Table 12 indicates the unconditional coefficients of variation of second period income of Ghanaian households due to agricultural risks. The computed coefficients of variation take into account only agricultural income, and neglect variability in any other source of income, hence, under the assumption of independence between agricultural and other sources of income, they can be regarded as lower bounds of the income risks faced by Ghanaian cocoa producing households. It is, of course, assumed that the price risk facing Ghanaian households is the international price risk, and hence we do not consider the reductions in price risk due to the stabilization activities of the government parastatal Cocobod. The implication is that the indicated risks are the ones that would be faced by cocoa producing households under a liberalized system, namely without Cocobod.

It can be noticed that the income risks vary positively with the share of cocoa in household income. Households with low exposure to cocoa (cocoa income share less than 20 percent) have small coefficients of variation (between 1.2 and 13.1 percent) irrespective of whether their share of agriculture in total income is large (namely larger than 60 percent) or small. By contrast, the households that have large shares of cocoa in total income (cocoa income share larger than 40 percent) have much larger coefficients of variation of income (between 19 and 31.5 percent). This is despite the fact, that, as is obvious from tables 4 and 6, both the yield as well as the monthly domestic price variations of the other products are often larger than those of cocoa. The reason is that the unconditional variance of the international cocoa price, implied by the estimated time series models, is much larger than the unconditional price variances of domestic products (except for cassava, which is a largely subsistence crop)[13]. Hence larger exposure to cocoa implies larger overall unconditional income variability.

In the estimates presented below, 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. Binswanger (1980) for instance found the parameter to be in the range .32 to 1.74, Antle (1987) found relative risk aversion to lie between .19 and 1.77, while Kurosaki (1998) found the coefficient to lie between 1.12 and 3.34. It thus appears that a range of 0.2 and 3.5 is reasonable, albeit quite large. For the estimates reported here three

[13] The unconditional price variance for an AR(2) stationary price model similar to the ones estimated, and of the form $p_t = g_1 p_{t-1} + g_2 p_{t-2} + e_t$, where the error epsilon is iid, can be derived from the solution to the corresponding Yule-Walker equations, and is given by the following formula (which is different from the incorrect one given in Green, 2000, p. 755)

$$Var(p_t) = \frac{s_e^2}{(1+g_2)(1-g_2-\frac{g_1^2}{(1-g_2)})}$$

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 β=0.5, and ρ=0.4 (hence θ=0.2), one with β=0.5, and ρ=2 (hence θ=1), and one with β=0.8, and ρ=3 (hence θ=2.4). The first experiment can be considered as representing relatively moderate smoothing with low risk aversion, the second an intermediate case, and the last can be thought of as one representing little smoothing and large risk aversion. Clearly many cases lie in between.

Tables 13,14, and 15 present the estimates of the implied benefit of Ghanaian cocoa producing households in the three regions distinguished (rural forest, other rural, and urban), under the three different hypotheses concerning the risk aversion and consumption smoothing parameters, and for periods to maturity of six and 12 months respectively. All figures are reported as shares of the household cocoa income, but the cocoa income shares in total income are also reported, so that one can easily compute the WTP values as shares of total income. This is done for reference in tables 16-18. Clearly larger values of the cocoa income share imply larger values of the WTP as share of total income.

The first observation is that the various WTP estimates differ considerably for different types of households. This is to be expected as the households differ considerably among them both with respect to their income sources, as well as their dependence on cocoa and agriculture. Households with large dependence on cocoa exhibit, as expected, considerably larger WTP estimates. For instance if we consider for the exposition the insurance that provides a minimum price equal to the currently expected future price (namely a strike price that differs by 0 percent from the future expected price), then the WTP for households in the rural forest region, the largest cocoa growing region in Ghana, as a share of total income (table 16) and for a six month in advance contract range from 0.5 percent to 5 percent of total income in the case of the lowest value of the parameter θ, and from 0.8 to 13.2 percent of income in the case of the highest value of θ. For the other two regions (tables 16 and 17) the ranges are equally extreme. These are very large numbers and suggest that there is a large potential benefit from providing price insurance in areas where there is large dependence on cocoa.

The second observation is that the estimated WTP measures differ considerably, and are generally larger, than the actuarially fair values of table 9. Consider, for instance the figures in table 13, that present WTP estimates for the cocoa households in the rural forest region as shares of cocoa income, and as such are comparable to the figures of table 9. Comparing the columns for each group of simulations in table 13 with the rows for month 6 and month 12 before maturity from table 9, it can be seen that for the low theta cases the differences are not large, as expected. However, for the highest theta cases the differences are substantial. For instance the WTP for poor households that have cocoa income share larger than 40 percent and agricultural income share larger than 60 percent, the estimates for WTP for the six month advance period in the highest theta case, are between 18 and 28.7 percent depending on the strike price, while the actuarially fair premium is between 3.3 and 13 percent. The differences are larger than 100 percent in all cases, which suggests that potential benefits from commodity price insurance are heavily underestimated in such settings 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.

A large part of the difference between actuarially fair values and the reported WTP estimates is accounted for by the contribution of the unconditional income variance term, which in the estimates stays constant over the different maturity periods. Table 19 indicates the proportions of the WTP accounted for by the actuarially fair component, the unconditional variance and the conditional terms indicated in equation (23). The case illustrated is for a strike price equal to the expected future price, and for six and twelve months in advance of maturity. It can be seen that the conditional terms never account for more than 7 percent of the WTP, while the unconditional variance term accounts for substantial parts of the WTP, sometimes exceeding 70 percent.

The final comment concerns the case where the quantity insured of the commodity is whatever is produced, irrespective of amount. In other words the idea is that the insurance contract offers a minimum price but on a variable quantity, and hence resembles what many governments have done for their producers. The results point out that the estimates of WTP are quite close to what was already indicated in tables 13-18. In other words the average WTP does not increase by large noticeable amounts (normally of the order of 0.1 percent of income or less) if the insurance contract covers only what is produced and not a fixed amount, irrespective of actual production. This suggests that as far as price insurance is concerned a fixed quantity contract is worth to the households over time about as much as a contract providing minimum price only on what is produced.

7. Comparisons with market based option prices

An important question from the viewpoint of providing market based commodity price insurance is whether the estimated benefit or WTP compare with the market determined prices of put options in organized commodity exchanges. Tables 20 and 21 try to answer this by comparing, for the rural region of Ghana[14], the estimated WTP with the methodology presented here, for the same strike prices (relative to the future prices) as observed in the market, with the actual cocoa put option prices for three months (table 20) and five months (table 21) in advance of maturity, in the New York Board of Trade. All estimates of WTP have been computed under the assumption that a producer obtains price insurance for a fixed amount equal to 100 percent of average production, and for the same values of the parameters β and ρ (and hence θ) as the ones simulated in tables 12-17. All WTP figures are presented as shares of cocoa income, which, since the assumption is that producers insure 100 percent of their average production, translates to a WTP that can be expressed as a share of the average future cocoa price. In this fashion the WTP figures and the observed put option prices, which are expressed as functions of the underlying future prices, are directly comparable.

Table 20 shows for put option prices observed on June 5, 2002, that for the low theta case, the estimated WTP is below the market based put option prices for some households, namely those with low cocoa dependence, but is higher than the market based put option prices for the households with high cocoa dependence. The difference, however, between the WTP and the market based put option prices becomes considerably larger when the value of θ is large. For instance in the last set of row, which indicate the values of WTP when θ is 2.4, it appears that in all cases, namely for all strike prices, and for all types of households, the WTP is much larger than the market based put option prices.

[14] Estimates for the other regions lead to similar conclusions

The same conclusion can be drawn from table 21, which indicates for a different date (July 5, 2000) the same comparisons as in table 20, but for five month options. For the lowest θ , all the estimated WTP figures are below 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.

8. Concluding remarks

The benefit of providing commodity insurance to agricultural producers is difficult to estimate empirically. The reason is that it involves the assessment of both a short term benefit, namely one under the assumption of no change in production pattern, as well as long term benefit, which involves the implications of insurance for diversification and general production and income structure of the household. This paper has concentrated on the first of these benefits.

The theory presented here has pointed out that the benefits from commodity price insurance are more complex than simple actuarially fair insurance premiums. This is because of risk aversion as well as different degrees of consumption smoothing practiced by households. These factors are quite important in developing countries where considerable liquidity constraints, as well as lack of adequate safety nets, imply that households are less well protected against income shocks than in developed countries. The implication of these factors, as far as the benefit from commodity insurance is concerned, is that the WTP depends on current income conditions, and also on the correlation of the return of the insured commodity contract with household income.

The methodology for estimating the WTP was empirically implemented with data for Ghana, a country with large dependence on cocoa. It was seen that there are many Ghanaian households, with significant dependence of income on cocoa, and many of them are poor. It was also seen that these households are subject to considerable income variability induced by dependence on agriculture as well as cocoa.

The estimated price models utilized for the estimates, were largely parsimonious time series ones, and suggested that the prices of the most important food commodities in Ghana are not related to international prices. Nevertheless, they seem to follow stationary processes, with marked seasonalities. The international cocoa prices on the other hand seem to follow a time series model that is close to a unit root process. The implication is that the conditional variances of future cocoa prices are large and stabilize only slowly. This implies that the unpredictability or volatility of cocoa prices, when examined ex-ante, is significant and increasing with the period of the prediction.

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 that they seem to be 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, and many times by amounts larger than 100 percent. They differ considerably among households, with the estimates for households with large cocoa dependence much larger than those for households with low cocoa dependence.

The fact that the magnitudes of the estimated benefits are large, and larger than the actuarially fair values, suggests that producers of cocoa in Ghana, if exposed to the full force of world prices, should be willing to pay the premiums for price insurance contracts of the type that was analyzed, and which could be profitably obtained from organized commodity exchanges. This was shown by comparing the estimated WTP figures and the actual prices of cocoa put options in the New York Board of Trade. The comparison revealed that under assumptions that seem reasonable in developing countries, a large number of producers would obtain benefits from commodity price insurance larger than the premiums suggested by the private markets. Thus it appears that local marketing intermediaries like Cocobod or others could easily incorporate the insurance premiums from buying put options into minimum forward prices offered to farmers, and that farmers would be amenable to such contracts.

A major conclusion of the analysis is that, as the estimated WTP figures differ considerably for different types of farm households, not all farmers would be equally willing to pay for market based commodity insurance. This is because farmers will differ in their consumption smoothing behavior as well as in their attitudes towards risk. The general finding from the empirical analysis was that 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. This suggests that the total demand for market based commodity price insurance will depend on the structure of the commodity producing households.

The analysis concerned cocoa and Ghana, and it is not clear whether the results would apply to other settings with different types of commodities, and producers. For instance, it is not clear at all, a-priori, as was found for Ghana, that the more dependent a household is on the insurable commodity, the larger will be his overall income coefficient of variation. This clearly depends on the portfolio of activities, coupled with the stochastic nature of these activities, and is not expected to be the same in every country, and for every commodity. The same holds as far as the risk and consumption smoothing characteristics of households are concerned. While a range of reasonable values was considered, it is not clear whether the bulk of the cocoa producing households in Ghana will have parameters compatible with significant WTP. This suggests that several similar studies for other commodities and countries, and also panel survey based studies to obtain the relevant parameters are needed, before one concludes beyond reasonable doubt, that there is significant benefit as well as demand for providing market based commodity price insurance, on a large scale..

While the analysis here considered only price insurance, the theoretical framework could readily be applied to yield insurance as well. While there may be considerable WTP for yield insurance by farmers, from an insurer's viewpoint there are considerable moral hazard problems, as yield can be influenced by farmers. This is in contrast to price insurance, which is based on a variable that cannot be influenced by individual farmers. It is such moral hazard problems that have induced the search for alternatives such as rainfall insurance. Nevertheless, the WTP for rainfall insurance can be estimated with similar methods, but this is something that is left for future research.

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Appendix. Covariance between the return to price insurance and the underlying price of the crop.

Consider the covariance between the return to the price insurance contract and the price of the underlying commodity, that was encountered in formula (29) in the text (the superscripts r and the subscript c are eliminated for simplicity of notation).

$$\begin{aligned}&E[(r-E(r))(\Delta p)]=E[(r-E(r))(p-p^{e})]=\\&\Pr ob(r=0)E[(-E(r))(p-p^{e})|(p\geq p_{S}]+\\&\Pr ob(r>0)E[(r-E(r))(p-p^{e})|(p<p_{S})]\end{aligned} \tag{A1}$$

The expectation of r can be derived from standard formulas for the expected value of a truncated normal variable (Greene, 2000, p. 907), and is not discussed further.

The following formulas now apply.

$$\Pr ob(r=0)=\Pr ob(p\geq p_{S})=1-\Phi(b) \tag{A2}$$

$$\Pr ob(r>0)=\Pr ob(p<p_{S})=\Phi(b) \tag{A3}$$

Where ϕ and Φ will denote the probability distribution and cumulative distribution of the standardized normal variable., and:

$$b=\frac{(p_{S}-p^{e})}{s} \tag{A4}$$

The term multiplying the first probability in the last part of (A1) can be written using the formulas for the expected value and variance of a truncated normal variable as follows.

$$E[(-E(r))(p-p^{e})|(p\geq p_{S}]=-E(r)E[(p-p^{e})|(p\geq p_{S})]=-E(r)s\ \frac{f(b)}{1-\Phi(b)} \tag{A5}$$

To estimate the term multiplying the second probability in the last part of (A1) we define the following expectation.

$$p_{S}^{e}\equiv E[p|(p<p_{S})]=p^{e}-s\ \frac{f(b)}{\Phi(b)}$$

Then we can write the term multiplying the second probability in the last part of (A1) as follows

$$\begin{aligned}&E[(r-E(r))(p-p^{e})|(p<p_{S})]=E[(p_{S}-p-E(r))(p-p^{e})|(p<p_{S})]=\\&E[(p_{S}-p_{S}^{e}-E(r)-(p-p_{S}^{e}))(p-p_{S}^{e}+p_{S}^{e}-p^{e})|(p<p_{S})]=\\&(p_{S}-p_{S}^{e}-E(r))(p_{S}^{e}-p^{e})-Var[p|(p<p_{S})]=\\&(p_{S}-p_{S}^{e}-E(r))(p_{S}^{e}-p^{e})-s^{2}[1-d(b)]\end{aligned} \tag{A6}$$

Where

$$d(b)=l(b)[l(b)-b] \qquad l(b)=-\frac{f(b)}{\Phi(b)} \tag{A7}$$

Table 1. Structure of income of cocoa producing households in the rural forest region

	Rural forest											
	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
Estimated number of households in Ghana	18668	50048	47133	106948	3983	11068	23540	64912	979	2855	23017	58395
Share of total households (%)	0.42	1.12	1.05	2.39	0.09	0.25	0.53	1.45	0.02	0.06	0.51	1.31
Share of total income from (%)												
Wages	26.79	21.94	1.34	2.19	16.58	14.49	1.93	2.01	0.00	41.84	1.06	1.03
Agriculture	40.95	30.09	90.60	87.93	44.74	44.07	90.26	90.57	51.50	55.56	89.71	92.34
Non-farm self-employment	23.25	30.71	4.68	5.84	28.41	15.64	3.02	4.43	12.90	0.00	4.41	3.65
Rents (actual and imputed)	1.66	3.73	1.34	1.18	1.20	2.37	1.87	0.93	28.33	2.28	2.30	1.53
Remittances	6.37	8.35	1.56	2.41	3.45	10.58	2.87	1.79	5.64	0.32	1.62	0.94
Other activities	0.98	5.18	0.48	0.45	5.62	12.86	0.05	0.27	1.63	0.00	0.90	0.51
Per capita income (000 cedi/year)	338	1102	446	1028	678	783	371	1183	204	813	495	1199
Per capita expenditure (000 cedi/year)	458	1633	490	1241	420	1232	525	1275	596	1016	498	1433
Share of total income from (%)												
Cocoa	6.77	6.08	8.61	8.87	26.42	26.13	31.73	28.60	42.16	46.85	53.47	56.59
Cereals	2.16	1.31	5.33	3.01	0.11	1.49	3.45	1.95	0.00	0.00	1.62	1.84
Other Cash Crops	0.28	1.51	0.45	0.51	0.00	0.00	0.86	0.08	0.00	0.00	0.05	0.07
Roots	2.80	3.23	18.37	14.36	0.39	0.13	5.28	10.98	0.00	0.00	1.92	2.47
Fruits	0.52	0.89	8.55	10.82	0.74	0.33	3.18	3.98	0.00	0.00	1.84	0.52
Vegetables	0.14	1.08	7.08	4.30	0.60	1.68	2.06	1.99	0.00	0.00	0.72	0.63
Processed Crops	4.48	1.21	11.59	10.57	2.23	0.00	3.37	5.43	0.00	0.00	6.75	3.38
Other Agriculture	0.07	0.22	1.78	0.94	0.06	0.25	2.70	0.33	0.00	0.24	0.25	0.50
Consumption of own Production	23.74	14.56	28.84	34.55	14.19	14.06	37.64	37.23	9.35	8.47	23.08	26.34
All agriculture	40.95	30.09	90.60	87.93	44.74	44.07	90.26	90.57	51.50	55.56	89.71	92.34

Source. Author’s calculations from the GLSS

Table 2. Structure of income of cocoa producing households in the other rural areas

	Other rural											
	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
Estimated number of households in Ghana	6957	14251	8975	11411		1980	389	2279	643		2421	1031
Share of total households (%)	0.16	0.32	0.20	0.26		0.04	0.01	0.05	0.01		0.05	0.02
Share of total income from (%)												
Wages	0.00	23.57	1.52	3.63		26.41	0.00	10.71	0.00		0.00	0.00
Agriculture	45.31	33.11	82.09	85.30		49.16	97.97	80.13	54.92		98.10	97.20
Non-farm self-employment	40.42	33.98	9.17	8.50		10.71	0.00	0.00	0.00		0.00	0.00
Rents (actual and imputed)	2.07	0.79	3.01	0.90		8.83	2.03	6.29	16.75		1.39	2.60
Remittances	12.06	5.43	3.34	1.07		1.58	0.00	1.87	28.34		0.50	0.20
Other activities	0.14	3.12	0.86	0.59		3.32	0.00	1.00	0.00		0.00	0.00
Per capita income (000 cedi/year)	276	871	188	922		625	509	513	176		502	222
Per capita expenditure (000 cedi/year)	455	961	459	1247		1045	531	1209	116		440	1077
Share of total income from (%)												
Cocoa	5.80	2.55	10.64	6.57		35.08	37.59	23.14	42.51		61.63	48.49
Cereals	1.95	3.87	3.90	4.19		1.06	1.96	2.38	0.00		1.18	0.00
Other Cash Crops	0.07	0.17	-0.01	0.38		0.73	0.98	2.12	0.00		0.07	0.00
Roots	8.39	6.62	7.09	11.31		0.00	0.00	18.59	0.00		3.09	4.84
Fruits	7.23	0.00	3.97	8.77		0.00	0.00	0.00	0.00		0.00	0.00
Vegetables	1.55	0.00	0.21	2.41		0.28	0.00	0.99	0.00		2.63	0.00
Processed Crops	0.00	0.00	9.64	5.13		0.00	2.56	0.00	0.00		0.00	0.00
Other Agriculture	4.77	9.33	0.67	0.67		0.91	0.00	0.24	0.00		0.00	0.58
Consumption of own Production	15.54	10.56	45.98	45.88		11.10	54.88	32.68	12.41		29.50	43.29
All agriculture	45.31	33.11	82.09	85.30		49.16	97.97	80.13	54.92		98.10	97.20

Source. Author's calculations from the GLSS

Table 3. Structure of income of cocoa producing households in urban areas

	Urban											
	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
Estimated number of households in Ghana	5254	10081	4140	3273	411	1719	4409	5014			2227	3378
Share of total households (%)	0.12	0.23	0.09	0.07	0.01	0.04	0.10	0.11			0.05	0.08
Share of total income from (%)												
Wages	37.83	7.97	1.25	2.79	0.00	42.75	0.00	0.00			0.00	0.00
Agriculture	24.39	10.05	88.96	91.70	57.19	34.68	81.82	68.27			88.37	78.53
Non-farm self-employment	22.21	64.68	4.28	0.00	0.00	17.87	6.01	22.05			0.00	9.14
Rents (actual and imputed)	4.27	1.40	2.88	0.76	2.24	0.00	3.00	1.47			8.19	4.81
Remittances	3.58	8.59	2.11	4.75	0.00	4.26	9.17	7.49			3.38	7.34
Other activities	7.72	7.31	0.52	0.00	40.57	0.43	0.00	0.72			0.06	0.19
Per capita income (000 cedi/year)	342	816	297	1027	320	667	416	1035			377	408
Per capita expenditure (000 cedi/year)	476	1543	484	1372	506	4355	615	1890			452	1020
Share of total income from (%)												
Cocoa	7.80	2.29	12.42	3.56	26.42	23.51	26.40	24.79			70.01	60.68
Cereals	0.91	0.46	4.47	4.45	0.00	1.69	4.01	2.74			1.14	2.55
Other Cash Crops	0.03	0.43	2.99	0.03	0.00	0.13	0.06	0.20			1.89	0.00
Roots	1.23	0.34	28.02	25.82	0.00	0.00	15.11	5.61			0.77	0.43
Fruits	0.00	0.31	9.50	21.59	20.18	0.00	2.65	3.14			3.92	0.00
Vegetables	0.00	0.26	3.84	2.63	0.00	0.00	2.39	1.35			0.62	0.00
Processed Crops	2.06	1.17	2.53	3.57	0.00	0.00	0.00	0.00			0.00	0.00
Other Agriculture	0.20	0.16	0.18	0.34	0.00	3.49	1.08	2.17			0.31	1.09
Consumption of own Production	12.16	4.62	25.00	29.71	10.59	5.86	30.11	28.28			9.71	13.79
All agriculture	24.39	10.05	88.96	91.70	57.19	34.68	81.82	68.27			88.37	78.53

Source. Author's calculations from the GLSS

Table 4. Coefficients of variation and correlation matrix of domestic production yields (only significant correlations at 10% or better are shown)

		Correlation matrix						
	Coefficient of variation	Cocoa	Maize	Groundnuts	Cassava	Plantain	Onions	Consumption of own Production
Cocoa	0.200	1.000						
Maize	0.176	0.452	1.000					
Groundnuts	0.225	-0.288		1.000				
Cassava	0.132		0.496	-0.566	1.000			
Plantain	0.116	0.366	0.563		0.440	1.000		
Onions	0.167		-0.281		-0.519	-0.358	1.000	
Consumption of own Production	0.128		0.611	-0.539	0.990	0.491	-0.518	1.000

Source. Computed by author

Table 5. Results of time series regressions for world monthly prices of products relevant to Ghana (Dependent variable is $\Delta \ln x_t$ where x_t is the deflated world monthly price of the reported commodity)

	Cocoa		Maize		Banana		Groundnuts	
Independent variable	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
Constant	0.0345*	1.777	0.0336**	2.142	0.6633***	5.998	0.1175***	2.950
Linear trend	-0.0001**	-1.991	-0.0002**	-2.115	-0.0008***	-3.730	-0.0001**	-2.229
$\Delta \ln x_{t-1}$	0.1560***	3.045	0.2960***	4.636	-0.4703***	-6.923	0.3549***	5.681
$\ln x_{t-2}$	-0.0181**	-2.199	-0.0484***	-2.805	-0.3656***	-6.000	-0.0480***	-3.093
January	0.0194	1.162	-0.0003	-0.019	0.1179**	2.231	-0.0020	-0.115
February	-0.0187	-1.120	-0.0167	-1.032	0.1926***	3.578	-0.0141	-0.815
March	0.0101	0.609	0.0158	0.991	0.0768	1.394	0.0058	0.341
April	-0.0169	-1.010	-0.0182	-1.125	0.0611	1.080	0.0190	1.100
May	-0.0059	-0.353	-0.0048	-0.295	-0.0254	-0.451	0.0077	0.444
June	-0.0094	-0.564	-0.0066	-0.405	-0.0520	-0.934	0.0068	0.392
July	0.0132	0.792	-0.0378**	-2.331	-0.0372	-0.686	-0.0010	-0.059
August	-0.0096	-0.577	-0.0260	-1.587	-0.0274	-0.511	0.0158	0.916
September	0.0111	0.668	-0.0236	-1.441	0.0020	0.038	-0.0254	-1.464
October	-0.0184	-1.101	0.0046	0.279	-0.1292**	-2.430	0.0079	0.453
November	0.0019	0.112	-0.0014	-0.084	-0.0440	-0.820	0.0043	0.246
Adjusted R-squared	0.0344		0.1686		0.3055		0.1719	
S.E. of regression	0.0667		0.0498		0.1627		0.0533	

Source. Computed by author. One asterisk denotes significance at the 10 % level, two asterisks denote significance at 5%, and three asterisks denote significance at 1%.

Table 6. Results of time series regressions for domestic monthly prices of products relevant to Ghana (Dependent variable is $\Delta \ln x_t$ where x_t is the deflated domestic monthly national wholesale price of the reported commodity, and XW is the relevant world price. Estimation period is 1983-1999)

	Maize		Groundnut		Plantain	
	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
Constant	-0.4746	-0.612	1.1206**	2.488	1.9182	1.629
Linear trend	-0.0004	-1.525	-0.0007***	-3.276	0.0005	1.131
lnX(t-2)	-0.0843***	-3.040	-0.2595***	-4.440	-0.3408***	-5.071
ΔlnX(t-1)	-0.1321*	-1.820	-0.5443***	-7.786	-0.5333***	-7.394
ΔlnXW(t)	-0.1153	-0.696	0.1820	1.230	0.0953	1.117
ΔlnXW(t-1)	-0.0713	-0.412	-0.0441	-0.279	0.0261	0.291
ΔlnXW(t-2)	0.0016	0.010	0.0444	0.299	-0.0574	-0.673
lnPRODX(t)	0.0794	1.307	0.0610**	2.083	-0.0687	-0.798
January	0.0297	0.738	0.0073	0.180	-0.0375	-0.500
February	-0.0102	-0.253	0.0740*	1.816	0.0178	0.230
March	0.0379	0.926	0.0304	0.737	-0.0254	-0.322
April	0.0897**	2.215	0.0532	1.307	0.0233	0.307
May	0.0118	0.293	0.0562	1.376	0.3656***	4.914
June	0.0127	0.308	0.0308	0.748	0.2156***	2.749
July	-0.0865**	-2.059	0.0760*	1.842	0.1905**	2.568
August	-0.2786***	-6.326	0.0441	1.059	0.1404*	1.891
September	-0.2485***	-5.003	-0.1018**	-2.411	0.0565	0.763
October	0.0011	0.023	-0.1113**	-2.586	-0.0126	-0.169
November	0.1079***	2.711	-0.0285	-0.693	-0.0008	-0.011
Adjusted R-squared	0.5052		0.3158		0.3366	
S.E. of regression	0.1129		0.1150		0.2094	

Source. Computed by author. One asterisk denotes significance at the 10 % level, two asterisks denote significance at 5%, and three asterisks denote significance at 1%.

Table 7 Results of time series regressions for domestic monthly prices of products relevant to Ghana (Dependent variable is D$\ln x_t$ where x_t is the deflated domestic monthly national wholesale price of the reported commodity. Estimation period is 1970-1999)

	Maize		Groundnut		Plantain		Cassava		Onions	
	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
Constant	0.7028*	1.873	0.9172***	2.604	0.6835	0.880	2.7962**	2.307	2.3876***	6.550
Linear trend	-0.0003*	-1.918	-0.0003***	-3.672	0.0002	1.075	0.0001	0.107	-0.0007***	-4.705
lnX(t-2)	-0.1152***	-4.174	-0.1784***	-4.910	-0.2894***	-6.204	-0.2402***	-6.018	-0.3355***	-7.742
ΔlnX(t-1)	-0.2404***	-4.480	-0.4653***	-8.950	-0.5328***	-10.007	-0.3894***	-7.259	-0.2918***	-5.393
lnPRODX(t)	-0.0004	-0.014	0.0248	1.046	0.0132	0.234	-0.1113	-1.331	0.0018	0.092
January	0.0918**	2.438	0.0501	1.610	0.0051	0.089	0.1714**	2.149	-0.2014***	-4.208
February	0.0691*	1.862	0.0834***	2.668	-0.0415	-0.724	0.0830	1.030	-0.1985***	-4.015
March	0.0416	1.122	0.0575**	1.850	-0.0507	-0.881	-0.0534	-0.674	-0.2948***	-5.996
April	0.1103***	2.955	0.0507	1.633	-0.0965*	-1.670	0.0936	1.186	-0.2015***	-3.920
May	0.1013***	2.722	0.0607**	1.958	0.3337***	5.725	0.0397	0.500	-0.1185**	-2.289
June	0.0608	1.613	0.0439	1.403	0.2677***	4.408	-0.0412	-0.521	-0.0678	-1.323
July	-0.0437	-1.144	0.0770**	2.463	0.2094***	3.603	-0.0420	-0.532	0.0150	0.299
August	-0.2158***	-5.530	0.0401	1.273	0.1002*	1.707	0.0248	0.315	-0.0112	-0.230
September	-0.1935***	-4.710	-0.0832***	-2.643	0.0102	0.174	0.0084	0.106	-0.0201	-0.422
October	0.0397	1.005	-0.0589**	-1.855	-0.0567	-0.977	0.0657	0.825	-0.0267	-0.564
November	0.1168***	3.172	-0.0188	-0.604	-0.0091	-0.158	-0.0663	-0.830	0.0257	0.544
Adjusted R-squared	0.3708		0.2548		0.379829		0.1686		0.3273	
S.E. of regression	0.1420		0.1185		0.218147		0.3025		0.1828	

Source. Computed by author. One asterisk denotes significance at the 10 % level, two asterisks denote significance at 5%, and three asterisks denote significance at 1%.

Table 8. Coefficients of variation and correlation matrix of domestic real prices.

	Coefficient of variation	Maize	Cassava	Groundnut	Plantain	Onion
Maize	0.142	1.000				
Cassava	0.303	0.097	1.000			
Groundnut	0.118	0.094		1.000		
Plantain	0.218				1.000	
Onion	0.183	0.121		0.088		1.000

Source. Computed by author.

Table 9. Actuarially fair premium for a minimum price insurance contract for cocoa at different strike prices. All figures are expressed as percent of the expected future price

	Strike price as percent of expected (futures) price				
Months before contract expiration	-10	-5	0	5	10
1	0.20	0.88	2.66	5.86	10.16
2	0.88	2.04	4.05	7.00	10.80
3	1.59	2.98	5.07	7.92	11.47
4	2.22	3.74	5.87	8.66	12.06
5	2.77	4.38	6.54	9.28	12.57
6	3.27	4.93	7.11	9.81	13.03
7	3.71	5.42	7.61	10.28	13.43
8	4.11	5.85	8.04	10.69	13.79
9	4.47	6.24	8.43	11.06	14.11
10	4.80	6.59	8.78	11.39	14.40
11	5.10	6.90	9.10	11.69	14.67
12	5.38	7.19	9.38	11.95	14.90

Source. Computed by author.

Table 10. 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)	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 June 5, 2002						
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
	1700	9.45	11.73	11.18	0.55	4.65
Cocoa option prices NYBOT Feb 2, 2001						
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
	1200	13.42	16.82	14.41	2.42	14.37
Cocoa option prices NYBOT April 4, 2000						
Three months ahead (July 2000)						
838	700	-16.47	0.95	0.61	0.35	36.14
	750	-10.50	2.03	1.50	0.53	26.04
	800	-4.53	4.18	3.18	1.00	23.92
	850	1.43	7.28	5.88	1.40	19.26
	900	7.40	11.58	9.66	1.92	16.59
	950	13.37	16.23	14.36	1.87	11.53

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

Table 11. 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)	Put option price as share of futures price (% of future 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 option prices NYBOT July 5, 2000						
Two months ahead (September 2000)						
841	750	-10.82	0.59	0.76	-0.17	-28.45
	800	-4.88	1.90	2.10	-0.20	-10.38
	850	1.07	5.11	4.64	0.47	9.24
	900	7.02	9.16	8.51	0.64	7.01
	950	12.96	14.27	13.46	0.81	5.66
	1000	18.91	19.74	19.04	0.70	3.56
Five months ahead (December 2000)						
878	750	-14.58	2.05	1.77	0.28	13.68
	800	-8.88	4.10	3.15	0.95	23.14
	850	-3.19	6.83	5.20	1.63	23.91
	900	2.51	10.25	8.00	2.25	21.94
	950	8.20	14.01	11.56	2.45	17.48
	1000	13.90	18.45	15.80	2.65	14.37
Cocoa option prices NYBOT July 2, 1999						
Two months ahead (September 1999)						
1048	950	-9.35	1.34	1.00	0.33	24.97
	1000	-4.58	2.39	2.20	0.19	7.98
	1050	0.19	4.77	4.18	0.59	12.41
	1100	4.96	7.82	7.03	0.79	10.10
	1150	9.73	11.55	10.67	0.88	7.60
	1200	14.50	15.55	14.87	0.69	4.43
Five months ahead (December,1999)						
1084	950	-12.36	3.04	2.24	0.81	26.54
	1000	-7.75	4.52	3.50	1.02	22.51
	1050	-3.14	6.46	5.22	1.24	19.13
	1100	1.48	8.76	7.44	1.33	15.13
	1150	6.09	11.90	10.16	1.75	14.67
	1200	10.70	15.41	13.34	2.06	13.38

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

Table 12. Coefficient of variation of income of Ghanaian cocoa producing households due to agricultural uncertainties (all figure in percentage)

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
Rural forest											
4.9	3.7	10.1	9.7	12.0	12.0	15.7	14.9	19.0	21.1	24.4	25.8
Other rural											
5.6	3.7	9.4	9.7	NA	15.8	18.4	13.6	19.2	NA	28.0	22.7
Urban											
4.0	1.2	13.0	13.1	13.4	10.7	14.4	12.4	NA	NA	31.5	27.4

Source. Computed by author.

Note. A NA for a group means that there no households in the relevant class

Table 13. WTP (as share of cocoa income) of Ghanaian cocoa producing households in rural forest region for cocoa price insurance at various levels

	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
Strike price relative to future expected price (%)	WTP (share of cocoa income) for price insurance for a fixed 100% of average production with theta=0.2 and 6 months in advance											
10.00	13.5	13.3	14.6	14.5	13.8	13.8	14.1	14.1	14.3	14.4	14.7	14.8
5.00	10.3	10.1	11.4	11.2	10.6	10.6	10.9	10.9	11.1	11.2	11.4	11.5
0.00	7.6	7.4	8.7	8.5	7.9	7.9	8.2	8.2	8.3	8.5	8.7	8.8
-5.00	5.4	5.2	6.5	6.4	5.7	5.7	6.0	6.0	6.1	6.3	6.5	6.6
-10.00	3.8	3.6	4.9	4.7	4.0	4.0	4.3	4.4	4.5	4.6	4.8	4.9
	WTP (share of cocoa income) for price insurance for a fixed 100% of average production with theta=0.2 and 12 months in advance											
10.00	15.4	15.2	16.5	16.3	15.8	15.8	16.1	16.1	16.2	16.4	16.6	16.7
5.00	12.5	12.3	13.6	13.4	12.8	12.8	13.1	13.1	13.3	13.4	13.7	13.8
0.00	9.9	9.7	11.0	10.8	10.2	10.2	10.5	10.5	10.7	10.8	11.1	11.2
-5.00	7.7	7.5	8.8	8.6	8.0	8.0	8.3	8.3	8.5	8.6	8.8	8.9
-10.00	5.9	5.7	7.0	6.8	6.2	6.2	6.5	6.5	6.6	6.8	7.0	7.1
	WTP (share of cocoa income) for price insurance for a fixed 100% of average production with theta=1 and 6 months in advance											
10.00	15.5	14.6	21.1	20.2	17.0	17.0	18.6	18.6	19.3	20.0	21.2	21.6
5.00	12.3	11.4	17.8	16.9	13.8	13.8	15.4	15.4	16.0	16.7	17.9	18.4
0.00	9.5	8.7	15.1	14.2	11.0	11.0	12.6	12.6	13.2	13.9	15.1	15.6
-5.00	7.4	6.5	12.9	12.0	8.8	8.8	10.4	10.4	11.0	11.7	12.8	13.3
-10.00	5.7	4.8	11.2	10.3	7.1	7.1	8.7	8.7	9.3	9.9	11.0	11.5
	WTP (share of cocoa income) for price insurance for a fixed 100% of average production with theta=1 and 12 months in advance											
10.00	17.4	16.6	23.0	22.1	19.2	19.2	20.8	20.8	21.6	22.3	23.5	24.1
5.00	14.5	13.6	20.1	19.2	16.2	16.2	17.8	17.8	18.5	19.3	20.5	21.0
0.00	11.9	11.0	17.5	16.6	13.5	13.5	15.1	15.1	15.9	16.6	17.8	18.3
-5.00	9.7	8.8	15.2	14.4	11.3	11.3	12.9	12.9	13.6	14.3	15.5	16.0
-10.00	7.8	7.0	13.4	12.5	9.4	9.4	11.0	11.0	11.7	12.4	13.5	14.0
	WTP (share of cocoa income) for price insurance for a fixed 100% of average production with theta=2.4 and 6 months in advance											
10.00	17.7	16.1	28.2	26.5	20.7	20.7	23.7	23.7	25.1	26.4	28.7	29.6
5.00	14.4	12.8	24.9	23.2	17.4	17.4	20.4	20.4	21.7	23.0	25.3	26.2
0.00	11.7	10.1	22.2	20.5	14.6	14.6	17.6	17.6	18.9	20.2	22.4	23.3
-5.00	9.5	7.9	20.0	18.3	12.3	12.3	15.3	15.3	16.5	17.8	19.9	20.8
-10.00	7.8	6.2	18.3	16.6	10.6	10.5	13.5	13.5	14.6	15.9	18.0	18.9
	WTP (share of cocoa income) for price insurance for a fixed 100% of average production with theta=2.4 and 12 months in advance											
10.00	19.7	18.1	30.2	28.6	23.2	23.2	26.3	26.3	27.9	29.4	31.8	32.8
5.00	16.7	15.1	27.2	25.6	20.2	20.1	23.3	23.2	24.8	26.2	28.6	29.5
0.00	14.1	12.5	24.6	22.9	17.4	17.4	20.5	20.5	22.0	23.4	25.7	26.7
-5.00	11.9	10.3	22.4	20.7	15.1	15.1	18.1	18.1	19.5	20.9	23.2	24.2
-10.00	10.0	8.4	20.5	18.8	13.1	13.1	16.1	16.1	17.5	18.8	21.1	22.0

Source. Computed by author

Table 14. WTP (as share of cocoa income) of Ghanaian cocoa producing households in other rural regions for cocoa price insurance at various levels

	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	6957	14251	8975	11411	0	1980	389	2279	643	0	2421	1031
Share of total income from cocoa (%)	5.8	2.6	10.6	6.6	0.0	35.1	37.6	23.1	42.5	0.0	61.6	48.5
Strike price relative to future expected price (%)	WTP (share of cocoa income) for price insurance for a fixed 100% of average production with theta=0.2 and 6 months in advance											
10.00	13.8	13.8	14.2	15.0		14.1	14.3	14.2	14.3		14.9	14.6
5.00	10.5	10.5	10.9	11.7		10.9	11.1	10.9	11.1		11.7	11.3
0.00	7.8	7.8	8.2	9.0		8.1	8.4	8.2	8.4		8.9	8.6
-5.00	5.7	5.7	6.0	6.9		5.9	6.2	6.0	6.2		6.7	6.4
-10.00	4.0	4.0	4.4	5.2		4.3	4.5	4.4	4.5		5.1	4.8
	WTP (share of cocoa income) for price insurance for a fixed 100% of average production with theta=0.2 and 12 months in advance											
10.00	15.6	15.6	16.0	16.8		16.0	16.3	16.1	16.2		16.9	16.5
5.00	12.7	12.7	13.1	13.9		13.1	13.3	13.1	13.3		13.9	13.6
0.00	10.1	10.1	10.5	11.3		10.5	10.7	10.5	10.7		11.3	11.0
-5.00	7.9	7.9	8.3	9.1		8.3	8.5	8.3	8.5		9.1	8.8
-10.00	6.1	6.1	6.5	7.3		6.4	6.7	6.5	6.6		7.3	6.9
	WTP (share of cocoa income) for price insurance for a fixed 100% of average production with theta=1 and 6 months in advance											
10.00	16.7	16.7	18.7	22.7		18.3	19.5	18.7	19.4		22.4	20.8
5.00	13.4	13.4	15.4	19.5		15.0	16.3	15.4	16.1		19.1	17.5
0.00	10.7	10.7	12.7	16.8		12.3	13.5	12.7	13.3		16.3	14.7
-5.00	8.5	8.5	10.5	14.6		10.0	11.3	10.5	11.1		14.0	12.4
-10.00	6.9	6.9	8.8	12.9		8.3	9.5	8.8	9.3		12.2	10.7
	WTP (share of cocoa income) for price insurance for a fixed 100% of average production with theta=1 and 12 months in advance											
10.00	18.6	18.5	20.6	24.6		20.5	21.8	20.8	21.6		24.8	23.1
5.00	15.6	15.6	17.7	21.7		17.5	18.7	17.8	18.6		21.8	20.1
0.00	13.0	13.0	15.1	19.1		14.8	16.1	15.2	15.9		19.1	17.4
-5.00	10.8	10.8	12.8	16.9		12.5	13.8	12.9	13.7		16.7	15.1
-10.00	9.0	9.0	11.0	15.0		10.6	11.9	11.0	11.7		14.8	13.1
	WTP (share of cocoa income) for price insurance for a fixed 100% of average production with theta=2.4 and 6 months in advance											
10.00	19.9	19.8	23.7	31.2		23.1	25.5	23.8	25.2		31.0	27.9
5.00	16.6	16.6	20.4	28.0		19.8	22.2	20.5	21.9		27.6	24.5
0.00	13.9	13.9	17.7	25.2		16.9	19.3	17.7	19.0		24.6	21.6
-5.00	11.7	11.7	15.4	23.0		14.6	17.0	15.4	16.6		22.2	19.2
-10.00	10.0	10.0	13.7	21.3		12.8	15.1	13.7	14.8		20.2	17.3
	WTP (share of cocoa income) for price insurance for a fixed 100% of average production with theta=2.4 and 12 months in advance											
10.00	21.9	21.8	25.8	33.2		25.8	28.2	26.2	28.1		34.3	30.9
5.00	18.9	18.8	22.8	30.3		22.7	25.1	23.1	24.9		31.1	27.7
0.00	16.3	16.2	20.1	27.6		19.9	22.3	20.4	22.1		28.2	24.9
-5.00	14.1	14.0	17.9	25.4		17.5	19.9	18.1	19.7		25.6	22.4
-10.00	12.2	12.2	16.0	23.6		15.5	17.9	16.2	17.6		23.4	20.3

Source. Computed by author

Table 15. WTP (as share of cocoa income) of Ghanaian cocoa producing households in urban regions for cocoa price insurance at various levels

	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	5254	10081	4140	3273	411	1719	4409	5014	0	0	2227	3378
Share of total income from cocoa (%)	7.8	2.3	12.4	3.6	26.4	23.5	26.4	24.8	0.0	0.0	70.0	60.7
Strike price relative to future expected price (%)	WTP (share of cocoa income) for price insurance for a fixed 100% of average production with theta=0.2 and 6 months in advance											
10.00	13.3	13.1	14.9	19.5	14.0	13.7	14.2	13.9			15.1	14.8
5.00	10.1	9.9	11.7	16.3	10.8	10.5	10.9	10.7			11.9	11.6
0.00	7.4	7.2	9.0	13.6	8.1	7.8	8.2	8.0			9.2	8.9
-5.00	5.2	5.0	6.8	11.4	5.9	5.6	6.0	5.8			7.0	6.7
-10.00	3.6	3.4	5.1	9.7	4.2	3.9	4.4	4.1			5.3	5.0
	WTP (share of cocoa income) for price insurance for a fixed 100% of average production with theta=0.2 and 12 months in advance											
10.00	15.2	15.0	16.8	21.4	15.9	15.7	16.1	15.8			17.1	16.8
5.00	12.3	12.1	13.8	18.4	13.0	12.7	13.1	12.9			14.1	13.9
0.00	9.7	9.5	11.3	15.9	10.4	10.1	10.5	10.3			11.5	11.3
-5.00	7.5	7.3	9.1	13.7	8.2	7.9	8.3	8.1			9.3	9.0
-10.00	5.7	5.5	7.2	11.9	6.4	6.1	6.5	6.3			7.5	7.2
	WTP (share of cocoa income) for price insurance for a fixed 100% of average production with theta=1 and 6 months in advance											
10.00	14.5	13.5	22.3	45.4	17.9	16.6	18.6	17.5			23.5	22.1
5.00	11.3	10.3	19.1	42.2	14.7	13.3	15.4	14.3			20.2	18.8
0.00	8.6	7.6	16.4	39.5	11.9	10.6	12.6	11.5			17.3	16.0
-5.00	6.4	5.4	14.2	37.3	9.7	8.4	10.4	9.3			15.0	13.7
-10.00	4.7	3.7	12.5	35.6	8.0	6.7	8.7	7.6			13.2	12.0
	WTP (share of cocoa income) for price insurance for a fixed 100% of average production with theta=1 and 12 months in advance											
10.00	16.4	15.4	24.3	47.3	20.1	18.7	20.8	19.6			26.0	24.6
5.00	13.5	12.4	21.3	44.4	17.1	15.7	17.8	16.6			22.9	21.5
0.00	10.9	9.9	18.7	41.8	14.4	13.1	15.1	14.0			20.2	18.8
-5.00	8.7	7.7	16.5	39.6	12.2	10.8	12.9	11.7			17.8	16.5
-10.00	6.9	5.9	14.7	37.8	10.3	8.9	11.0	9.9			15.8	14.5
	WTP (share of cocoa income) for price insurance for a fixed 100% of average production with theta=2.4 and 6 months in advance											
10.00	15.8	13.9	30.5	73.8	22.4	19.8	23.7	21.6			33.1	30.5
5.00	12.6	10.7	27.3	70.5	19.1	16.6	20.4	18.3			29.7	27.1
0.00	9.9	8.0	24.5	67.8	16.3	13.8	17.6	15.5			26.7	24.2
-5.00	7.7	5.8	22.3	65.6	14.0	11.5	15.3	13.2			24.2	21.7
-10.00	6.0	4.1	20.6	63.9	12.2	9.7	13.5	11.4			22.2	19.8
	WTP (share of cocoa income) for price insurance for a fixed 100% of average production with theta=2.4 and 12 months in advance											
10.00	17.9	15.9	32.7	75.7	24.9	22.3	26.2	24.0			36.6	33.8
5.00	14.9	12.9	29.7	72.7	21.8	19.2	23.1	21.0			33.3	30.6
0.00	12.3	10.3	27.0	70.2	19.1	16.5	20.4	18.3			30.4	27.7
-5.00	10.1	8.1	24.8	67.9	16.8	14.2	18.1	15.9			27.8	25.1
-10.00	8.2	6.3	22.9	66.1	14.8	12.2	16.1	14.0			25.5	22.9

Source. Computed by author

Table 16. WTP (share of total income) of Ghanaian cocoa producing households in rural forest region for cocoa price insurance at various levels

	Share of cocoa in household income											
	0-20%				20-40%				>40%			
	Share of agricult ure 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
Strike price relative to future expected price (%)	WTP (share of total income) for price insurance for a fixed 100% of average production with theta=0.2 and 6 months in advance											
10.00	0.9	0.8	1.3	1.3	3.7	3.6	4.5	4.0	6.0	6.8	7.8	8.3
5.00	0.7	0.6	1.0	1.0	2.8	2.8	3.5	3.1	4.7	5.2	6.1	6.5
0.00	0.5	0.5	0.8	0.8	2.1	2.1	2.6	2.3	3.5	4.0	4.7	5.0
-5.00	0.4	0.3	0.6	0.6	1.5	1.5	1.9	1.7	2.6	2.9	3.5	3.7
-10.00	0.3	0.2	0.4	0.4	1.1	1.1	1.4	1.2	1.9	2.2	2.6	2.8
	WTP (share of total income) for price insurance for a fixed 100% of average production with theta=0.2 and 12 months in advance											
10.00	1.0	0.9	1.4	1.4	4.2	4.1	5.1	4.6	6.8	7.7	8.9	9.5
5.00	0.8	0.7	1.2	1.2	3.4	3.3	4.2	3.8	5.6	6.3	7.3	7.8
0.00	0.7	0.6	0.9	1.0	2.7	2.7	3.3	3.0	4.5	5.1	5.9	6.3
-5.00	0.5	0.5	0.8	0.8	2.1	2.1	2.6	2.4	3.6	4.0	4.7	5.1
-10.00	0.4	0.3	0.6	0.6	1.6	1.6	2.1	1.9	2.8	3.2	3.7	4.0
	WTP (share of total income) for price insurance for a fixed 100% of average production with theta=1 and 6 months in advance											
10.00	1.0	0.9	1.8	1.8	4.5	4.5	5.9	5.3	8.1	9.4	11.3	12.2
5.00	0.8	0.7	1.5	1.5	3.6	3.6	4.9	4.4	6.8	7.8	9.6	10.4
0.00	0.6	0.5	1.3	1.3	2.9	2.9	4.0	3.6	5.6	6.5	8.1	8.8
-5.00	0.5	0.4	1.1	1.1	2.3	2.3	3.3	3.0	4.6	5.5	6.8	7.5
-10.00	0.4	0.3	1.0	0.9	1.9	1.9	2.7	2.5	3.9	4.6	5.9	6.5
	WTP (share of total income) for price insurance for a fixed 100% of average production with theta=1 and 12 months in advance											
10.00	1.2	1.0	2.0	2.0	5.1	5.0	6.6	5.9	9.1	10.4	12.6	13.6
5.00	1.0	0.8	1.7	1.7	4.3	4.2	5.6	5.1	7.8	9.0	11.0	11.9
0.00	0.8	0.7	1.5	1.5	3.6	3.5	4.8	4.3	6.7	7.8	9.5	10.4
-5.00	0.7	0.5	1.3	1.3	3.0	2.9	4.1	3.7	5.7	6.7	8.3	9.0
-10.00	0.5	0.4	1.2	1.1	2.5	2.5	3.5	3.1	4.9	5.8	7.2	7.9
	WTP (share of total income) for price insurance for a fixed 100% of average production with theta=2.4 and 6 months in advance											
10.00	1.2	1.0	2.4	2.3	5.5	5.4	7.5	6.8	10.6	12.4	15.3	16.7
5.00	1.0	0.8	2.1	2.1	4.6	4.6	6.5	5.8	9.2	10.8	13.5	14.8
0.00	0.8	0.6	1.9	1.8	3.9	3.8	5.6	5.0	8.0	9.4	12.0	13.2
-5.00	0.6	0.5	1.7	1.6	3.3	3.2	4.8	4.4	7.0	8.3	10.7	11.8
-10.00	0.5	0.4	1.6	1.5	2.8	2.8	4.3	3.9	6.2	7.4	9.6	10.7
	WTP (share of total income) for price insurance for a fixed 100% of average production with theta=2.4 and 12 months in advance											
10.00	1.3	1.1	2.6	2.5	6.1	6.1	8.4	7.5	11.8	13.8	17.0	18.5
5.00	1.1	0.9	2.3	2.3	5.3	5.3	7.4	6.6	10.4	12.3	15.3	16.7
0.00	1.0	0.8	2.1	2.0	4.6	4.5	6.5	5.9	9.3	10.9	13.7	15.1
-5.00	0.8	0.6	1.9	1.8	4.0	3.9	5.8	5.2	8.2	9.8	12.4	13.7
-10.00	0.7	0.5	1.8	1.7	3.5	3.4	5.1	4.6	7.4	8.8	11.3	12.4

Source. Computed by author

Table 17. WTP (share of total income) of Ghanaian cocoa producing households in other rural regions for cocoa price insurance at various levels

	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	6957	14251	8975	11411	0	1980	389	2279	643	0	2421	1031
Share of total income from cocoa (%)	5.8	2.6	10.6	6.6	0.0	35.1	37.6	23.1	42.5	0.0	61.6	48.5
Strike price relative to future expected price (%)	WTP (share of total income) for price insurance for a fixed 100% of average production with theta=0.2 and 6 months in advance											
10.00	0.8	0.4	1.5	1.0	0.0	4.9	5.4	3.3	6.1	0.0	9.2	7.1
5.00	0.6	0.3	1.2	0.8	0.0	3.8	4.2	2.5	4.7	0.0	7.2	5.5
0.00	0.5	0.2	0.9	0.6	0.0	2.9	3.2	1.9	3.5	0.0	5.5	4.2
-5.00	0.3	0.1	0.6	0.5	0.0	2.1	2.3	1.4	2.6	0.0	4.2	3.1
-10.00	0.2	0.1	0.5	0.3	0.0	1.5	1.7	1.0	1.9	0.0	3.1	2.3
	WTP (share of total income) for price insurance for a fixed 100% of average production with theta=0.2 and 12 months in advance											
10.00	0.9	0.4	1.7	1.1	0.0	5.6	6.1	3.7	6.9	0.0	10.4	8.0
5.00	0.7	0.3	1.4	0.9	0.0	4.6	5.0	3.0	5.6	0.0	8.6	6.6
0.00	0.6	0.3	1.1	0.7	0.0	3.7	4.0	2.4	4.5	0.0	7.0	5.3
-5.00	0.5	0.2	0.9	0.6	0.0	2.9	3.2	1.9	3.6	0.0	5.6	4.3
-10.00	0.4	0.2	0.7	0.5	0.0	2.3	2.5	1.5	2.8	0.0	4.5	3.4
	WTP (share oftotal income) for price insurance for a fixed 100% of average production with theta=1 and 6 months in advance											
10.00	1.0	0.4	2.0	1.5	0.0	6.4	7.3	4.3	8.2	0.0	13.8	10.1
5.00	0.8	0.3	1.6	1.3	0.0	5.3	6.1	3.6	6.8	0.0	11.8	8.5
0.00	0.6	0.3	1.4	1.1	0.0	4.3	5.1	2.9	5.7	0.0	10.0	6.0
-5.00	0.5	0.2	1.1	1.0	0.0	3.5	4.2	2.4	4.7	0.0	8.6	6.0
-10.00	0.4	0.2	0.9	0.8	0.0	2.9	3.6	2.0	4.0	0.0	7.5	5.2
	WTP (share of total income) for price insurance for a fixed 100% of average production with theta=1 and 12 months in advance											
10.00	1.1	0.5	2.2	1.6	0.0	7.2	8.2	4.8	9.2	0.0	15.3	11.2
5.00	0.9	0.4	1.9	1.4	0.0	6.1	7.0	4.1	7.9	0.0	13.4	9.7
0.00	0.8	0.3	1.6	1.3	0.0	5.2	6.0	3.5	6.8	0.0	11.7	8.4
-5.00	0.6	0.3	1.4	1.1	0.0	4.4	5.2	3.0	5.8	0.0	10.3	7.3
-10.00	0.5	0.2	1.2	1.0	0.0	3.7	4.5	2.6	5.0	0.0	9.1	6.4
	WTP (share of total income) for price insurance for a fixed 100% of average production with theta=2.4 and 6 months in advance											
10.00	1.2	0.5	2.5	2.1	0.0	8.1	9.6	5.5	10.7	0.0	19.1	13.5
5.00	1.0	0.4	2.2	1.8	0.0	6.9	8.3	4.7	9.3	0.0	17.0	11.9
0.00	0.8	0.4	1.9	1.7	0.0	5.9	7.3	4.1	8.1	0.0	15.2	10.5
-5.00	0.7	0.3	1.6	1.5	0.0	5.1	6.4	3.6	7.1	0.0	13.7	9.3
-10.00	0.6	0.3	1.5	1.4	0.0	4.5	5.7	3.2	6.3	0.0	12.5	8.4
	WTP (share of total income) for price insurance for a fixed 100% of average production with theta=2.4 and 12 months in advance											
10.00	1.3	0.6	2.7	2.2	0.0	9.0	10.6	6.1	11.9	0.0	21.1	15.0
5.00	1.1	0.5	2.4	2.0	0.0	8.0	9.4	5.4	10.6	0.0	19.1	13.4
0.00	0.9	0.4	2.1	1.8	0.0	7.0	8.4	4.7	9.4	0.0	17.4	12.1
-5.00	0.8	0.4	1.9	1.7	0.0	6.1	7.5	4.2	8.4	0.0	15.8	10.9
-10.00	0.7	0.3	1.7	1.5	0.0	5.4	6.7	3.7	7.5	0.0	14.4	9.8

Source. Computed by author

Table 18. WTP (share of total income) of Ghanaian cocoa producing households in urban regions for cocoa price insurance at various levels

	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	5254	10081	4140	3273	411	1719	4409	5014	0	0	2227	3378
Share of total income from cocoa (%)	7.8	2.3	12.4	3.6	26.4	23.5	26.4	24.8	0.0	0.0	70.0	60.7
Strike price relative to future expected price (%)	WTP (share of total income) for price insurance for a fixed 100% of average production with theta=0.2 and 6 months in advance											
10.00	1.0	0.3	1.8	0.7	3.7	3.2	3.7	3.5	0.0	0.0	10.6	9.0
5.00	0.8	0.2	1.4	0.6	2.8	2.5	2.9	2.7	0.0	0.0	8.3	7.0
0.00	0.6	0.2	1.1	0.5	2.1	1.8	2.2	2.0	0.0	0.0	6.4	5.4
-5.00	0.4	0.1	0.8	0.4	1.6	1.3	1.6	1.4	0.0	0.0	4.9	4.1
-10.00	0.3	0.1	0.6	0.3	1.1	0.9	1.1	1.0	0.0	0.0	3.7	3.0
	WTP (share of total income) for price insurance for a fixed 100% of average production with theta=0.2 and 12 months in advance											
10.00	1.2	0.3	2.1	0.8	4.2	3.7	4.2	3.9	0.0	0.0	12.0	10.2
5.00	1.0	0.3	1.7	0.7	3.4	3.0	3.5	3.2	0.0	0.0	9.9	8.4
0.00	0.8	0.2	1.4	0.6	2.7	2.4	2.8	2.6	0.0	0.0	8.1	6.8
-5.00	0.6	0.2	1.1	0.5	2.2	1.9	2.2	2.0	0.0	0.0	6.5	5.5
-10.00	0.4	0.1	0.9	0.4	1.7	1.4	1.7	1.6	0.0	0.0	5.2	4.4
	WTP (share of total income) for price insurance for a fixed 100% of average production with theta=1 and 6 months in advance											
10.00	1.1	0.3	2.8	1.6	4.7	3.9	4.9	4.3	0.0	0.0	16.4	13.4
5.00	0.9	0.2	2.4	1.5	3.9	3.1	4.1	3.5	0.0	0.0	14.1	11.4
0.00	0.7	0.2	2.0	1.4	3.2	2.5	3.3	2.9	0.0	0.0	12.1	9.7
-5.00	0.5	0.1	1.8	1.3	2.6	2.0	2.7	2.3	0.0	0.0	10.5	8.3
-10.00	0.4	0.1	1.5	1.3	2.1	1.6	2.3	1.9	0.0	0.0	9.3	7.3
	WTP (share of total income) for price insurance for a fixed 100% of average production with theta=1 and 12 months in advance											
10.00	1.3	0.4	3.0	1.7	5.3	4.4	5.5	4.9	0.0	0.0	18.2	14.9
5.00	1.1	0.3	2.6	1.6	4.5	3.7	4.7	4.1	0.0	0.0	16.0	13.1
0.00	0.9	0.2	2.3	1.5	3.8	3.1	4.0	3.5	0.0	0.0	14.1	11.4
-5.00	0.7	0.2	2.1	1.4	3.2	2.5	3.4	2.9	0.0	0.0	12.5	10.0
-10.00	0.5	0.1	1.8	1.3	2.7	2.1	2.9	2.4	0.0	0.0	11.1	8.8
	WTP (share of total income) for price insurance for a fixed 100% of average production with theta=2.4 and 6 months in advance											
10.00	1.2	0.3	3.8	2.6	5.9	4.7	6.3	5.4	0.0	0.0	23.2	18.5
5.00	1.0	0.2	3.4	2.5	5.0	3.9	5.4	4.5	0.0	0.0	20.8	16.4
0.00	0.8	0.2	3.0	2.4	4.3	3.2	4.7	3.8	0.0	0.0	18.7	14.7
-5.00	0.6	0.1	2.8	2.3	3.7	2.7	4.0	3.3	0.0	0.0	16.9	13.2
-10.00	0.5	0.1	2.6	2.3	3.2	2.3	3.6	2.8	0.0	0.0	15.5	12.0
	WTP (share of total income) for price insurance for a fixed 100% of average production with theta=2.4 and 12 months in advance											
10.00	1.4	0.4	4.1	2.7	6.6	5.2	6.9	6.0	0.0	0.0	25.6	20.5
5.00	1.2	0.3	3.7	2.6	5.8	4.5	6.1	5.2	0.0	0.0	23.3	18.5
0.00	1.0	0.2	3.4	2.5	5.0	3.9	5.4	4.5	0.0	0.0	21.3	16.8
-5.00	0.8	0.2	3.1	2.4	4.4	3.3	4.8	4.0	0.0	0.0	19.4	15.2
-10.00	0.6	0.1	2.8	2.4	3.9	2.9	4.3	3.5	0.0	0.0	17.9	13.9

Source. Computed by author

Table 19. Proportions of the WTP that is accounted for by WTP_0 , the unconditional variance and the terms with conditional the expectations (all figures are in percent of WTP except where noted)

	Rural forest											
	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
	Price insurance for fixed 100% of average production with theta =1 and 6 months advance for strike price 0% from expected future price											
WTP (share of total income)	0.6	0.5	1.3	1.3	2.9	2.9	4.0	3.6	5.6	6.5	8.1	8.8
WTP0	74.5	81.8	47.0	50.0	64.4	64.4	56.4	56.3	53.7	51.1	47.1	45.7
Uncond. Variance term	24.8	17.5	52.4	49.3	33.1	33.0	40.9	41.3	42.9	45.3	49.1	50.4
Conditional terms	0.8	0.7	0.6	0.7	2.6	2.5	2.7	2.4	3.4	3.6	3.8	3.9
	Price insurance for fixed 100% of average production with theta =1 and 12 months advance for strike price 0 from expected future price											
WTP (share of total income)WTP	0.8	0.7	1.5	1.5	3.6	3.5	4.8	4.3	6.7	7.8	9.5	10.4
WTP0	79.0	85.1	53.7	56.6	69.3	69.4	61.9	62.0	59.1	56.5	52.7	51.3
Uncond. Variance term	19.9	13.8	45.3	42.4	27.0	26.9	34.1	34.4	35.8	38.1	41.6	42.8
Conditional terms	1.1	1.1	0.9	1.0	3.7	3.7	4.0	3.6	5.1	5.4	5.7	5.9
	Other rural											
	Price insurance for fixed 100% of average production with theta =1 and 6 months advance for strike price 0 from expected future price											
WTP (share of total income)WTP	0.6	0.3	1.4	1.1		4.3	5.1	2.9	5.7		10.0	7.1
WTP0	66.3	66.3	56.0	42.4		58.0	52.7	56.0	53.4		43.7	48.4
Uncond. Variance term	33.1	33.4	43.1	57.2		38.9	44.3	42.0	43.2		52.3	48.1
Conditional terms	0.6	0.3	0.9	0.4		3.1	3.0	2.0	3.4		4.1	3.5
	Price insurance for fixed 100% of average production with theta =1 and 12 months advance for strike price 0 from expected future price											
WTP (share of total income)WTP	0.8	0.3	1.6	1.3		5.2	6.0	3.5	6.8		11.7	8.4
WTP0	71.9	72.1	62.3	49.1		63.3	58.3	61.9	58.8		49.2	54.0
Uncond. Variance term	27.2	27.6	36.4	50.2		32.2	37.2	35.2	36.1		44.6	40.7
Conditional terms	0.9	0.4	1.4	0.7		4.5	4.5	2.9	5.1		6.2	5.3
	Urban											
	Price insurance for fixed 100% of average production with theta =1 and 6 months advance for strike price 0 from expected future price											
WTP (share of total income)WTP	0.7	0.2	2.0	1.4	3.2	2.5	3.3	2.9			12.1	9.7
WTP0	83.1	93.8	43.5	18.0	59.6	67.2	56.2	61.8			41.0	44.4
Uncond. Variance term	16.0	5.9	55.7	81.9	38.0	30.4	41.5	35.9			54.7	51.6
Conditional terms	1.0	0.3	0.8	0.1	2.4	2.4	2.2	2.3			4.3	4.1
	Price insurance for fixed 100% of average production with theta =1 and 12 months advance for strike price 0 from expected future price											
WTP (share of total income)WTP	0.9	0.2	2.3	1.5	3.8	3.1	4.0	3.5			14.1	11.4
WTP0	86.1	95.1	50.1	22.5	65.0	71.9	62.0	67.1			46.4	49.9
Uncond. Variance term	12.5	4.5	48.7	77.4	31.5	24.7	34.7	29.6			46.9	43.9
Conditional terms	1.4	0.4	1.3	0.2	3.5	3.4	3.3	3.4			6.6	6.2

Source. Computed by author

Table 20. 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.

			Rural forest											
			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
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											
	-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
5-Jun-02	-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											
	-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
5-Jun-02	-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											
	-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
5-Jun-02	-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.

Table 21. Comparison of WTP and actual cocoa put option prices in the NYBOT for a fixed 100% of total production and five months in advance, for the producers in the rural forest region of Ghana.

			Rural forest											
			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
Date of observation	Strike price in relation to future price (%)	Actual put option price (% of future price)	WTP with theta=0.2 and 5 months in advance											
5-Jul-00	-8.88	4.10	3.6	3.4	4.7	4.5	3.9	3.8	4.2	4.2	4.3	4.4	4.6	4.7
	-3.19	6.83	5.6	5.4	6.7	6.5	5.9	5.9	6.2	6.2	6.3	6.4	6.7	6.8
	2.51	10.25	8.3	8.2	9.4	9.3	8.6	8.6	8.9	8.9	9.1	9.2	9.4	9.5
	8.20	14.01	11.8	11.6	12.9	12.8	12.1	12.1	12.4	12.4	12.6	12.7	12.9	13.0
	13.90	18.45	16.0	15.8	17.1	16.9	16.3	16.3	16.6	16.6	16.7	16.9	17.1	17.2
Date			WTP with theta=1 and 5 months in advance											
5-Jul-00	-8.88	4.10	5.5	4.6	11.1	10.2	6.9	6.9	8.4	8.5	9.0	9.7	10.8	11.3
	-3.19	6.83	7.5	6.7	13.1	12.2	9.0	8.9	10.5	10.5	11.1	11.8	12.9	13.4
	2.51	10.25	10.3	9.4	15.8	14.9	11.8	11.7	13.3	13.3	13.9	14.6	15.8	16.2
	8.20	14.01	13.8	12.9	19.3	18.4	15.3	15.3	16.8	16.9	17.5	18.2	19.3	19.8
	13.90	18.45	17.9	17.1	23.5	22.6	19.5	19.5	21.0	21.0	21.7	22.4	23.5	24.0
Date			WTP with theta=2.4 and 5 months in advance											
5-Jul-00	-8.88	4.10	7.6	6.0	18.1	16.4	10.3	10.3	13.2	13.3	14.4	15.6	17.7	18.6
	-3.19	6.83	9.7	8.1	20.1	18.4	12.4	12.4	15.4	15.4	16.6	17.8	20.0	20.9
	2.51	10.25	12.4	10.8	22.9	21.2	15.3	15.3	18.3	18.3	19.5	20.8	23.0	23.9
	8.20	14.01	15.9	14.3	26.4	24.7	18.9	18.9	21.9	21.9	23.1	24.4	26.7	27.6
	13.90	18.45	20.1	18.5	30.6	28.9	23.1	23.1	26.1	26.1	27.4	28.7	30.9	31.9

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

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