FAO COMMODITY AND TRADE POLICY RESEARCH WORKING PAPER
No. 18

Producer demand and welfare benefits of rainfall insurance in Tanzania

Alexander Sarris[1], Panayiotis Karfakis[2], and Luc Christiaensen[3]

May 2006

---

[1] Director Commodities and Trade Division, Food and Agriculture Organization of the United Nations

[2] PhD candidate, University of Athens, Greece

[3] Senior Economist, World Bank

FAO Commodity and Trade Policy Research Working Papers are published by the Commodities and Trade Division of the Food and Agriculture Organization of the United Nations (FAO). They are working documents and do not reflect the opinion of FAO or its member governments.

Also available at http://www.fao.org/es/ESC/

Additional copies of this working paper can be obtained from Olwen.Gotts@fao.org

ABSTRACT

This paper explores empirically the issue of the demand, namely the willingness to pay (WTP), for rainfall-based insurance, in the context of a poor agrarian economy, with rural households significantly dependent on agricultural commodity risks. Using data from recent household surveys in the Kilimanjaro and Ruvuma regions of the United Republic of Tanzania, both important agricultural producing regions, the paper ascertains the nature of the weather related risks faced by smallholder growers in the context of their overall risk environment. It then estimates their desirability for weather-based income insurance as well as their demand for it by utilizing contingent valuation (CV) techniques. The results indicate that producer households are affected by a variety of shocks, of which weather related ones are very important. The paper estimates the demand for weather-based crop insurance in each of the two regions, and indicates that there seem to be considerable welfare benefits (net of costs) for such insurance, but differentiated according to regional rainfall instability, as well as producer incomes.

Keywords. Agricultural income instability, weather insurance, willingness to pay for weather insurance, developing country low income farmers.

JEL Subject Codes. O12,O13,12,Q18,C35

RÉSUMÉ

Cette étude aborde, en termes empiriques, la question de la demande, à savoir la volonté d’acheter une assurance contre les effets de la pluie, dans le contexte d’économie agricole pauvre, où les familles rurales sont fortement dépendantes des risques que présentent les produits agricoles. Sur la base d’une information récente provenant d’enquêtes sur les ménages dans la région du Kilimandjaro et de Ruvuma, dans la République unie de Tanzanie, qui sont deux régions fortement agricoles, l’étude établit la nature des risques de type climatique auxquels sont exposés les petits cultivateurs dans le contexte général de risques. L’étude estime ensuite leur désir d’obtenir une assurance revenu en fonction de conditions climatiques et la demande de ce type d’assurance moyennant l’application de techniques d’évaluation contingente. Les résultats indiquent que les familles de producteurs sont frappées par une série d’aléas, dont les principaux sont associés au climat. L’étude estime la demande d’assurance de la récolte contre les aléas climatiques dans chacune des deux régions et indique que ce type d’assurance semble présenter des avantages sociaux considérables (hors coûts) mais variables en fonction de l’instabilité de la pluviosité régionale, de même que des revenus des producteurs.

RESUMEN

Esta publicación realiza un estudio empírico sobre la cuestión de la demanda, es decir, la voluntad de pago de pólizas de seguros contra riesgos ocasionados por lluvias en el contexto de una economía agraria de escasos recursos y hogares rurales sumamente dependientes de los riesgos a que están supeditados los bienes agropecuarios. Sobre la base estudios de hogares realizados recientemente en las regiones de Kilimanjaro y Ruvuma en la República Unida de Tanzania, ambas importantes regiones agrícolas, esta publicación establece la naturaleza de los riesgos relativos a las inclemencias del tiempo a que deben hacer frente los pequeños agricultores en el contexto de su entorno general de riesgos. Posteriormente, el documento plantea las expectativas de los agricultores sobre la posibilidad de contar con seguros de ingresos agrarios frente a riesgos climáticos, al igual que la demanda de estos productos, para lo cual se utilizan técnicas de valoración contingente. Los resultados indican que los hogares productores se ven afectados por una gama de riesgos diversos, donde resultan más relevantes aquellos relacionados con los eventos climáticos. El documento calcula la demanda de seguros contra riesgos para la agricultura originados en eventos climáticos en las dos regiones de la muestra e indica que aparentemente se dispone de una cantidad considerable de beneficios sociales (netos de costos) para dichos seguros, aun cuando diferenciados en virtud de la inestabilidad de las lluvias en cada región y de los ingresos de los productores.

CONTENTS

The authors are respectively, Director Commodities and Trade Division, Food and Agriculture Organization of the United Nations (FAO), PhD candidate, University of Athens, Greece, and Senior Economist, World Bank. The authors would like to thank Donald Mmari, Lucas Katera and Professor Joseph Semboja at Research on Poverty Alleviation (REPOA) in Dar es Salaam, United Republic of Tanzania, who have managed the surveys on which this research is based, Panos Varangis and Benno Ndulu for their continuous support of the project, and Vivian Hoffman, Sara Savastano, and Danforth Sango for valuable research assistance. The study has been funded by the EU Trust Fund on Commodity Management and the Dutch-Japanese Poverty Reduction Strategy Trust Fund. The findings, interpretations, and conclusions expressed are entirely those of the authors, and they do not necessarily represent the views of the World Bank, its Executive Directors, or the countries they represent, or the views of FAO and its member countries.

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 (2005a).

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 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 and weather insurance for internationally traded commodities (ITF, 1999), while other proposals have suggested using market-based weather insurance to cover yield risks (Skees, Hartell, and Hao, 2006; World Bank, 2006). 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 mitigation 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 weather 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 has 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, jewellery, 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, Udry and Czukas, 1998; Dercon, 2005a; Kazianga and Udry, 2006). 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). 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.

There are two consequences of providing in every period some type of income insurance to a household. 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 and 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, Finkelshtain and Chalfant, 1991). Empirical verification of these theoretical predictions, however, is difficult (for a review of relevant studies and problems see Moschini and Hennessy, 2001).

In this paper we explore the issue of the demand, namely the willingness to pay (WTP), for weather-based agricultural income insurance in the context of a poor agrarian economy, with rural households significantly dependent on agricultural commodity risks. Using data from recent household surveys in the Kilimanjaro and Ruvuma regions of Tanzania, both important agricultural producing areas in Tanzania, the paper seeks to first ascertain the nature of the risks faced by smallholder growers in the context of their overall risk environment and their ability to cope with negative shocks. It then estimates their demand for weather insurance.

The contribution of the paper is methodological as well as relating to the policy dialogue on rural safety nets. On methodology, apart from the theoretical model that yields, with some approximations, relevant variables to include in the empirical analysis, we utilize an approach whereby we use the first period of a two period panel to formulate the appropriate questions with which to elicit the WTP for weather insurance in the second period. Concerning policy we show that there is considerable weather basis risk, uninsured income loss from weather variations, and substantial demand for weather-based insurance, even among the poor farmers of the study areas. However, the demand is not universal, and at actuarially fair market values only a small portion of the total cultivated land would be insured.

Tanzania is among the world's poorest countries with a per capita annual income of about US$280. From a macroeconomic perspective, agriculture plays a dominant role in the economy, accounting for nearly 45 percent of GDP in 2003, and employing around 70 percent of labour force. Agriculture accounts for three quarters of merchandise exports and represents a source of livelihood to about 80 percent of the population. Agricultural income is the main source of income for the poor, especially in rural areas. The majority of production is not sold but consumed by the households.

Smallholder farmers characterize Tanzanian agriculture. The average size of land cultivated varies between less than 1 - 3 ha of land. The large majority of the crop area is cultivated by hand. The main food crops are maize, rice, wheat, sorghum/millet, cassava and beans and they represent nearly 85 percent of the area cultivated. Export crops[1] represent 12 percent of the value of crop production. Poverty levels are high in Tanzania. The aggregate poverty level in 2000/01 was 35.7 percent compared to 38.6 percent in 1991/92. Poverty levels are highest in rural areas, where 39.9 percent of households are below the basic needs poverty line, and they make up about 81 percent of the poor in Tanzania.

The rest of the paper is organized as follows. In Section 2 we make a brief review of the literature on weather insurance. In Section 3 we discuss the theory as well as the methodology of estimation of the WTP for weather insurance. In Section 4 the survey on which the results are based is discussed and the characteristics of the households are exhibited. Section 5 presents an analysis of household perceptions

---

[1] 85 percent of the agricultural exports of Tanzania come from five crops, namely coffee, cashew nuts, cotton, tobacco, and tea, in that order or importance.

of rainfall risks, and discusses the specification of the hypothetical contracts used in the survey. In Section 6, we exhibit and discuss the results of empirical analysis concerning the WTP for weather related income insurance. In Section 7 we estimate the aggregate demand and welfare benefits from providing weather related income insurance. The final section summarizes the main conclusions of the paper.

2 PREVIOUS LITERATURE RELATED TO WEATHER 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 behaviour 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, for example, the papers in Hausman (1993)). However, in the case of well specified risks, such as 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 drought insurance if weather in recent periods has been adverse. There are also several technical 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 (Hanemann and Kanninen, 1998).

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. For developing country contexts the only study seems to be the one by McCarthy (2003), who finds considerable demand for weather-based wheat insurance in Morocco among farmers.

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, 1989), 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 behavioural patterns can be deduced, from which risk attitudes as well as WTP measures can be estimated. The problem, of course, is 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 explicitly consider 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 behaviour is assumed to be described by the maximization of the expected value of an intertemporal utility function. The production, saving, labour 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 behaviour of farmers, and deduce that there seems to be considerable latent demand for crop insurance, and furthermore that the implied WTP is in the neighbourhood of 13 to 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 and weather risks adjust their long-term production structures (for instance through diversification), and what implicit risk attitudes dictate the production patterns observed. The method may also be suitable for assessing the WTP for price or weather 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 head 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 THEORY AND METHODOLOGY FOR THE ESTIMATION OF THE WTP FOR WEATHER INSURANCE

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 assumes that the long term diversification pattern of the producer stays unaffected by the provision of the insurance. In this sense, the estimated benefit, and WTP can be considered as the minimum demand for weather insurance. Any changes in production structure, induced by the provision of the insurance, will provide an additional benefit, and 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 represents the period after planting, but before the resolution of production and price uncertainty, while the second period represents 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 labour) respectively at time t. Denote by $U(C_t)$ the instantaneous household utility in period t. The household will be postulated to maximize the ex-ante expected value of the discounted sum of instantaneous utilities, over n crop years.

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

where δ denotes an appropriate discount factor. The 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.

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

$$x_t \in X_t \tag{3}$$

Equation (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.[2] The subscript j in the income function denotes the possibility that income sources may be different in the two periods of each crop year. 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, (e.g. Deaton, 1992a, Zeldes, 1989). In general the solution is not analytically tractable, and can be written as follows.

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

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.

$$W = E\left\{ \{\sum_{T=0}^{n} \delta^{2T} \left[U(C_{2T+1}) + \delta E\left(C_{2T+2} \middle| I_{2T+1}\right)\right]\} \middle| I_0 \right\} \equiv E\left\{ \sum_{T=0}^{n} \delta_1^T V(C_{2T+1}, I_{2T+1}) \middle| I_0 \right\} \tag{5}$$

In (5) $\delta_1 = \delta^2$, the consumption within the various parentheses and brackets has a form like (4), and the function V just defines the quantity inside the bracket in the left had side of (4). The expectation inside the brackets are taken conditional on information available in the first period of a given crop year T, while the unconditional expectations outside the brackets are taken with information available in the beginning of the planning horizon, namely year 0.[3]

Consider the provision of an insurance contract to the farmer in the first period of the crop year, whose outcome depends on events of the second period. The contract considered is in the form of a promise to be paid automatically a certain amount per unit area insured (the indemnity) if a given, undesirable weather event occurs. Denote the amount of the area that is insured as q, and the return to the insurance contract per unit area as r.

If we assume that the nature of the function f in (4) is not affected by the provision of this contract, then we can define the benefit of this contract as the amount that must be subtracted from income of the first period in the crop year, so that the two-period utility with the contract is equal to the utility without it. Analytically we define the benefit in year T to be the solution B to the following implicit equation.

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

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.

The implicit function B that can be derived from (6) is generally impossible to solve analytically, without further assumptions. In appendix A we derive, based on the analysis of Sarris (2002), one such function analytically from (6) by approximating the consumption by a linear function of current resources Rt, and making several other simplifying assumptions. We show that this function depends

---

[2] 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.

[3] 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 from the discount rate outside the same bracket.

on the degree of consumption smoothing, the degree of farmer risk aversion, the current level of resources of the household, the expected value and variability of the returns of the insurance contract, and on the correlation between the return of the insurance contract with the current level of resources.

The analysis in the appendix leads to several conclusions compatible with intuition. For instance, the larger the degree of risk aversion, and the smaller the degree of consumption smoothing, the larger the benefit of insurance. Second, the larger the degree of (unpredictable) deviation of current resources from normal (positive or negative), the larger the WTP for insurance. Third, the larger 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. These are all variables that should enter a direct estimation of the WTP for insurance.

The problem at hand involves the issue of eliciting, by direct questioning, from surveyed households how much they are willing to pay to obtain a change from their current status quo to a new status that involves the provision of some type of insurance. The basic theory of the CV approach has been known for some time, and a comprehensive survey can be found in Hanemann and Kanninen (1998) (hereafter HK). The idea favoured by current CV practice is to ask each respondent a closed form question, namely whether they would accept to pay a given amount to obtain a given change in their status quo. Hence the answers obtained are of the “Yes” or “No” type, necessitating a theory of how to translate these discrete responses into meaningful WTP estimates. HK show that the WTP can be obtained by estimating probit or logit regressions with the dependent variable being the “Yes” answers to such questions, and the price of the hypothetical insurance contract (the “bid value”) one of the independent variables (which is expected to have a negative sign).

4 THE SURVEY AND THE BASIC CHARACTERISTICS OF HOUSEHOLDS

The analysis of the paper is based on a representative survey of 957 rural households in 45 villages carried out in the Kilimanjaro region, in November 2003 and again in November 2004, and a representative survey of 892 rural households in 36 villages carried out in the Ruvuma region in February-March 2004 and again in 2005. Kilimanjaro is a relatively well-off region in north-eastern Tanzania. Its area is only 1.4 percent of the total of Tanzania, but its population of 1.38 million is 4 percent of the Tanzanian total, and it is the region with the third highest population density in Tanzania, after Dar es Salaam and Mwanza. Coffee is the main cash crop in the region, and about 70 percent of the coffee area is held by smallholders, the remaining being cultivated as private and public plantations as well as large scale farmers. These large scale entities were not part of the survey. This is a predominantly rural region, with only 12 percent of people living in urban areas.

Ruvuma is the southernmost region of Tanzania, and is much larger than Kilimanjaro, comprising 4.9 times the land area of the latter. Its population, however, is lower than Kilimanjaro at 1.12 million, implying that the region is sparsely populated. The region has many agro ecological zones, and hence can grow a variety of agricultural products. About 90 percent of the population lives in rural areas and agriculture constitutes 77 percent of regional product. There are three main exportable crops in the region, namely coffee, tobacco, and cashew nuts, each grown in a distinct geographical part of the region. Coffee is the main cash crop followed by cashew nuts. This is acknowledged as one of the poorest regions of Tanzania. The contrast between one of the wealthiest and one of the poorest regions of an otherwise low income agrarian country is interesting for the policy lessons concerning weather insurance.

The survey by design was representative of rural farm households, and among them of cash crop (coffee in Kilimanjaro, coffee, tobacco and cashew nuts in Ruvuma) as well as non-cash crop producing households. The questionnaire was designed to investigate the complete economic characteristics of households focusing on their vulnerability to a variety of risks. A community-level questionnaire was administered concurrently to village focus groups consisting of leaders and other knowledgeable members of the community, in order to elicit village specific information. The survey sampled only agricultural households, as defined by the National Bureau of Statistics (NBS)). All questions were answered by recall.

For both regions Table 1 presents the basic socio-economic characteristics of all rural households classified by their poverty status. The table reports results from the first round surveys, but the general picture does not change much in the second rounds. Overall, households in Ruvuma tend to be[4] poorer than those in Kilimanjaro, as reflected in the much lower value of their total wealth (820 000 Tsh versus 3 375 000 Tsh), their lower average annual per capita expenditures (162 000 Tsh versus 214 000 Tsh) and their higher poverty incidence (55.7 percent versus 33.1 percent). Analysis of their livelihoods structure suggests that households in Ruvuma are more agriculture and subsistence oriented. The average household in Kilimanjaro obtains 43.3 percent of total income from non-cash sources (own production and gifts) compared to 58.5 percent for households in Ruvuma. Moreover, households in Kilimanjaro appear much less dependent on cash crops for their cash income than households in Ruvuma, are more diversified, and tend to get a higher share of their cash income from non-crop agriculture and wages. Notable are the high values of the Herfindahl indices of total as well as cash income diversification. The indices reported in the tables are very large, indicating that farmers in general are very concentrated in their total as well as cash income structure. This does not appear to be reflected in the average shares of total income also reported in the table. The reason is that the H indices are averages of the individual H indices of each household, which are large, while the shares of income reported are averages of the individual shares.[5]

Concerning differences between poor and non-poor, the average per capita expenditure of the non-poor appears to be about 2.5 times that of the poor in both regions. The poorer households in each region tend to be more subsistence oriented, i.e. they have larger shares of non-cash incomes. Yet, they tend to get a larger share of cash income from wages. These findings point to both lack of land (and thus engagement in low remunerative off-farm employment) and lower agricultural productivity as underlying sources of poverty.

Concerning households' asset base, the value of average household wealth in Ruvuma is only about one fifth of that in Kilimanjaro. The bulk of household wealth in both regions consists of dwellings and consumer durables followed by land and animals. The total number of animals owned per household (in cattle equivalents), is more than twice as high in Kilimanjaro, as compared to Ruvuma. Agricultural and non-agricultural capital account for very small shares of total wealth. The average size of cultivated land is much larger in Ruvuma, compared to Kilimanjaro, but the poor possess on average less land than the non-poor in both regions.

Yields for maize, the major food staple crop in both regions, differ significantly among regions but even more so between poor and non-poor households within both regions with yields among the non-poor about 50 percent higher than among the poor. A similar picture emerges when looking at total agricultural crop value added per acre which appears on average more than twice as high in Kilimanjaro than in Ruvuma. Within each region there appear to be significant differences between the productivity of poor and non-poor farmers, with the value added of non-poor farmers about 25 percent higher than that of the poor in Kilimanjaro and 54 percent higher in Ruvuma. Land productivity emerges a major factor in distinguishing farmers among poor and non-poor (this is elaborated further in Sarris, Savastano and Christiaensen, 2006).

The value of productivity seems related to the value of purchased inputs (more than three times as large in Kilimanjaro compared to Ruvuma and substantially higher among the non-poor compared to the poor. Moreover, despite the small share of agricultural capital in total wealth the average value of total agricultural capital per household (value of machines, implements, etc) is about twice as high in Kilimanjaro compared to Ruvuma, and since the average amount of cultivated land is lower in Kilimanjaro, capital/land ratios is considerably higher in Kilimanjaro.

---

[4] Somewhat surprisingly, household heads in Ruvuma tend on average to be better educated than those in Kilimanjaro. This may be related to the high level of out migration in Kilimanjaro, whereby the less educated household heads stay behind.

[5] For instance, if there are two households in the survey each obtaining 100 percent of income from one source, but a different source from the other, then the average share indicated would be 0.5 for each one of the sources, but the average H index indicated would be 1, as each household would have an H index equal to 1.

As purchased input use appears to be a major differentiating factor in land productivity, we explored credit related information (not reported in the table). A very small share of households are members of the local credit cooperatives (called Sacco), less than 14 percent in both regions, or have a bank account (less than 13 percent). The incidence, however, is higher among non-poor households in both regions. It is impressive that more than 80 percent of all households, without much differentiation among various groups declared that it was difficult to get seasonal credit from any source, for purchasing inputs, and less than 15 percent declared that it was easy to obtain formal seasonal credit. An even smaller share (8.2 percent in Kilimanjaro and 9.3 percent in Ruvuma) declared that it was easy to obtain credit for farm investments. Lack of seasonal credit, as well as the small amount of accumulated agricultural capital, emerge as potentially important constraints for the farmers in the survey, and are factors that could affect the WTP.

The picture that emerges from the above brief descriptive analysis is that farm households have a low overall capital asset base (agricultural as well as non-agricultural), and use mostly labour intensive technology. They also seem to have very little access to formal credit, both seasonal and as for investments, potentially limiting the use of modern inputs. There seem to be significant differences between poor and non-poor households so far as agricultural productivity is concerned, and this seems to be due to differences in overall agricultural and total capital availability.

The first step toward understanding households' vulnerability, as a prelude to understanding their demand for insurance, entails characterization of the risk environment they face. We need to know which types of shocks are commonly encountered. Shocks enumerated in the household survey fall into four broad categories: (1) climatic and agricultural - which includes drought, heavy rainfall, including flooding, hailstorm and major harvest losses due to pests; (2) health - comprising death of a household member and illness not resulting in death; (3) economic - including unemployment and negative price shocks; and (4) asset shocks - which include theft, loss of livestock, loss of land or eviction, and fire. Table 2 summarizes the incidence of shocks among cash and non-cash producing households in the two regions.

More than 80 percent of all surveyed households in Kilimanjaro and 60 percent in Ruvuma reported having experienced at least one major shock over the past five years with shock incidence among cash crop growers reaching almost 90 percent in Kilimanjaro and over 50 percent in Ruvuma. Clearly, households' livelihoods are prone to external shocks, even in traditionally better off regions such as Kilimanjaro. Health shocks (either major illness or death) affected about 20 percent of households in both regions, while drought shocks affected almost as many. It is interesting that the incidence of drought shocks appears to be higher among non-cash crop producers. The incidence of other types of shocks appears markedly lower than the incidence of health and climatic ones.

Households utilize a variety of coping mechanisms to deal with shocks. The majority of them (more than 70 percent) use mainly their own assets and savings to deal with income shortfalls, or other shocks. The second most common strategy is to receive aid from the family, and the third is to seek additional income through new income earning activities. Other coping mechanisms, such as receiving aid from others than family, reducing consumption, etc. are much less prevalent as coping mechanisms. The incidence of and response to shocks is analysed in more detail by Christiaensen, Hoffman and Sarris (2006).

5 OBJECTIVE AND HOUSEHOLD PERCEPTIONS CONCERNING RAINFALL PATTERNS AND THE DESIGN OF RAINFALL INSURANCE CONTRACTS

While weather-based insurance is normally designed on the basis of objective rainfall measurements in specific sites, it is not clear whether rainfall in such sites is related to village rainfall patterns (basis risk), and to what extent farmer perceptions about rainfall relate to objective rainfall measurements. This is what makes the design of appropriate hypothetical contracts for the survey of WTP challenging, as it is quite unlikely that farmers will be aware of objective rainfall levels, but may have only ordinal perceptions of it. The procedure we follow in this study is to first examine whether objective rainfall measures correlate among weather stations, then we try to explore whether objective rainfall measures are related to farmer perceptions of what constitutes ordinal rainfall rankings. We subsequently estimate the agricultural income losses from ordinal rainfall shocks, based on production data from the first round of our survey. Then we translate ordinal rainfall shocks to objective rainfall declines, and on the basis of these estimates we design the hypothetical contracts for the second round of the survey.

In Tanzania, there are few rainfall stations in each region, and most rainfall stations are rather concentrated geographically within each region. Nevertheless, given the size of each region it is not clear whether rainfall patterns are correlated among rainfall stations. To analyze this we obtained monthly rainfall data for all the 20 rainfall stations in Kilimanjaro and the 14 rainfall stations in Ruvuma over the period 1964-2005. The simple bilateral correlation coefficients of these long time series are quite high. In Kilimanjaro, 70 percent of the bilateral correlation coefficients are higher than 0.5, and most are much higher. In fact almost all the low correlation coefficients pertain to five stations. In Ruvuma the rainfall patterns are even more correlated. Only 10 percent of the bilateral correlation coefficients are smaller than 0.5. Hence in Ruvuma the rainfall pattern is much more even across the region. These results suggest that rainfall patterns are relatively uniform within each region, and this is important for the design of a weather-based insurance product.

In the first round of our surveys, household heads were asked about their ordinal perceptions concerning weather in their farms. Table 3 gives a summary of their responses. Households were asked to report in how many years out of the last ten the rainfall in their farms was much below normal, somewhat below normal, normal, somewhat above normal and much above normal. The table reports the average number of years perceived by households in the various subjective rainfall ranges relative to normal. In Kilimanjaro, households indicate that rainfall is much below normal in one out of every four years on average, while in one out of every 5 years rainfall is perceived as somewhat below normal. In only slightly above half of the years is rainfall perceived as being normal or above normal. In Ruvuma, rainfall appears to be much less variable, and the incidence of somewhat below and much below normal rainfall, as perceived by households, is much lower than in Kilimanjaro, and this is consistent with the results of Table 2.

As the tabulations in Table 3 were subjective, it is interesting to explore the similarity of responses of farmers. This is interesting not only to elicit perceptions, but also to gauge whether rainfall patterns are similar for all farmers within a village. In Tanzania, farms within villages are quite dispersed, with distances between farms within the same administrative village sometimes being more than 10 kilometres. Hence it is important to understand the uniformity of rainfall patterns, at least as perceived by farmers. We computed similarity indices for each village as follows. For each ordinal category of rainfall we computed the proportions p of years out of the last ten that each farmer indicated that rainfall was in that category. Then if q denotes the average such proportion among sampled farmers in the same village, the index is calculated as $D= 2 \Sigma \min(p,q) / (\Sigma p + \Sigma q)$, where the sums are over all sampled farmers in a village. The index can range theoretically from a value of 1 (perfect similarity of perceptions) to zero (perfect dissimilarity).

The average similarity indices computed in this fashion are quite high. In Kilimanjaro the averages across all villages sampled for each district, for the cases of perceptions with respect to rainfall being somewhat below and much below normal, are close to 0.8. In Ruvuma, the average similarity indices for the same cases are much lower (around 0.3-0.5 for the case of rain much below normal, and around 0.6-0.75 for the case of rain somewhat below normal) but is much higher (above 0.8) for the case of rainfall being normal. This is most likely because in Ruvuma, as already seen, there is much lower probability of below average rainfall.

To relate the ordinal perceptions of households to objective rainfall shortfalls, we tabulated the responses of households concerning how they would classify rainfall when objectively the rain in a given year is a certain amount below normal. Table 4 summarizes the results. For small negative rainfall deviations (one tenth and one quarter below normal) the households have differences in perceptions (especially between classifying rainfall as being somewhat and much below normal). However, when it comes to rainfall below one third or one half of normal, then there are much more uniform perceptions, namely that in such cases rainfall is much below normal. The reason for which these figures are important, is that the estimates on the basis of which the contracts are specified for the questionnaire, as well as the amounts of income shortfall estimated are based on variables utilizing these perceptions. That household perceptions are closely related to objective rainfall shortfalls is further supported by the data in Table 5. It can be seen that in the year of the survey the rainfall in

Kilimanjaro was about 30 percent below the long run average, and almost 80 percent of households surveyed indicated that indeed rainfall was either below or much below normal. In Ruvuma by contrast rainfall in the survey year was about 10 percent above the long run average, and indeed more than 80 percent of households reported that their perceived rainfall was either normal or above normal.

The first issue in the design of appropriate contracts to present to farmers, concerns the probability distribution of rainfall. These were estimated in each region by reference to the historical rainfall patterns observed. The second issue concerns objective and subjective estimations of the probabilities of below normal weather events. This was done by first utilizing data from village questionnaires (normally answered by village officials), relating to the frequency of occurrence of a "drought" for the village, in the last ten years. These turned out to be quite consistent with individual farmer responses. To relate objective and subjective perceptions of rainfall, we need to specify what is meant by villagers when they report that rainfall is somewhat below normal and much below normal, and then relate these variables to actual income losses. To this end, we assumed that "drought" as defined at the village level was equivalent to the households' subjective estimates of rain as being "much below normal". Then by reference to the actual annual rainfall distributions we computed the annual rainfall that corresponds to a cumulative distribution point equal to the reported frequency of droughts. This cut-off point we regarded as the borderline rainfall below which rain may be considered as being much below normal. The next issue is to specify what is meant by rainfall "somewhat below normal". This was arbitrarily defined as the rainfall point in the cumulative rainfall distribution that corresponds to a probability mass equal to one half of the mass between the median (namely 50 percent of the mass) and the drought point indicated above. These calculations result in "quasi-objective", probabilities of having rainfall "much below normal", and somewhat below normal", as perceived by farmers.

Next we need to estimate the agricultural income losses from rainfall being much below and somewhat below normal. This is done by utilizing the first round survey of rainfall incidence by parcel for each household, to construct a household specific index of rainfall. From this index we created two separate dummy variables, each corresponding to one of the two types of rainfall below normal levels discussed above. These two dummy variables are then utilized in cross section agricultural production function estimates to estimate the losses from weather somewhat and much below normal. The dependent variable in such an estimate is the (natural logarithm of) gross value of agricultural production per acre. The production function, apart from the normal input variables, included the weather dummy variables discussed above. As expected, the dummies for weather somewhat or much below normal were negative and significant.

Given the production function estimate, the "predicted" value of total output for each household is computed by omitting all the below normal weather dummy variables. This value is the basis from which we estimated losses due to weather shocks. As there is considerable size variation among farmers, we separated the predicted values of agricultural output in three terciles. For each tercile we computed the average value of "predicted" agricultural output, and the amount lost if the weather is somewhat below normal and much below normal, by multiplying this average by the corresponding coefficients of the respective dummies from the production function estimates. We then computed the average loss, if weather is below normal., by the weighted average of these losses (weights are the respective probabilities). The same procedure is followed for computing the loss if weather is much below normal. The actuarially fair price for a weather insurance contract that will pay the computed average loss if weather is below normal or much below normal can be easily calculated from the above losses and the respective probabilities. The separation of these computations by terciles allowed us to design a variety of contracts (three) that could be administered in the survey.

6 INTEREST IN AND WTP FOR RAINFALL INSURANCE

The survey asked a variety of questions related to rainfall-based income insurance. At first the concept of rainfall insurance was explained and farmers were asked whether they were interested in such insurance. After this question, the questionnaire proceeded to ask whether farmers would be willing to pay various amounts for given rainfall-based contracts. Table 6 indicates the reasons for which some households declared that they were not interested in the rainfall-based insurance contracts. The interest in rainfall insurance is much higher in Kilimanjaro (47 percent of households), compared to Ruvuma (34 percent of households), but overall the interest is not universal. This most likely reflects the fact that rainfall is much more reliable in Ruvuma, as already discussed. The major reason of those not interested in Kilimanjaro was lack of funds to pay for it at any price, while in Ruvuma, a large share declared that droughts were infrequent, and when occurring would not hurt them too much. Clearly the interest for weather insurance appears larger in Kilimanjaro.

This seems contrary to the fact that households in Kilimanjaro are both less vulnerable than those in Ruvuma, and less prone to covariate weather and price risks. Sarris and Karfakis (2006) defined a vulnerability index incorporating both covariate and idiosyncratic risks, and using the same survey data as in this analysis showed that in Kilimanjaro 23 percent of rural households are vulnerable to poverty (in the sense of exhibiting high probability of their consumption falling below a poverty threshold) while in Ruvuma 54 percent of the households are vulnerable in the same sense. Furthermore, covariate shocks contribute only 15 percent of household vulnerability in Kilimanjaro, while they contribute 71 percent of vulnerability in Ruvuma. This, in conjunction with the evidence presented earlier that Kilimanjaro seems to be a much wealthier region than Ruvuma, suggests that income is a key determinant of the desire for additional income insurance.

Apart from the descriptive results of Table 6, we explored the desirability of drought insurance via a probit regression. The results indicate that significant variables are education of head (positive but in Ruvuma only), per capita income (positive, but in Kilimanjaro only - which is consistent with the observation above), easy access to short term credit (positive in Ruvuma only), and a cashew production dummy. Interestingly vulnerability to poverty, as proxied by the index of Sarris and Karfakis (2006) seems negatively associated with the desirability of drought insurance. These results suggest that the more education and higher income a household head has, or the less vulnerable the houehold, the more likely it is that the head will understand and appreciate income insurance. This, however, implies that rainfall insurance is not desirable among those who are likely to need it most, namely the more vulnerable.

In the survey each farmer was offered two different types of rainfall-based contract. The first type involved a hypothetical rainfall reduction of 10 percent below normal rainfall, and the second a hypothetical rainfall reduction of 33 percent (one third) below normal. For each hypothetical scenario three contracts were designed, offering a progressively higher indemnity under the given rainfall shortfall, for a correspondingly higher premium. This was done, in order to capture all the different income classes within the sample, and as it was impossible *-priori* to know the income class of the farmer interviewed. Hence each farmer was offered six different hypothetical contracts. For each one of these there were five different options for the premium, structured around what was estimated as the actuarially fair premium for that type of contract. Farmers were split randomly into five even groups and within each group each farmer was given a different unique choice among the five premiums for each contract.

Irrespective of their answers to the desirability question all farmers were asked about their willingness to pay specific amounts for rainfall insurance. Tables 7 and 8 indicate the results of probit regressions concerning Kilimanjaro and Ruvuma, for the hypothetical contracts that stipulated 10 percent rainfall decline. Tables 9 and 10 repeat this for the contracts that stipulated one third below normal rainfall decline. In general the following types of variables are utilized. First we use household characteristic variables, such as education of head and household size. Then we use income and asset variables such as per capita income, cultivated land size, number of trees and animals owned. Thirdly we use diversification variables, such as the Herfindahl index of total gross income diversification and the share of cash in total gross income. Fourth we use variables designed to proxy for recent conditions, such as whether the household experienced recent drought. Fifth we use variables designed to indicate the level of instability faced, such as the number of years in last 10 when income was much below normal. Sixth we use variables designed to indicate how households deal with adverse income shocks, such as dummies indicating what type of coping mechanism was used when faced with shocks. We use specific crop production dummies, to capture attributes related to production of specific crops. Finally we use the vulnerability index computed by Sarris and Karfakis (2006).

These groups of variables are designed to proxy for the types of variables that the theory mentioned earlier points to. For instance the degree of risk aversion can be related to the level of assets, while the degree of consumption smoothing to the dummies discussed above. The degree of deviation of current resources from normal can be proxied by the variables relating to income instability, and the correlation between the return to insurance and the second period resource uncertainty can be proxied by the structural variables relating to the production of specific crops, or the share of cash in total income.

The coefficients of the bid values are everywhere negative as expected, and significant in all cases in Kilimanjaro but only in few cases in Ruvuma. In Kilimanjaro other significant variables appear to be the size of household (positive), per capita income (positive), the share of cash in total income (positive), and two coping variables, the one indicating that the household uses own savings when facing a shock (positive), and the one indicating that the household used family assistance when in shock (negative). These results suggest that higher income and exposure to the market make households more sensitive to income instability, and thus more open to paying for additional income insurance. Also it appears that the type of coping mechanism makes a difference in their desire for weather insurance. If they use mostly own savings, namely if they self insure, they seem to be more open to external insurance. If, on the contrary they use family assistance, they seem to consider this enough of a safety net, and they are less open to paying for additional drought insurance.

In Ruvuma, while all the coefficients of the bid values are negative, only one is significant at the 5 percent level. Other variables that appear significant are the level of education of the household head (positive), and the same types of coping mechanism dummies as in Kilimanjaro. The lack of significance of the bid values indicates much less interest in drought insurance in Ruvuma, a conclusion that is consistent with earlier results that indicated both less interest in drought insurance in Ruvuma as a result of more stable rainfall patterns, but also with the lower general incomes in Ruvuma. Despite the non-significance of most variables, however, and the low pseudo R-squared values, the proportion of correct predictions (on the basis of a probability larger than 50 percent) is larger than 70 percent in all cases.

Tables 11 and 12 for Kilimanjaro and Ruvuma respectively indicate the summary statistics of the individual WTP values computed for each household. These values were computed for each household as indicated earlier in equation (13), utilizing the directly estimated values of the coefficients, and the household specific values for its characteristics, and averaging the results. The estimated WTP values for some households were negative. For such households this result can be interpreted as indicating low or no interest in insurance, and for them the individual WTP was set at zero in estimating the averages. Such households accounted for about 30 to 40 percent of households in Kilimanjaro and more than 50 percent of households in Ruvuma.

The results indicate that in Kilimanjaro households who are willing to pay some amount for rainfall insurance, are willing to pay on average 12 to 23 percent of the underlying indemnity value as premium for insurance against a 10 percent rainfall decline. They are willing to pay considerably less, between 10 to14 percent for insurance against the more improbable event of one third rainfall decline. In Ruvuma, a poorer region, and a more reliable one from a rainfall perspective, producers are much less interested in rainfall insurance, but those exhibiting a positive WTP for rainfall insurance, are willing to pay on average 3 to 6 percent of the underlying indemnity value for insurance against a 10 percent rainfall decline. They are willing to pay considerably less, 0.6 to 0.9 percent for insurance against the more improbable event of 30 percent rainfall decline. Noticeable throughout is the result that the average WTP is lower, and substantially so in some cases, than the actuarially fair price of the contract. These results suggest that it is mainly in Kilimanjaro where rainfall insurance appears viable, while in Ruvuma, there is a small group of households (fewer than 20 percent) willing to pay considerable amounts for rainfall insurance against a rather frequent event, namely rainfall declines of 10 percent.

7 THE DEMAND FOR WEATHER INSURANCE AND THE WELFARE BENEFIT FOR PROVIDING IT

Given that the results suggest that there is considerable demand for weather insurance, at least in Kilimanjaro, it is interesting to ascertain the overall demand curves for such type of insurance. To do this we utilize the following method. For each contract we first rank all estimates of WTP for the households in descending order. For each point estimate, we have independent estimates from the questionnaire concerning the number of acres, households would be willing to insure at the relevant contract. The area each household is willing to insure was then multiplied by the sampling weight corresponding to the household in the survey. For each new value of the WTP, the quantity desired is equal to the quantity desired at the immediately larger value plus the quantity desired for the specified value. This specifies the demand curve for each weather insurance contract, which by construction has a negative slope.

Given the demand curves, it is simple to compute the total consumer surplus, namely the area above a given WTP and below the demand curve, for any given contract. Tables 13 and 14 present these estimates for Kilimanjaro for three values of the premium. The first is equal to the average WTP estimated above. The second is equal to a the average WTP plus one standard deviation of the empirical WTP distribution. The third is the approximate actuarially fair value The table also indicates estimates of the number of acres that would be insured, the number of producers affected, and the total cost and consumer surplus (welfare) of the insurance.

The results indicate that in Kilimanjaro for the 10 percent rainfall shortfall case, about 30-40 percent of households would purchase the insurance at the average WTP, insuring around 40-45 percent of their total acres cultivated. The premium paid would constitute 2.9-4.2 percent of total crop sales, and consumer surplus would be between 4.8 and 10.2 percent of total crop sales. The insured land would constitute 15 to 20 percent of total cultivated land. These numbers, however decline significantly (while the share of premium in total sales increases), and for some contracts to less than half of these values when computed at the actuarially fair values of the contracts.

For the case of insurance against a one third rainfall shortfall, participation at average WTP would be around 25-35 percent of households, the cost would amount to 2.4 to 3.5 percent of total crop sales, and they would insure 40-45 percent of their cultivated acres. Total area insured would be around 15 to 20 percent of total cultivated land, and consumer surplus in this case would amount to 4.9-9.8 percent of total crop sales.

For Ruvuma and for the case of 10 percent rainfall shortfall, the participation at average WTP would be of only 10 to 15 percent of households, insuring about 20 to 30 percent of their total area cultivated. The cost of the insurance would constitute 0.4-0.5 percent of their crop sales, and the total consumer surplus would amount to 3-4.7of total crop sales. At actuarially fair prices, however, participation would fall to less than 10 percent of households, insuring about 30 percent of their cultivated land.

For the case of insurance against one third rainfall reduction, at average WTP only between 5-7 percent of households would insure, and they would insure around 30 percent of their total cultivated area. The insured land would amount to about 2 percent of total cultivated land. At actuarially fair prices less than 3 percent of households would insure, and total insured land would be less than 1 percent of cultivated land.

8 SUMMARY AND CONCLUSIONS

The results of this paper highlight several points that can contribute towards better design of producer safety nets among low income agricultural producers. First, producer households are affected by a variety of shocks, and prominent among them are those related to health and death, and weather-induced. These shocks induce considerable variability of incomes, which to a large extent is dealt with through own savings and asset depletion. Second, there seems to be considerable incidence of rainfall shortfall among producers. This appears to induce interest in rainfall-based insurance.

About half of all households in Kilimanjaro and about one third of all households in Ruvuma indicated an interest in weather-based insurance. More importantly, liquidity constraints were mentioned as the main reason for not being interested in such a scheme. Also the type of coping mechanism seems to affect the demand for rainfall insurance, with those that use own savings more interested and more willing to pay, compared with those that use other safety mechanisms, especially family-based ones. This may be related both to differential liquidity constraints and different costs related to these coping strategies.

The demand for weather insurance seems to be enhanced by higher incomes. Also exposure to the market makes households more sensitive to income instability, and thus more open to paying for additional income insurance. Finally it appears that the type of coping mechanism makes a difference in their desire for weather insurance. In Ruvuma, there is much less interest in drought insurance, despite the fact that households there are poorer and more vulnerable. This suggests that market demand for weather insurance is less among those that may need it most, but cannot afford it.

Households were more interested in weather insurance in Kilimanjaro, which is more exposed to rainfall declines, and they wanted protection against the more frequent shocks, compared to the less frequent ones. This is manifested by a larger interest in contracts which paid out the indemnity when rainfall falls by 10 percent below normal as opposed to 30 percent below normal and is reflected in a larger average willingness to pay for the more frequent contracts. For example, average WTP for the 10 percent below normal contracts was between 12 and 23 percent of the payout in Kilimanjaro compared with between 10 and 14 percent for contracts which pay out only when the rain drops 30 percent below normal. In Kilimanjaro the average WTP constitutes about 30-55 percent of the actuarially fair value of the contract, depending on the contract. In Ruvuma the average WTP is only 4 to 18 percent of the actuarially fair premium, in line with the lower WTP in that region.

Were the premium to be set at the actuarially fair value, about 10 to 18 percent of all rural households in Kilimanjaro would insure about 28 000 to 87 000 acres (about 6 to 17 percent of total land cultivated) resulting in a consumer surplus or benefit to society of more than 300 million Tsh or 300 thousand US dollars. This is substantial and underscores the welfare loss associated with uninsured risks. In Ruvuma, at actuarially fair value of the contracts less than 8 percent of households would insure and the total land insured would not surpass 3 percent of total land cultivated.

In sum, while households extensively use self and mutual insurance to cope with weather induced income shocks, our findings indicate that there is considerable market demand for weather-based insurance, indicating both substantial uninsured risks as well as “latent demand” due to the costs of current ways of coping with shocks or the opportunities insurance opens up. Liquidity constraints at the household emerge as an important constraint to translate this stated demand into actual demand. Thus, while the demand and societal benefits are sizeable, great care will have to go into the design and institutional delivery mechanisms of market-based insurance. Most interestingly there appears to be a poverty and vulnerability related externality with respect to provision of market-based weather insurance, in the sense that those who may need it more are less able and willing to pay for it. This opens the possibility that such schemes, if they are to be effective safety nets, may need some kind of subsidisation, as at actuarially fair values only a small portion of the potential need maybe covered.

APPENDIX A. AN APPROXIMATE ANALYTICAL SOLUTION FOR THE DEMAND FOR INSURANCE

To derive an analytical expression for (6) 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.

$$\hat{C}_t = C_t^* + \beta(R_t - R_t^*) \tag{A1}$$

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 (A1) is the one that has been utilized as an approximation to the optimal rule (4) in the literature of the general lifetime optimization problem under uncertainty as well as under liquidity constraints (for useful surveys see Deaton, 1992b; Browning and Lusardi, 1996;Morduch, 1995).

In (A1) the value of "trend" or "permanent" 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 real valuation of the household assets. As such it accounts for both covariate risks, such as price variations and idiosyncratic risks. The starred value of R is the trend or expected value of these resources. 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. In addition the linear approximation may not be valid.

Denote by z the term in (6) that includes the total (real) return to the insurance contract.

$$z = rq \tag{A2}$$

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).

$$\hat{C}_1 = C_1^* + \beta(R_1 - B - R_1^*) = C_1^* + \beta(R_1 - R_1^*) - \beta B \equiv C_1^* + \beta\Delta R_1 - \beta B = C_1 - \beta B \tag{A3}$$

$$\hat{C}_2 = C_2^* + \beta(R_2 + z - R_2^*) = C_2^* + \beta(R_2 - R_2^*) + \beta z \equiv C_2^* + \beta\Delta R_2 + \beta z = C_2 + \beta z \tag{A4}$$

In (A3) and (A4) 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 cancelling similar terms from the left and right hand sides of (6), results in the following equation (primes denote differentiation).

$$0 = -U'(C_1^*)B + \frac{1}{2}\beta U''(C_1^*)\cdot(B^2 - 2B\cdot\Delta R_1) + \delta\left[U'(C_2^*)E(z) + \frac{1}{2}\beta U''(C_2^*)\cdot\left\{E(z^2) + 2E(z\Delta R_2)\right\}\right] \tag{A5}$$

In (A5) E(.) denotes conditional expectation, given information in period 1 of the crop year. To proceed, assume for convenience 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.

$$r^r \equiv \frac{r}{p_{i2}^e} \tag{A6}$$

$$B^r \equiv \frac{B}{C^*} \tag{A7}$$

$$q^r \equiv \frac{p_{i2}^e q}{C^*} \tag{A8}$$

$$z^r \equiv r^r q^r = \frac{z}{C^*} \tag{A9}$$

$$R_j^r \equiv \frac{R_j}{C^*} \qquad \text{(j=1,2)} \tag{A10}$$

$$R_j^{*r} \equiv \frac{R_j^*}{C^*} \qquad \text{(j=1,2)} \tag{A11}$$

$$\rho = -\frac{U''}{C^* \cdot U'} \tag{A12}$$

In (A6) the price in the denominator is the expected or normal price of the insured commodity in period 2. In (A7)-(A12) all variables are defined as shares of trend real expenditures, and (A12) just defines the coefficient of relative risk aversion.

With these definitions, equation (A5) can be rewritten as a quadratic equation in the normalized benefit, as follows.

$$\frac{1}{2}\theta(B^r)^2 + (B^r)(1-\theta\Delta R_1^r) + \delta\left[-E(z^r) + \frac{1}{2}\theta\left\{E(z^r)^2 + 2E(z^r\Delta R_2^r)\right\}\right] = 0 \tag{A13}$$

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

$$\theta = \rho\beta \tag{A14}$$

Solving the quadratic equation (A13) and using the approximation $(1+\varepsilon)^{1/2} \approx 1 + \frac{1}{2}\varepsilon$ we find the following expression for the WTP for commodity insurance.

$$B^r = \delta E(z^r) + \frac{1}{2}\theta\left[(\Delta R_1^r)^2 - \delta\left\{E(z^r)^2 + 2E(z^r\Delta R_2^r)\right\}\right] \tag{A15}$$

From (A15) 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

$$B_0^r = \delta E(z^r) = \delta E(r^r q^r) \tag{A16}$$

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 it 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 (A16), that reflect the joint risk aversion and consumption smoothing behaviour of the farm household. The formula in (A16) 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 (A15) 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 (A16) leads to several conclusions that are compatible with intuition. First, the larger the degree of risk aversion (larger value of ρ), and the smaller the degree of consumption smoothing (larger values of β), the larger the benefit of insurance. Second, the larger the degree of (unpredictable) deviation of resources from normal (positive or negative), the larger the WTP for insurance. Third, the larger 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.

REFERENCES

Antle, J.M. 1987. Econometric estimation of producers' risk attitudes. *American Journal of Agricultural Economics*, vol. 69, pp. 509-22.

Antle, J.M. 1989. Nonstructural risk attitude estimation. *American Journal of Agricultural Economics,* vol. 71, pp.774-84.

Bardsley, P. & Harris, M. 1987. An approach to the econometric estimation of attitudes to risk in agriculture. *Australian Journal of Agricultural Economics,* vol. 31, no.2, pp. 112-26.

Bardsley, P. Abey, A. & Davenport, S. 1984. The economics of insuring crops against drought. *Australian Journal of Agricultural Economics*, vol. 28, no.1, pp. 1-14.

Binswanger, H.P. & Sillers, D.A. 1983. Risk aversion and credit constraints in farmers' decision-making. *Journal of Development Studies*, vol. 21, pp.5-21

Binswanger, H.P. 1980. Attitudes towards risk: experimental measurement in rural India. *American Journal of Agricultural Economics*, vol. 62, pp. 395-407.

Browning, M. & Lusardi, A. 1996. Household saving: micro theories and micro facts. *Journal of Economic Literature*, vol. XXXIV: 1797-1855.

Carter, M.R. 1997. Environment, technology, and the social articulation of risk in West African agriculture, *Economic Development and Cultural Change*, vol. 45 3: 557-590.

Christaensen, L., Hoffman, V. & Sarris, A. 2006. *Coffee price risk in perspective – household vulnerability among rural coffee growing smallholders in rural Tanzania*. Paper presented at the CSAE Conference 2006: Reducing poverty and inequality: How can Africa be included? 19-21 March 2006, St Catherine's College, Oxford, England.

Christiaensen, L., Hoffmann, V. & Sarris, A. 2006. *Coffee price risk in perspective – household vulnerability among rural coffee growing smallholders in rural Tanzania*. Paper presented at the CSAE Conference 2006: Reducing Poverty and Inequality: How can Africa be included? 19-21 March 2006, St Catherine's College, Oxford, England.

Deaton, A. 1991. Savings and liquidity constraints. *Econometrica*, vol. 59, no.5, pp.1221-48.

Deaton, A. 1992a. Household saving in LDCs: credit markets, insurance and welfare. *Scandinavian Journal of Economics*, vol. 94 2: 253-273.

Deaton, A. 1992b. *Understanding consumption*. Oxford, Clarendon Press.

Dercon, S. 1996. Risk, crop choice and savings: evidence from Tanzania. *Economic Development and Cultural Change,* vol. 44 3: 385-514.

Dercon, S. 1998. Wealth, risk, and activity choice: cattle in western Tanzania. *Journal of Development Economics,* vol. 55:1-42.

Dercon, S. 2005a. Risk, insurance and poverty: a review. *In* Dercon, S. (ed.) *Insurance against poverty.* Helsinki: Oxford University Press and World Institute of Development Economics Research, United Nations University.

Dercon, S. ed. 2005b. *Insurance against poverty*. Helsinki: Oxford University Press and World Institute of Development Economics Research, United Nations University.

Fafchamps, M. & Pender, J. 1997. Precautionary saving, credit constraints, and irreversible Investment: Theory and Evidence from Semiarid India, *Journal of Business and Economic Statistics*, vol. 152 2: 180-194.

Fafchamps, M., Udry, C. & Czukas, K. 1998. Drought and saving in West-Africa: are livestock a buffer stock? *Journal of Development Economics*, vol. 55, pp.273-305.

Finkelshtain, I. & Chalfant, J.A. 1991. Marketed surplus under risk: do peasants agree with Sandmo? *American Journal of Agricultural Economics*, vol. 73 August, pp. 557-67.

Fraser, R.W. 1992. An analysis of willingness-to-pay for crop insurance. *The Australian Journal of Agricultural Economics*, 36 1, pp. 83 – 95.

Gautam, M., Hazell, P. & Alderman, H. 1994. *Rural demand for drought insurance*. World Bank, Policy Research Working Paper No. 1383.

Hanemman, W.M. & Kanninen, B. 1998. *The statistical analysis of discrete-response data.* Working paper No. 798, Department of Agricultural and Resource Economics and Policy, University of California, Berkeley.

Hausman, J.A. **ed**. 1993. *Contingent valuation: a critical assessment*. Amsterdam, North Holland.

Hazell, P. Bassoco, L.M. & Arcia, G. 1986. A model for evaluating farmers' demand for insurance: applications in Mexico and Panama. *In* P. Hazell, C. Pomareda & A. Valdes (eds) *Crop insurance for agricultural development*. Baltimore, The Johns Hopkins University Press for the International Food Policy Research Institute.

International Task Force on Commodity Risk Management in Developing Countries ITF. 1999. *Dealing with commodity price volatility in developing countries: a proposal for a market-based approach*. Discussion Paper for the Roundtable on Commodity Risk Management in Developing Countries World Bank. Washington DC. September 24, processed.

Jalan, J. & Ravallion, M. 1999. Are the poor less well insured? Evidence on vulnerability to income risk in Rural China. *Journal of Development Economics*, vol. 58, pp. 61-81.

Kazianga, H. & Udry, C. 2006. Consumption smoothing? Livestock, insurance and drought in rural Burkina Faso. *Journal of Development Economics*, 79 2, 413-446.

Kurosaki, T. & Fafchamps, M. 2002. Insurance market efficiency and crop choices in Pakistan,. *Journal of Development Economics* Vol. 67, No. 2, April 2002, pp. 419-453.

Kurosaki, T. 1998. *Risk and household behaviour in Pakistan's Agriculture.* Institute of Development Economies, Tokyo.

McCarthy N. 2003. *Demand for rainfall index-based insurance: A case study from Morocco*, International Food Policy Research Institute, EPTD Discussion Paper 106.

Morduch, J. 1995. Income smoothing and consumption smoothing. *Journal of Economic Perspectives*, vol. 9, Summer, pp. 103-114.

Moschini, G. & Hennessy, D.A. 2001. Uncertainty, risk aversion and risk management for agricultural producers. Chapter 2 *in* B.L. Gardner & G.C. Rausser (eds.). *Handbook of Agricultural Economics.* vol. 1A Agricultural Production. Amsterdam, Elsevier.

Newberry, D.M.G. & Stiglitz, J.E. 1981. *The theory of commodity price stabilization*. Oxford, Clarendon Press.

Patrick J.F. 1988**.** Mallee farmers' demand for crop and rainfall insurance. *Australian Journal of Agricultural Economics ,*vol. 32 no. 1, pp. 37 – 49.

Rosenszeig, M. & Binswanger, H. 1993. Wealth, weather risk, and the composition and profitability of agricultural investments. *Economic Journal,* vol. 103, pp. 56-78.

Rosenszeig, M. & Wolpin, K. 1993. Credit market constraints, consumption smoothing, and the accumulation of durable production assets in low-income countries: investment in bullocks in India. *Journal of Political Economy*, vol. 101 2, pp. 223-244.

Sakurai, T. & Reardon, T. 1997, Potential demand for drought insurance in Burkina Faso and its determinants. *American Journal of Agricultural Economics*, vol. 79, pp. 1193-1207.

Sarris, A. & Karfakis, P. 2006. *Household vulnerability in rural Tanzania.* Paper presented at the CSAE Conference 2006: Reducing Poverty and Inequality: How can Africa be included? 19-21 March 2006, St Catherine's College, Oxford, England.

Sarris, A. 2002. *The demand for commodity insurance by developing country agricultural producers: theory and an application to cocoa in Ghana*. World Bank, Policy Research Working Paper No. 2887, September.

Sarris, A. 2003. *Methodology for the choice of villages and agricultural households for the REPOA/FAO/World Bank Tanzania Vulnerability Survey in the Kilimanjaro region*, unprocessed note.

Sarris, A. 2004. *Methodology for the choice of villages and agricultural households for the REPOA/FAO/World Bank Tanzania Vulnerability Survey in the Ruvuma region*, unprocessed note.

Sarris, A., Savastano, S. & Christiaensen, L. 2006. *The role of agriculture in reducing poverty in Tanzania: A household perspective from rural Kilimanjaro and Ruvuma.* Paper presented at the CSAE Conference 2006: Reducing Poverty and Inequality: How can Africa be included? 19-21 March 2006, St Catherine's College, Oxford, England.

Skees, J.R., Hartell, J. & Hao, J. 2006. Weather and index-based insurance for developing countries: experience and possibilities. *In* A. Sarris & D. Hallam, (eds.) *Agricultural commodity markets and trade: new approaches to analyzing market structure and instability*. Edward Elgar and Food and Agriculture Organization of the United Nations, Cheltenham, UK and Rome, Italy.

Townsend, R.M. 1995. Consumption insurance: An evaluation of risk-bearing systems in low-income economies. *Journal of Economic Perspectives*, vol. 9, Summer, pp. 83-102.

Turvey, C.G. 1992. An economic analysis of alternative farm revenue insurance policies. *Canadian Journal of Agricultural Economics*, vol. 40:403-426.

Vandeveer, M. L. & Loehman, E. T. 1994. Farmer response to modified crop insurance: a case study of corn in Indiana. *American Journal of Agricultural Economics,* vol. 76, pp. 128-140.

Varangis, P., Larson, D. & Anderson, J. 2002. *Agricultural markets and risks: management of the latter not the former.* World Bank, Policy Research Working Paper No. 2793.

World Bank. 2001. *World development report 2000/2001: attacking poverty*, Oxford University Press.

World Bank, 2006. *Managing agricultural production risks: innovations in developing countries.* Agriculture and Rural Development Department, Report No 32727-GLB.

Zeldes, S.P. 1989. Consumption and liquidity constraints: an empirical investigation. *Journal of Political Economy,* vol. 79 2: 305-346.

TABLES

TABLE 1: General characteristics of rural households in Kilimanjaro and Ruvuma

		Kilimanjaro			Ruvuma		
	Unit	All	Poor	Non Poor	All	Poor	Non Poor
Number of households	Number	190 744	63 171	128 351	173 921	96 897	77 024
Household size	Number	5.3	6.5	4.7	5.2	5.7	4.6
Age of Head	Years	53.5	50.8	54.8	43.37	43.93	42.67
Annual per capita total expenditure	'000 Tsh	214	105	268	162	93	249
Annual per capita total income	'000 Tsh	158	80	204	148.6	85.7	227.9
Livelihoods							
Share of non-cash income in total income	Percent	43.3	46.5	41.7	58.5	61.0	55.3
Share in total cash income of							
Coffee	Percent	5.4	6.5	4.8	13.5	12.2	15.2
Tobacco	Percent				2.4	3.0	1.7
Cashew nuts	Percent				9.2	13.0	4.6
Other crops	Percent	27.1	22.6	29.3	28.1	26.6	29.9
Non-crop agriculture	Percent	14.6	12.4	15.8	3.0	3.3	2.8
Wages	Percent	21.8	27.8	18.9	15.5	18.0	12.4
Other non-farm income	Percent	31.0	30.7	31.2	28.2	24.1	33.3
Herfindahl Index of cash income diversification	Index 0 to 1	0.556	0.588	0.539	0.619	0.615	0.623
Herfindahl Index of total income diversification	Index 0 to 1	0.438	0.439	0.437	0.361	0.367	0.353
Asset base							
Value of wealth per household	‘000 Tsh	3 375	2 334	3 888	820	671	1006
Share of wealth from							
Agriculture capital	Percent	1.6	1.2	1.8	2.9	2.0	4.1
Non agriculture capital	Percent	1.4	1.0	1.6	1.0	0.7	1.3
Consumer durables	Percent	28.0	23.2	30.4	17.3	17.0	17.8
Agricultural land	Percent	18.4	21.3	17.0	23.3	23.9	22.6
Dwellings	Percent	58.2	63.3	55.8	45.0	48.1	43.1
Animals	Percent	10.2	10.8	10.0	9.5	8.3	11.0
Area of land cultivated	Acres	2.66	2.36	2.81	6.1	5.6	5.9
Number of plots cultivated	Number	1.96	1.93	1.97	2.6	2.9	3.0
Number of animals in cattle equivalent	Number	2.43	1.97	2.65	1.04	.747	1.42
Education of the head	Years	6.3	5.8	6.3	8.1	8.3	8.0
Agricultural productivity							
Yield from maize	kg/acre	217	160	245	203	167	248
Value added from crop production/acre	'000 Tsh/acre	116	100	125	46	37	57
Value of input for crop production/acre	'000 Tsh/acre	32	25	35	9.76	4.43	11.64

Source: Authors’ calculations.

TABLE 2: Percentage of households affected by various shocks between 1999 and 2003, by region and status as cash crop grower or not

	Kilimanjaro		Ruvuma		All households
	Cash crop grower	Non cash crop grower	Cash crop grower	Non cash crop grower	
Health					
Death	23.1	29.9	16.3	19	21.8
Illness	23.3	22.8	18.5	19.1	21
Climatic					
Drought	27.8	39.9	2.8	7.1	19.2
Excessive rains	4.3	11.5	4.2	2.2	5.4
Agricultural production					
Harvest loss	5.2	8.6	6.1	4.4	6
Livestock loss	5.1	8.5	3.1	5.4	5.3
Post harvest cereal loss	-	-	0.9	2.9	1.7
Economic					
Cash crop price shock	-	-	5.8	2.7	4.6
Cereal price shock	-	-	0.8	5.1	2.5
Unemployment	0.3	1.7	0.2	0	0.5
Property					
Theft	4.4	6.9	3.7	6.9	5.2
Fire/house destroyed	0.2	1.4	3	3.7	1.9
Land loss	0.2	0.9	0.2	0	0.3

Source: Authors' calculations.

TABLE 3. Average number of years in past 10 that households report rainfall as being in different ranges relative to normal

	Mean	SD
Kilimanjaro		
Much below	2.47	1.42
Somewhat below	2.01	1.23
Normal	3.53	1.77
Somewhat above	1.03	0.88
Much above	0.96	0.47
Ruvuma		
Much below	0.63	0.94
Somewhat below	1.50	1.24
Normal	5.78	2.21
Somewhat above	1.24	1.15
Much above	0.85	0.74

Source: Authors' calculations.

TABLE 4. Perceptions of households concerning rainfall

If rainfall was one tenth, one quarter one third or one half below normal you would say that it was:
(percentage of household responses)

	Normal	Somewhat below	A lot below	NA	Total
Kilimanjaro					
one tenth below normal	19.9	52.34	25.85	1.91	100
one quarter below normal	1.69	32.41	63.99	1.91	100
one third below normal	2.63	8.49	86.86	2.02	100
one half below normal	0.21	1.46	96.42	1.91	100
Number of households	182 775				
Ruvuma					
one tenth below normal	28.28	53.55	15.71	2.46	100
one quarter below normal	2.55	37.17	57.96	2.32	100
one third below normal	0.87	12.22	84.6	2.32	100
one half below normal	0.08	1.59	96.01	2.32	100
Number of households	161 619				

Source: Authors' calculations

TABLE 5. Households' assessments of yearly rainfall in year of survey compared with actual rainfall relative to long run average

	Kilimanjaro	Ruvuma
Long run average yearly rainfall (mm)	1 303	1 106
	Dec 03 to Nov 04	**Mar 04 to Feb 05**
Survey year actual rainfall (mm)	990	1 246
Households' rainfall assessment relative to normal rainfall (percent of households):		
	Dec03 to Nov04	**Mar 04 to Feb 05**
Much above	0.4	4.5
Above	3.5	8.4
Normal	19.2	76.4
Below	41.3	10.6
Much below	35.6	0.0
No of households	182 834	162 722

Source: Authors' calculations

TABLE 6. Reasons for which households indicated they were not interested in rainfall (or drought) insurance

Why not interested in drought insurance?	**(percentage of total households in the region)**
Kilimanjaro	
I cannot pay any amount for rainfall	29.28
I am short of funds in the period before planting	1.98
I have other pressing cash needs in the period before planting	1.15
Declines in rainfall do not hurt me too much	4.70
I have other means of covering losses due to bad rainfall	0.82
Major declines in rainfall do not occur too often	0.94
Other	14.32
percent of households not interested	53.19
Total number of households	182 775
Ruvuma	
I cannot afford to pay any amount	20.71
I am short of funds in the period before planting	0.78
I have other pressing cash needs in the period before planting	0.46
Declines in rainfall do not hurt me too much	17.32
I have other means of recovering losses due to bad rainfall	0.21
Major droughts do not occur too often	20.20
Other	3.48
NA	2.44
percent of households not interested	65.60
Total number of households	161 619

Source: Authors’ calculations

TABLE 7. WTP for weather insurance in Kilimanjaro under a hypothetical 10 percent decline in rainfall below normal (coefficients indicate the marginal effects)

	(A type contract) Insured for 22 000Tsh/acre	**(B type contract) Insured for 38 000Tsh/acre**	**(C type contract) Insured for 61 000Tsh/acre**
Bid for type A contracts	-0.0000311		
	(5.06)**		
Bid for type B contracts		-0.0000171	
		(5.30)**	
Bid for type C contracts			-0.0000106
			(5.59)**
Education of head (years)	-0.0015171	-0.0065241	-0.0004663
	(0.18)	(0.85)	(0.06)
Household size (number of adult equivalent)	0.0289585	0.0245129	0.0240692
	(2.57)*	(2.40)*	(2.37)*
Per capita income in Tsh	0.0000003	0.0000004	0.0000004
	(2.64)**	(3.32)**	(4.00)**
Cultivated land (acres)	-0.0156065	-0.0113542	-0.0125972
	(1.44)	(1.16)	(1.33)
Number of animals (cattle equivalent)	0.0024028	0.0037901	0.0034603
	(0.60)	(1.08)	(0.96)
Herfindahl Index of gross income diversification	-0.0026249	-0.0015374	-0.0005271
	(2.44)*	(1.55)	(0.55)
Share of cash to total gross income	0.0023250	0.0032866	0.0024593
	(2.35)*	(3.49)**	(2.72)**
Proportion of irrigated land	0.0001996	0.0006397	0.0000183
	(0.29)	(1.00)	(0.03)
Dummy: 1=drought since 1998 affected living conditions	0.0278826	0.0608728	0.0798378
	(0.59)	(1.41)	(1.86)
Number of years in past 10, when total household ncome declined a lot below normal	-0.0094498	-0.0083481	-0.0073630
	(0.80)	(0.77)	(0.68)
Dummy: 1= easy access to short term credit	0.0209702	0.0762850	0.0685108
	(0.33)	(1.24)	(1.15)
Dum=1 if when shock occurred used own savings	0.2035622	0.2794161	0.2381621
	(4.63)**	(6.62)**	(5.81)**
Dum=1 if when shock occurred used family assistance	-0.1250291	-0.1359342	-0.0887069
	(2.52)*	(3.16)**	(2.08)*
Dum=1 if when shock occurred used other assistance	0.0492685	0.0889814	0.1849691
	(0.53)	(1.04)	(2.04)*
Dum=1 if when shock occurred used new ways to earn income	-0.0127718	-0.0589814	-0.0495804
	(0.24)	(1.26)	(1.07)
Coffee production dummy	0.0423754	0.0941659	0.0922978
	(0.74)	(1.77)	(1.76)
Banana production dummy	0.0207279	-0.0116160	0.0008054
	(0.34)	(0.20)	(0.01)
Vulnerability index	-0.2713344	-0.1293888	-0.2191889
	(2.02)*	(1.04)	(1.75)
Observations	914	914	914
Pseudo R-squared	0.14	0.18	0.18
Proportion of correct predictions	71.18	74.61	75.61

Robust z statistics in parentheses. * significant at 5 percent; ** significant at 1 percent

Source: Authors' calculations

TABLE 8. WTP for weather insurance in Ruvuma under a hypothetical 10 percent decline in rainfall below normal (coefficients indicate the marginal effects)

	(A type contract) Insured for 12 000Tsh/acre	**(B type contract) Insured for 21 000Tsh/acre**	**(C type contract) Insured for 35 000Tsh/acre**
Bid for type A contracts	-0.0000213		
	(1.51)		
Bid for type B contracts		-0.0000138	
		(1.90)	
Bid for type C contracts			-0.0000117
			(2.58)**
Education of head (years)	0.0153675	0.0180349	0.0195932
	(1.94)	(2.84)**	(3.34)**
Household size (number of adult equivalent)	0.0087433	0.0167361	0.0194514
	(0.65)	(1.58)	(2.23)*
Per capita income in Tsh	0.0000000	0.0000001	0.0000002
	(0.05)	(0.87)	(2.01)*
Number of animals (cattle equivalent)	0.0025218	0.0016571	-0.0002741
	(0.87)	(0.71)	(0.14)
Number of animals (cattle equivalent)	-0.0091327	-0.0041867	-0.0002064
	(0.74)	(0.45)	(0.03)
Herfindahl Index of gross income diversification	0.0016381	0.0002419	0.0004132
	(1.45)	(0.28)	(0.58)
Share of cash to total gross income	0.0006248	0.0001201	-0.0004190
	(0.67)	(0.16)	(0.67)
Proportion of irrigated land	0.0022501	-0.0011189	-0.0007107
	(0.82)	(0.55)	(0.44)
Rainfall last year was below normal	0.0015442	0.0409188	0.0258055
	(0.03)	(0.98)	(0.74)
Number of years in past 10 when revenue per acre was less than half of normal	0.0001945 (0.02)	-0.0071490 (0.75)	0.0028882 (0.36)
Dum=1 cash income from cash crop production and sales is most or second most unreliable	-0.0317011 (0.76)	-0.0017635 (0.05)	0.0332439 (1.13)
Dummy: 1=easy access to short term credit	0.0413870	-0.0828594	-0.0619875
	(0.76)	(2.14)*	(2.02)*
Dum=1 if when shock occurred used own savings	0.0641022	0.1283204	0.1301363
	(1.34)	(3.15)**	(3.61)**
Dum=1 if when shock occurred used family assistance	-0.0748980 (1.19)	-0.0992822 (2.45)*	-0.0616748 (1.85)
Dum=1 if when shock occurred used other assistance	-0.0971490 (1.15)	-0.0417681 (0.60)	-0.0461154 (0.85)
Dum=1 if when shock occurred used new ways to earn income	0.1890877 (2.78)**	0.1040891 (1.95)	0.1484072 (2.90)**
Coffee production dummy	-0.0969641	0.0143164	-0.0615483
	(1.15)	(0.20)	(1.37)
Cashew production dummy	0.1281399	-0.0152677	0.0139454
	(1.62)	(0.26)	(0.28)
Tobacco production dummy	0.0486115	0.2258134	0.2626168
	(0.32)	(1.56)	(2.05)*
Banana production dummy	0.0500753	-0.0031172	-0.0127360
	(1.22)	(0.10)	(0.50)
Vulnerability index	-0.2287345	-0.2106202	-0.1457216
	(1.68)	(1.99)*	(1.68)
Observations	838	815	817
Pseudo R-squared	0.10	0.16	0.18
Proportion of correct predictions	75.62	82.55	85.83

Robust z statistics in parentheses. * significant at 5 percent; ** significant at 1 percent

Source: Authors' calculations

TABLE 9. WTP for weather insurance in Kilimanjaro under a hypothetical one third decline in rainfall below normal (coefficients indicate the marginal effects)

	(A type contract) Indemnity 24 000Tsh/acre	(B type contract) Indemnity 41 000Tsh/acre	(C type contract) Indemnity 66 000Tsh/acre
Bid for type A contracts	-0.0000296		
	(4.97)**		
Bid for type B contracts		-0.0000173	
		(4.94)**	
Bid for type C contracts			-0.0000109
			(4.96)**
Education of head (years)	0.0051382	0.0025834	0.0036294
	(0.64)	(0.34)	(0.48)
Household size (number of adult equivalent)	0.0282076	0.0303157	0.0347648
	(2.52)*	(2.90)**	(3.40)**
Per capita income in Tsh	0.0000004	0.0000004	0.0000005
	(3.63)**	(3.83)**	(4.35)**
Cultivated land (acres)	-0.0191016	-0.0129556	-0.0120295
	(1.75)	(1.28)	(1.22)
Number of animals (cattle equivalent)	0.0063863	0.0044043	0.0025670
	(1.54)	(1.16)	(0.76)
Herfindahl Index of gross income diversification	-0.0005826	-0.0008111	-0.0005761
	(0.55)	(0.81)	(0.58)
Share of cash to total gross income	0.0032735	0.0035005	0.0034033
	(3.17)**	(3.58)**	(3.53)**
Proportion of irrigated land	0.0003580	0.0001387	0.0001490
	(0.53)	(0.21)	(0.24)
Dummy: 1=drought since 1998 affected living conditions	0.0849949	0.0640875	0.0647671
	(1.88)	(1.48)	(1.54)
Number of years in past 10, when total household income declined a lot below normal	-0.0001039	-0.0032223	-0.0078681
	(0.01)	(0.30)	(0.74)
Dummy: 1= easy access to short term credit	0.0152773	0.0083930	0.0196854
	(0.24)	(0.14)	(0.33)
Dum=1 if when shock occurred used own savings	0.2212950	0.2244386	0.2067804
	(5.13)**	(5.36)**	(5.04)**
Dum=1 if when shock occurred used family assistance	-0.1122368	-0.0736697	-0.0661003
	(2.40)*	(1.65)	(1.50)
Dum=1 if when shock occurred used other assistance	0.0881901	0.0954009	0.1035699
	(0.96)	(1.11)	(1.26)
Dum=1 if when shock occurred used new ways to earn income	-0.0586405	-0.0565901	-0.0570676
	(1.18)	(1.19)	(1.23)
Coffee production dummy	0.1082017	0.1198331	0.1161030
	(1.95)	(2.24)*	(2.23)*
Banana production dummy	0.0189364	-0.0022550	0.0126633
	(0.32)	(0.04)	(0.22)
Vulnerability index	-0.2365073	-0.1712120	-0.1832340
	(1.77)	(1.36)	(1.47)
Observations	914	914	914
Pseudo R-squared	0.18	0.17	0.17
Proportion of correct predictions	71.48	73.24	74.50

Robust z statistics in parentheses * significant at 5 percent; ** significant at 1 percent

Source: Authors' calculations

TABLE 10. WTP for weather insurance in Ruvuma under a hypothetical one third decline in rainfall below normal (coefficients indicate the marginal effects)

	(A type contract) Insured for 12 000Tsh/acre	**(B type contract) Insured for 21 000Tsh/acre**	**(C type contract) Insured for 35 000Tsh/acre**
Bid for type A contracts	-0.0000213		
	(1.51)		
Bid for type B contracts		-0.0000138	
		(1.90)	
Bid for type C contracts			-0.0000117
			(2.58)**
Education of head (years)	0.0153675	0.0180349	0.0195932
	(1.94)	(2.84)**	(3.34)**
Household size (number of adult equivalent)	0.0087433	0.0167361	0.0194514
	(0.65)	(1.58)	(2.23)*
Per capita income in Tsh	0.0000000	0.0000001	0.0000002
	(0.05)	(0.87)	(2.01)*
Number of animals (cattle equivalent)	0.0025218	0.0016571	-0.0002741
	(0.87)	(0.71)	(0.14)
Number of animals (cattle equivalent)	-0.0091327	-0.0041867	-0.0002064
	(0.74)	(0.45)	(0.03)
Herfindahl Index of gross income diversification	0.0016381	0.0002419	0.0004132
	(1.45)	(0.28)	(0.58)
Share of cash to total gross income	0.0006248	0.0001201	-0.0004190
	(0.67)	(0.16)	(0.67)
Proportion of irrigated land	0.0022501	-0.0011189	-0.0007107
	(0.82)	(0.55)	(0.44)
Rainfall last year was below normal	0.0015442	0.0409188	0.0258055
	(0.03)	(0.98)	(0.74)
Number of years in past 10 when revenue per acre was less than half of normal	0.0001945	-0.0071490	0.0028882
	(0.02)	(0.75)	(0.36)
Dum=1 cash income from cash crop production and sales is most or second most unreliable	-0.0317011	-0.0017635	0.0332439
	(0.76)	(0.05)	(1.13)
Dummy: 1=easy access to short term credit	0.0413870	-0.0828594	-0.0619875
	(0.76)	(2.14)*	(2.02)*
Dum=1 if when shock occurred used own savings	0.0641022	0.1283204	0.1301363
	(1.34)	(3.15)**	(3.61)**
Dum=1 if when shock occurred used family assistance	-0.0748980	-0.0992822	-0.0616748
	(1.19)	(2.45)*	(1.85)
Dum=1 if when shock occurred used other assistance	-0.0971490	-0.0417681	-0.0461154
	(1.15)	(0.60)	(0.85)
Dum=1 if when shock occurred used new ways to earn income	0.1890877	0.1040891	0.1484072
	(2.78)**	(1.95)	(2.90)**
Coffee production dummy	-0.0969641	0.0143164	-0.0615483
	(1.15)	(0.20)	(1.37)
Cashew production dummy	0.1281399	-0.0152677	0.0139454
	(1.62)	(0.26)	(0.28)
Tobacco production dummy	0.0486115	0.2258134	0.2626168
	(0.32)	(1.56)	(2.05)*
Banana production dummy	0.0500753	-0.0031172	-0.0127360
	(1.22)	(0.10)	(0.50)
Vulnerability index	-0.2287345	-0.2106202	-0.1457216
	(1.68)	(1.99)*	(1.68)
Observations	838	815	817
Pseudo R-squared	0.10	0.16	0.18
Proportion of correct predictions	75.62	82.55	85.83

Robust z statistics in parentheses. * significant at 5 percent; ** significant at 1 percent

Source. Authors' calculations

TABLE 11. Summary statistics of the WTP for rainfall insurance in Kilimanjaro (AFP denotes the approximate Actuarially Fair Price of the contract in Tsh/acre)

Drought WTP Kilimanjaro –10 percent rainfall decline below normal			
	22 000 Tsh contract (AFP 9000)		
	No of households	Average WTP	St. Dev.
WTP (Tsh)	182 539	4 991.9	5 505.9
WTP (Share on 22 000 Tsh)	182 539	22.7	25.0
	38 000Tsh contract (AFP (15 000)		
	No of households	Average WTP	St. Dev.
WTP (Tsh)	182 539	5 041.0	7 806.5
WTP (Share of 38 000 Tsh)	182 539	13.3	20.5
	61 000 Tsh contract (25 000)		
	No of households	Average WTP	St. Dev.
WTP (Tsh)	182539	7 487.5	12 449.6
WTP (Share of 61 000 Tsh)	182539	12.3	20.4
Drought WTP Kilimanjaro –30 percent rainfall decline below normal			
	24 000 Tsh contract (AFP 8 000)		
	No of households	Average WTP	SD
WTP (Tsh)	182 539	3 401.2	5 061.5
WTP (Share on 24 000 Tsh)	182 539	14.2	21.1
	41 000 Tsh contract (AFP 13 000)		
	No of households	Average WTP	SD
WTP (Tsh)	182 539	4 333.0	7 229.3
WTP (Share of 41 000 Tsh)	182 539	10.6	17.6
	66 000 Tsh contract (AFP 21 000)		
	No of households	Average WTP	SD
WTP (Tsh)	182 539	6 310.2	10 943.3
WTP (Share of 66 000 Tsh)	182 539	9.6	16.6

Source. Authors' calculations

TABLE 12. Summary statistics of the WTP for rainfall insurance in Ruvuma (AFP denotes the approximate Actuarially Fair Price of the contract in Tsh/acre)

Drought WTP Ruvuma –10 percent rainfall decline below normal			
	12 000 Tsh contract (AFP 4000)		
	No of households	Average WTP	SD
WTP (Tsh)	162 707	719.3	2 294.7
WTP (Share on 12 000 Tsh)	162 707	6.0	19.1
	21 000 Tsh contract (AFP 7000)		
	No of households	Average WTP	SD.
WTP (Tsh)	160 913	651.4	2 489.4
WTP (Share of 21 000 Tsh)	160 913	3.1	11.9
	35 000 Tsh contract (AFP 11500)		
	No of households	Average WTP	SD
WTP (Tsh)	159 494	1 042.8	3 240.2
WTP (Share of 35 000 Tsh)	159 494	3.0	9.3
Drought WTP Ruvuma –30 percent rainfall decline below normal			
	2 0000 Tsh contract (AFP 3000)		
	No of households	Average WTP	SD
WTP (Tsh)	162 707	182.6	961.6
WTP (Share on 20 000 Tsh)	162 707	0.9	4.8
	35 000 Tsh contract (AFP 5300)		
	No of households	Average WTP	SD
WTP (Tsh)	157 523	328.4	1 536.9
WTP (Share of 35 000 Tsh)	157 523	0.9	4.4
	58 000 Tsh contract (AFP 8700)		
	No of households	Average WTP	SD
WTP (Tsh)	162 707	348.1	1 889.6
WTP (Share of 58 000 Tsh)	162 707	0.6	3.3

Source. Authors' calculations

TABLE 13. Kilimanjaro. Welfare benefits and cost of rainfall insurance (AFP denotes the approximate Actuarially Fair Price of the contract in '000 Tsh/acre)

	Premium value (000Tsh/ acre)	**Acres insured**	**Number of households**	**Total premium (million Tsh)**	**Premium as share of crop sales**	**Consumer surplus (million Tsh)**	**Consumer surplus as share of crop sales**	**Acres cultivated**
Kilimanjaro surplus estimation from insurance against 10 percent rainfall reduction								
				22 000 Tsh contact				
At mean WTP	4.99	110 676	75 411	552.48	3.27	815.58	4.83	237 896
At mean WTP+1 SD	10.50	68 449	32 789	718.56	7.84	318.28	3.47	116 994
At AFP	9.00	86 847	32 789	781.62	6.68	318.28	2.72	148 392
				38 000 Tsh contract				
At mean WTP	5.04	86 439	60 945	435.74	2.90	1050.26	7.00	200 142
At mean WTP+1 SD	12.85	49 983	28 722	642.16	7.35	517.49	5.92	109 876
At AFP	15.00	42 288	23 121	634.32	8.33	394.17	5.18	86 715
				61 000 Tsh contract				
At mean WTP	7.49	88 403	59 204	661.92	4.22	1607.73	10.24	199 625
At mean WTP+1 SD	19.94	46 568	29 132	928.42	9.87	766.87	8.16	100 628
At AFP	25.00	27 792	18 284	694.81	9.54	555.84	7.63	65 090
Total number of households/acres			182 834					504 152
Kilimanjaro surplus estimation from insurance against one third rainfall reduction								
				24 000 Tsh contact				
At mean WTP	3.40	109 947	64 467	373.95	2.40	760.21	4.87	208 118
At mean WTP+1 SD	8.46	52 129	28 811	441.15	5.52	325.45	4.07	97 829
At AFP	8.00	66 669	28 811	533.35	5.62	325.45	3.43	114 677
				41 000 Tsh contract				
At mean WTP	4.33	90 569	56 580	392.43	2.67	1067.93	7.26	194 063
At mean WTP+1 SD	11.56	54 899	28 070	634.75	7.23	509.47	5.81	101 737
At AFP	13.00	46 799	23 565	608.38	7.96	435.98	5.70	88 774
				66 000 Tsh contract				
At mean WTP	6.31	85 230	56 815	537.82	3.49	1512.40	9.82	192 017
At mean WTP+1 SD	17.25	50 898	26 161	878.17	9.06	713.84	7.36	98 996
At AFP	21.00	33 089	18 219	694.87	10.08	554.36	8.04	63 481
Total number of households/acres			182 834					504 152

Source. Authors' calculations

TABLE 14. Ruvuma. Welfare benefits and cost of rainfall insurance (AFP denotes the approximate Actuarially Fair Price of the contract in '000 Tsh/acre)

	Premium value (000Tsh/ acre)	Acres insured	Number of households	Total premium (million Tsh)	Premium as share of crop sales	Consumer surplus (million Tsh)	Consumer surplus as share of crop sales	Acres cultivated
Kilimanjaro surplus estimation from insurance against 10 percent rainfall reduction								
12 000 Tsh contact								
At mean WTP	0.72	59 771	21 675	42.99	0.52	361.56	4.38	187 169
At mean WTP+1 SD	3.01	44 346	14 395	133.66	2.19	244.33	4.00	133 380
At AFP	4.00	35 700	11 342	142.80	3.15	203.58	4.49	107 721
21 000 Tsh contract								
At mean WTP	0.65	41 833	16 411	27.25	0.43	298.76	4.73	161 721
At mean WTP+1 SD	3.14	33 814	10 957	106.20	2.33	204.40	4.48	113 494
At AFP	7.00	17 162	6 167	120.13	4.84	102.19	4.12	68 882
35 000sh contract								
At mean WTP	1.04	42 168	24 558	43.97	0.44	302.57	3.04	225 208
At mean WTP+1 SD	4.28	27 126	14 472	116.18	1.70	190.24	2.78	143 196
At AFP	11.50	10 654	3 026	122.52	9.88	43.84	3.53	27 570
Total number of households/acres			162 722					1 216 465
Kilimanjaro surplus estimation from insurance against one third rainfall reduction								
24 000 Tsh contact								
At mean WTP	0.18	23 798	9 780	4.35	0.09	80.26	1.63	93 264
At mean WTP+1 SD	1.14	17 134	6 857	19.61	0.51	60.30	1.58	66 201
At AFP	3.00	12 251	4 122	36.75	1.65	34.04	1.52	40 913
35 000 Tsh contract								
At mean WTP	0.33	27 660	11 483	9.08	0.16	113.58	2.02	84 915
At mean WTP+1 SD	1.87	17 449	8 177	32.55	0.74	79.38	1.80	54 366
At AFP	5.30	7 401	3 189	39.23	2.33	35.65	2.12	20 406
58 000 Tsh contract								
At mean WTP	0.35	24 277	9 599	8.45	0.17	147.62	3.05	83 331
At mean WTP+1 SD	2.24	16 536	6 100	37.00	0.94	112.44	2.85	42 481
At AFP	0.35	24 277	9 599	8.45	0.17	147.62	3.05	83 331
Total number of households/acres			162 722					1 216 465

Source. Authors' calculations

FAO COMMODITY AND TRADE POLICY RESEARCH WORKING PAPERS

2006

22 Threshold cointegration in the sugar-ethanol-oil price system in Brazil: evidence from nonlinear vector error correction models
George Rapsomanikis and David Hallam

21 Estimating price elasticities of supply for cotton: a structural time-series approach
Ben Shepherd

20 Market access and preferential trading schemes: Evidence from selected developed and developing countries
Piero Conforti and Luca Salvatici

19 The role of agriculture in reducing poverty in Tanzania: A household perspective from rural Kilimanjaro and Ruvuma
Alexander Sarris, Sara Savastano and Luc Christiaensen

18 Producer demand and welfare benefits of rainfall insurance in the United Republic of Tanzania
Alexander Sarris, Panayiotis Karfakis, and Luc Christiaensen

17 Household vulnerability in rural Tanzania ***Alexander Sarris and Panayiotis Karfakis***

16 The use of organized commodity markets to manage food import price instability and risk
Alexander Sarris, Piero Conforti and Adam Prakash

15 The impact of domestic and international commodity price volatility on agricultural income instability in Ghana, Vietnam and Peru
George Rapsomanikis and Alexander Sarris

14 Linkages between domestic and international maize markets, and market-based strategies for hedging maize import price risks in Tanzania
Alexander Sarris and Ekaterini Mantzou

13 Food import risk in Malawi: simulating a hedging scheme for Malawi food imports using historical data ***Wouter Zant***

2005

12 The effect of direct payments of the OECD countries in world agricultural markets. Evidence from partial and general equilibrium frameworks ***Piero Conforti***

11 The impact of import surges: country case study results for Senegal and Tanzania
Ramesh Sharma, David Nyange, Guillaume Duteutre and Nancy Morgan

2004

10 Agricultural trade liberalization in the Doha round. Alternative scenarios and strategic interactions between developed and developing countries ***Piero Conforti and Luca Salvatici***

9 The EU cotton policy regime and the implications of the proposed changes for producer welfare ***Giannis Karagiannis***

8 The impact of domestic and trade policies on the world cotton market
Daneswar Poonyth, Alexander Sarris, Ramesh Sharma and Shangnan Shui

7 Price transmission in selected agricultural markets ***Piero Conforti***

6 The marketing potential of date palm fruits in the European market ***Pascal Liu***

5 World markets for organic citrus and citrus juices: Current market situation and medium-term prospects ***Pascal Liu***

4 Agricultural Policy Indicators ***Timothy Josling and Alberto Valdés***
(also issued as ESA Working Paper No. 2004/4)

2003

3 Quantifying *appropriate* levels of the WTO bound tariffs on basic food products in the context of the Development Box proposals ***Ramesh Sharma***

2 The WTO and environmental and social standards, certification and labelling in agriculture. ***Cora Dankers***

1 The Brazilian ethanol programme: impacts on world ethanol and sugar markets
Tatsuji Koizumi