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Rural Demand for Drought Insurance

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There appears to be an unmet demand for insurance against drought risks in poor rural areas.

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Summary findings

Many agricultural regions in the developing world are subject to severe droughts, which can have devastating effects on household incomes and consumption, especially for the poor. To protect consumption, rural households engage in many different risk management strategies — some mainly risk-reducing and some simply coping devices to protect consumption once income has been lost. An important limitation of these traditional risk management strategies is their inability to insure against covariate risks. And they are costly. The absence of formal credit and insurance institutions, which offer an efficient alternative by overcoming regional covariance problems and reducing the cost of risk management, amounts to a market failure. Past research has paid much more attention to the supply-side reasons for this market failure than to the demand side question of whether there exist financial instruments that farmers want and would be willing to pay for.

Gautam, Hazell, and Alderman use a dynamic household model to examine the efficiency of drought management strategies used by peasant households. An attractive feature of the method is that it exploits actual production (input-output) data and does not deal with the usually unreliable data on household consumption and leisure activities. The model is applied to a two-year panel of data on households from five villages in Tamil Nadu (South India). The sample is small, but the data are special, as one of the two years was a severe drought year.

The results indicate that agricultural households exhibit significant risk-avoidance behavior, and that even though they may use a range of risk management strategies, there still remains an unmet demand for insurance against drought risks. The study did not estimate the likely costs of supplying drought insurance, but the latent demand in the study region is strong enough to more than cover the breakeven rate of approximately the pure risk cost (the probability of drought) plus 5 percent administration costs.

The findings confirm the inadequacies of traditional strategies of coping with droughts in poor rural areas. Because of the catastrophic and simultaneous effects of droughts on all households over large areas, there is limited scope for spreading risks effectively at the local level. Either households must increase their savings significantly (a problem with low average incomes and an absence of safe and convenient savings instruments), or more effective risk management aids are needed that can overcome the covariation problem. Improved financial markets (with both credit and savings facilities) could be helpful, particularly if they intermediate over a larger and more diverse economic base than the local economy. Alternatively, formal drought insurance in the form of a drought (or rainfall) lottery might be feasible, and the results suggest that it could be sold on a full-cost basis.

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Rural Demand for Drought Insurance*

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Introduction

Many agricultural regions in the developing world are subject to severe droughts, which can have devastating effects on household incomes and consumption, particularly for the poor. In order to protect their consumption, rural households engage in a variety of risk management strategies (Walker and Jodha, 1986; Matlon, 1991). Some of these are primarily risk-reducing in nature (e.g., income diversification, intercropping, farm fragmentation and seasonal migration), while others are coping devices designed to protect consumption once income losses have occurred (e.g., borrowing from local stores and money lenders, drawing down food stocks, selling assets and participation in government relief programs).

Alderman and Paxson (1992) present evidence on the ability of households to effectively protect consumption against exogenous income shocks. One general conclusion is that households are collectively unable to insure against covariate risks. This feature of drought damage - the simultaneous effect on most households within a region - is an important limitation of many traditional risk management strategies. During droughts, many households seek credit at the same time, leading to increases in local interest rates. Similarly, local wages may be driven down by a surge of labor supply combined with a contraction of demand. Farmers may also face a buyers' market for their assets in a drought year but a sellers' market in a post-drought year making it difficult to replenish assets liquidated under stress (Jodha, 1975). To overcome the covariability problem requires risk-sharing arrangements that cut across regions that do not experience droughts simultaneously. Few informal arrangements can accomplish this (with the exception of seasonal migration and agricultural trader credit).

Another important limitation of traditional risk management strategies is their cost. For example, diversification pursued as a risk management aid reduces average incomes; credit borrowed in drought years must be repaid with interest; maintaining food stocks involves storage costs and losses; temporarily liquidating assets is costly due to capital losses as noted above; and off-farm work may entail a cost in terms of potential additional farm income foregone.

Formal credit and insurance institutions can pool risks across large and diversified portfolios and, in principle, offer an efficient way of overcoming regional covariance problems and reducing the cost of risk management. These institutions, however, are rarely well-developed in the developing world and their absence amounts to a market failure. Research on the reasons for this market failure has paid much more attention to supply-side problems (moral hazard, set-up costs, etc., cf. Hazell, Pomareda and Valdés, 1986) that limit the spread of formal credit and insurance instruments than to the demand-side questions of whether there are financial instruments that farmers want and would be willing to pay for on a full-cost basis. If the latter can be demonstrated, then governments may have a key role to play in either helping private banking and insurance institutions overcome supply-side constraints, or in offering these services themselves.[1]

The primary objective in this paper is to develop a model to determine if there is any latent demand for insurance by poor rural households against extreme outcomes such as droughts. If existing risk-management strategies are inadequate in the sense that households exhibit an unmet demand for insurance, potential Pareto gains may be possible should alternative income or consumption smoothing mechanisms be identified. An alternative that this paper explores is a hypothetical drought insurance scheme in the form of a drought (or rainfall) lottery described in Appendix A.

Defining welfare as the expected value of the sum of discounted lifetime utilities of consumption and leisure, dynamic programming is used to set up an inter-temporally separable household model. The dynamic equilibrium conditions are used to derive the benefits and costs associated with ex-ante household decisions. These conditions help in deriving empirical relationships that allow consistent estimation of key behavioral parameters. A distinctive feature of the approach used here is that the parameters needed

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[1] The latter should not be confused with government programs that are essentially income transfers, e.g., relief employment, food rations and subsidized crop insurance. While there is undoubtedly a need for some of these programs in many poor rural areas, the focus here is on facilitating the spread of risk-management instruments on purely economic grounds. Of course, successful instruments would also help reduce the need for welfare assistance.

to assess the efficiency of existing risk-management strategies can be obtained without explicitly specifying a utility function. The method yields a parsimonious empirical model, which requires detailed data only on production activities; such data are often more accessible and reliable than consumption data.

The focus here is on the latent demand for drought insurance. This demand is likely to be determined jointly by risk behavior and the ability of households to smooth welfare over states of nature. No attempt is made to distinguish or identify 'pure' risk attitudes, say by estimating the Arrow-Pratt risk aversion coefficients (Binswanger, 1981; Antle, 1987). Instead, a model which explicitly accounts for various risk-management mechanisms is used to empirically test for the joint hypothesis of risk avoidance and welfare smoothing.

The model is applied to a two-year panel from the IFPRI-TNAU[2] household survey of five villages in the North Arcot district of Tamil Nadu, India. Although the sample is small, the data are appropriate to the question as the region suffered a severe drought in the first year of the survey, with rainfall levels above the long-run average the following year. The estimates are used to derive implied premia that sample households might be willing to pay for a hypothetical drought insurance scheme. The empirical application is intended to be mainly demonstrative due to data limitations. The results obtained here complement an application of a similar method to data from Burkina Faso (Sakurai, et al., 1994).

The plan of the paper is as follows: the next section describes the problem under study; the third section briefly reviews the solution principle for a multiperiod consumption problem; the fourth section develops a household model with drought risks; the fifth section derives efficiency conditions for the risk-management strategies currently available to households; the sixth section is concerned with the empirical application of the model with sub-sections that describe the data, present the econometric procedures and discuss the results; and the final section summarizes and concludes.

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[2] IFPRI is the International Food Policy Research Institute, Washington D.C., and TNAU is the Tamil Nadu Agricultural University, Tamil Nadu, India.

The Problem

To conceptualize the sequential decision making process for an agricultural household, each production period (i.e., the agricultural year) is divided into two stages: stage I corresponds to the time between planting and harvesting, and stage II corresponds to the time from harvesting to the start of the next planting season. Each stage is different in terms of its decision-making environment and the nature of the problem faced by the household.

At the beginning of stage I, a household is endowed with a level of resources carried over as a result of previous actions. Frequent occurrence of droughts makes future income, and hence future welfare, of the household uncertain. It has to decide on how to allocate resources between current consumption, (precautionary) savings, and production in order to attain a plan that maximizes its welfare. These decisions are assumed to be made at the beginning of stage I and, hence, will be conditioned only on information available at the beginning of stage I.

The resources available to the household include a fixed labor endowment, an initial level of fixed capital, an initial level of savings, and initial disposable income. Fixed capital stock is combined with variable inputs (labor and working capital) in stage I to produce agricultural income that is realized in stage II. The production outcome is subject to uncertain weather, making the stage I decision-making environment risky. In response to this uncertainty, the household resorts to risk-management strategies in an attempt to maintain a desired balance between expected income and income risk.

The ex ante (stage I) risk-management strategies include risk-reducing actions such as diversifying investment of given resources (labor and capital) across farm and non-farm income sources, and within farm income diversifying across crops, fields and technologies. This 'self-insurance,' however, is bought at the cost of lower expected income. The 'premium' associated with, for example, risk-induced crop diversification is the expected income foregone by not adopting a profit-maximizing cropping pattern. Other ex ante strategies include precautionary savings. These savings tie up scarce capital in a liquid form at the cost of foregone production opportunities.

In stage II the outcome of stage I decisions is realized. With weather-related uncertainty resolved, the decision-making environment at this stage is certain. For simplicity, shocks are modelled as binary outcomes, namely 'non-drought' and 'drought': in the event of a non-drought year, anticipated income is realized; in the event of a drought year, realized income suffers a downward shock. The household responds to such shocks with risk-coping mechanisms such as obtaining temporary off-farm employment, drawing down savings, and borrowing to smooth consumption.

It should be reiterated that stage II risk-coping actions are ex post in nature. While decisions in this stage will be dependent on the outcome of stage I, they cannot influence that outcome *per se*.[3] The primary role of various risk-coping devices is to cushion income shortfalls in the same way that savings do. However, under the assumption of rational intertemporal behavior, the ability of households to smooth consumption ex post is expected to influence ex ante risk behavior. For example, if households know that they can obtain moderately priced consumption credit in the event of a drought, they are unlikely to pursue risk-reducing strategies in stage I that are more costly in terms of expected income.

In control parlance this forward-looking nature of decision making calls for a closed-loop solution. Dynamic programming provides such solutions to multi-period problems, and Bellman's Principle of Optimality (Bellman, 1957) ensures that decision rules obtained by this approach will be optimal at each stage, irrespective of the realization of future outcomes. Thus, assuming that households are aware of their options (i.e., risk-coping devices)[4], the efficiency of existing risk-management devices can be used to determine their costs in smoothing welfare over stage II outcomes. This cost of self-insurance can then be used to determine whether there is any demand for more cost-efficient alternatives.

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[3] Although, they will influence stage I decisions of the *following* year.

[4] In case the household is unaware of its future options, the situation corresponds to an open-loop decision framework. In such circumstances, what the household can or cannot do in the future is irrelevant for current decision making, and the dynamic optimization model reduces to a static optimization model.

Solving an Inter-temporal Utility Maximization Problem

For expositional purposes, consider the following general time-separable lifetime consumption planning problem:

$$\max_{\{C_t\}} E_t \sum_{t=1}^{T} \delta^{t-1} U(C_t) \tag{1}$$

subject to

$$W_{t+1} = (1+r)(W_t - C_t) + Y_t \tag{2}$$

$$E_t \sum_{t=1}^{T} r^{t-1}(C_t - Y_t) = W_t \tag{3}$$

where t denotes the time period, E_t denotes expectations conditioned on information available at time t, U(.) is an atemporal utility function, T is the terminal time period of the planning horizon, C_t represents total consumption during period t, W_t is opening or initial wealth for period t, Y_t is stochastic income generated in period t, δ is the rate at which future utility is discounted, and r is the rate of interest on savings. Equation (2) is the dynamic counterpart of a standard static budget constraint and equation (3) is a solvency constraint (see Dardanoni, 1991, for a concise historical development of this model).

Define $V_t(.)$ as the maximum value function at t, i.e., (1) evaluated at the optimal solution vector $\{C_t^*\}$. The existence of a unique solution to (1) can been shown under appropriate regularity conditions (Stokey and Lucas, 1989). In principle, given initial conditions (W_t) at each time period t, C_t^* will be a function of W_t and the various parameters of the maximization problem in (1) subject to (2) and (3) (Samuelson, 1969, and Hakansson, 1970, provide explicit solutions for some common utility functions). The value function $V_t(.)$, as a function of $C_t^*(W_t)$, will in turn be a function of initial wealth and the parameters of the intertemporal maximization problem. It can been shown that $V(W_t)$ is a differentiable function under very general conditions (Benveniste and Scheinkman, 1979)[5].

Using dynamic programming, substitute the value function representing the utility maximization problem for period t+1 in (1) to obtain the t^{th} period dynamic recursion

$$V(W_t) = \max_{C_t}\{U(C_t) + \delta E_t V(W_{t+1})\} \tag{4}$$

Solving (4) subject to (2), gives the first-order conditions

$$U'(C_t) = r\delta E_t V'(W_{t+1}) \tag{5}$$

Using the envelope condition, it can be shown that, at the optimum,

$$U'(C^*(W_t)) = V'(W_t) \tag{6}$$

for all t. Advancing the time subscript in (6) to t+1 and substituting in (5) yields the Euler equation for consumption:

$$U'(C^*_t) = r\delta E_t U'(C^*_{t+1}) \tag{7}$$

Equation (7) implies that, at the optimum, the marginal utility of current consumption will be equated to expected discounted marginal utility of future consumption.

While (7) characterizes the intertemporal equilibrium, a closed-form solution for C^*_t in the presence of uncertainty is in general not possible (see Zeldes, 1989a; Hayashi, 1985). Empirical studies dealing with intertemporal consumption problems with uncertainty have thus relied on Euler conditions (7) to test for theoretical restrictions on implied behavioral conditions (Zeldes, 1989b; Morduch, 1990).

This analysis will exploit the implied optimality conditions (5) for a household model to derive relations that allow for a simple procedure to estimate the behavioral parameters of interest. As will be apparent later, the main advantage of this approach is that it circumvents the need to explicitly specify

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[5] These conditions require that the solution set be convex, that the primal utility function be differentiable and concave, that an optimal solution path exists and that the solution, given initial conditions, is feasible. For the present study, these conditions are assumed.

consumption preferences. The resulting relationships are parsimonious in data requirements and model specification. In particular, the method will not require data on consumption or savings, which are often unavailable or unreliable. Information on actual production decisions is used to 'recover' preferences revealed by households during their normal course of activity.

A Household Model

Before applying the dynamic model represented by (4), the time subscript 't' needs to be carefully interpreted to avoid confusion about the relevant decision periods. Earlier, the agricultural year was divided into two distinct sub-periods, stage I and stage II. These stages are the appropriate time periods for this analysis. Hence the time subscript 't' represents one 'stage' of an agricultural year and 't+1' the immediately following 'stage'. Further, since the model must hold for all time periods, notation can be simplified by replacing t and t+1 by 1 and 2, respectively.

Next note that this analysis is limited to stage I decisions (and henceforth 1 refers to stage I). Stage II decisions are ex post, made in response to realized outcomes. With uncertainty resolved, stage II decisions are not appropriate to model ex ante behavioral response to weather-related risks. This is not to imply that stage II decisions are not relevant to the current problem or that they are ignored in the model. The fact that stage II decisions will be conditional on, and hence affected by, stage I decisions is fully accounted for by the dynamic programming approach used to solve the household problem.

A household derives utility from the consumption of goods and leisure (see Singh, Squire and Strauss, 1986, on household models). Using the dynamic programming recursion (4), the household's problem may be written as

$$V(W_1) = Max_{(C_1,l_1)} [U(C_1, l_1) + \delta E_1 V(W_2)] \tag{8}$$

where $V(W_i)$ is the value function representing optimal household welfare at time i, C_1 is period 1 consumption of goods, l_1 is period 1 leisure, E_1 denotes expectation taken over the distribution of random period 2 opening wealth, with subscript 1 signifying that expectations are based only on information available at the beginning of period 1, and δ is the rate at which the household discounts future welfare.

Assume droughts occur with a strictly positive probability 'q' in each period, but are independently and identically distributed over time. The complete household problem for stage I may thus be stated as

$$V(W_1) = Max_{Z_1}\Big[U(C_1,l_1) + \delta\big\{(1-q)V(W_{2n}) + qV(W_{2d})\big\}\Big] \tag{9}$$

where

$$C_1 = Y_0+B_1+wL_{o1}-k_1-S_1-pI_1 \tag{10}$$

$$l_1 = \bar{L}-L_{f1}-L_{o1} \tag{11}$$

$$W_{2d} = Y_{2d}+S_1+I_1-h_2(B_1) \tag{12}$$

$$W_{2n} = Y_{2n}+S_1-h_2(B_1) \tag{13}$$

$$Y_{2n} = \pi Y(L_{f1},k_1,D_1) \tag{14}$$

$$Y_{2d} = Y_{2n}[1-u(D_1,X)] \ , \quad 0 \leq u \leq 1 \tag{15}$$

$$Z_1 = [D_1,L_{o1},L_{f1},k_1,S_1,I_1,B_1]. \tag{16}$$

where Z_1 in (16) represents the vector of period 1 decision variables. The first term in (9) represents instantaneous utility from period 1 consumption of goods and leisure. Goods consumption, C_1, is defined in equation (10) as the difference between total resources at the household's disposal in period 1 and total diversions of income to uses other than current consumption. The components of this budget identity are defined as follows: Y_0 represents pre-determined or exogenous resources available in period 1 (e.g., opening wealth, previous savings, fixed transfers, etc.), B_1 is period 1 borrowing, L_{o1} is off-farm labor supplied in period 1 at market wage rate w, k_1 is non-labor production expenditure or working capital, S_1 is period 1 saving, and pI_1 is the (hypothetical) insurance premium that the household would choose to pay if such a scheme were to be made available. This premium is defined as a proportion, p, of the total indemnity, I_1, that the household wishes to insure against a drought-year outcome. Equation (11) represents the time constraint facing the household. With a fixed endowment of total time, $\bar{L}$, this constraint uniquely determines leisure as a residual of on-farm, L_{f1}, and off-farm, L_{o1}, labor supply decisions.

The second term in the objective function (9) represents the expected discounted maximum value function summarizing future welfare. The expectation has been made explicit by assuming (1-q) as the probability of non-drought outcome yielding farm income Y_{2n} in period 2, and q as the probability of a drought outcome yielding farm income Y_{2d} in period 2. As noted earlier, consumption in period 2 will be a function of period 2 initial endowment, W_2, which evolves according to equations (12) and (13) under drought and non-drought conditions, respectively. In a drought year, W_{2d} will be the sum of realized drought farm income, Y_{2d}, savings carried over from period 1, S_1, indemnity received from the hypothetical insurance scheme, I_1, less repayment of accumulated period 1 debt, B_1, determined by the repayment schedule h(.). In the event of a non-drought year W_{2n} will be realized income, Y_{2n}, plus savings S_1, less repayment of debt $h(B_1)$. In its simplest form, $h(B_1)$ can be written as $(1+r)B_1$ where r is the borrowing rate of interest.

Equation (14) defines non-drought or anticipated farm income as the product of anticipated value per-unit of output, π, and anticipated total production. The latter is defined as a whole-farm production function Y(.). On-farm labor, L_{f1}, working capital, k_1, and diversification (across crops), D_1, are the variables used to control production output.

Drought-year farm income, equation (15), is defined as anticipated income reduced by a random shock, u(.). This production shock is assumed to be affected by risk-reducing strategies such as diversification. It will also be a function of fixed (in the short run) household and farm characteristics, X. It is hypothesized that efficient diversification will reduce realized shocks.

Note that, for simplicity, savings, S_1, are assumed to be purely precautionary in nature, i.e., they do not earn any real rate of return. It is thus assumed that savings take the form of unproductive cash holdings. Note, however, that non-zero interest rates, as may be relevant to specific applications, can be easily accommodated in the model as negative borrowing.

The following assumptions are maintained for the rest of this analysis: the utility function U(.) is increasing and concave in its arguments; the maximal value function V(.) is increasing and differentiable; the production function Y(.) is increasing and concave in variable inputs L_{f1} and k_1, and the repayment function is an increasing function of accumulated debt, i.e., $\partial h/\partial B_1 \geq 0$, to signify non-negative costs of borrowing.

Characterizing the Equilibrium

Differentiating the model (9)-(15) with respect to the Z_1 variables, the first-order conditions for an equilibrium are

$$\frac{\partial V(W_t)}{\partial D_1} = (1-q)V'_{2n}\pi Y'_{D_1} + qV'_{2d}[(1-u)\pi Y'_{D_1} - \pi Y u'_{D_1}] = 0 \qquad (17)$$

$$\frac{\partial V(W_t)}{\partial L_{o1}} = wU'_{C_1} - U'_{l_1} = 0 \qquad (18)$$

$$\frac{\partial V(W_t)}{\partial L_{f1}} = -U'_{l_1} + \delta\left[(1-q)V'_{2n}\pi Y'_{L_{f1}} + qV'_{2d}(1-u)\pi Y'_{L_{f1}}\right] = 0 \qquad (19)$$

$$\frac{\partial V(W_t)}{\partial S_1} = -U'_{C_1} + \delta\left[(1-q)V'_{2n} + qV'_{2d}\right] = 0 \qquad (20)$$

$$\frac{\partial V(W_t)}{\partial k_1} = -U'_{C_1} + \delta\left[(1-q)V'_{2n}\pi Y'_{k_1} + qV'_{2d}(1-u)\pi Y'_{k_1}\right] = 0 \qquad (21)$$

$$\frac{\partial V(W_t)}{\partial I_1} = -pU'_{C_1} + \delta q V'_{2d} = 0 \qquad (22)$$

$$\frac{\partial V(W_t)}{\partial B_1} = U'_{C_1} - \delta\left[(1-q)V'_{2n}h'_2 + qV'_{2d}h'_2\right] = 0 \qquad (23)$$

where primes (') denote derivatives of functions with respect to the arguments denoted as subscripts. In particular note that $V_{2n}' = \partial V(W_{2n})/\partial W_{2n}$ and V_{2d}' is similarly defined.

Condition (17) states that, at the margin, expected benefits will be equated to expected costs of diversification. Condition (18) states that off-farm labor will be supplied up to the point where the marginal disutility of labor is exactly offset by the utility value of marginal labor earnings, i.e., wage rate weighted by the marginal utility of consumption. Conditions (19)-(23) state the familiar result that marginal utility of current consumption (of goods and leisure) will be equated to the discounted expected marginal utility of wealth (and, by the envelope condition, to the discounted expected marginal utility of future consumption).

Simple manipulation of the first-order conditions yields equilibrium relationships that provide useful insights into the cost-efficiency of the risk-management strategies used by households. They also suggest a framework that can be fruitfully used for empirical analysis.

Before proceeding further, define:

$$\phi \equiv \frac{q}{1-q}\psi \equiv \frac{q}{(1-q)}\frac{V'_{2d}}{V'_{2n}} \tag{24}$$

which, for a given q (the actuarial probability of drought), measures the utility tradeoff between drought and non-drought outcomes, $\psi = V'_{2d}/V'_{2n}$, and can be used as a measure of the potential demand for insurance against drought risks. Note that ψ measures both (i) the ability of the household to absorb risk and (ii) attitudes to risk. This is because the magnitude of ψ depends both on the expected deviation of W_{2d} from W_{2n} as well as the curvature of the indirect utility function V(.), which reflects risk attitudes. Even for a risk-averse household, it is possible to obtain $\psi=1$ if the household is able to absorb any drought shock by means of other actions which ensure $W_{2d}=W_{2n}$. A more intuitive way to interpret ϕ in (24) is to consider it as a ratio of marginal utility weighted probabilities of drought (q^u) to non-drought ($1-q^u$) outcomes. Thus, q^u will be equal to q when $\psi=1$ and the household will not exhibit any demand for external insurance (whether or not it is risk neutral).

Proceeding with the derivation of the equilibrium relationships, using (24), equation (17) can be rewritten as

$$-\pi Y'_{D_1}[1+\phi(1-u)] = -\phi\pi Y u'_{D_1} \tag{25}$$

Using (18), equating (19) and (20) yields

$$w[1+\phi] = \pi Y'_{L_n}[1+\phi(1-u)] \tag{26}$$

Equating (20) and (21) yields

$$\pi Y'_{k_1}[1+\phi(1-u)] = 1+\phi \tag{27}$$

Combining (21) and (22) gives

$$p\pi Y'_{k_1}[1+\phi(1-u)] = \phi \tag{28}$$

Finally, using (21) and (23) gives

$$h'_2(1+\phi) = \pi Y'_{k_1}[1+\phi(1-u)] \tag{29}$$

In each equality (25)-(29), the left-hand side gives the marginal cost and the right-hand side the marginal benefit associated with decision variables D_1, L_{n1}, S_1, I_1 and B_1, respectively. Note that in equilibrium the benefits and costs associated with each decision are evaluated in terms of their relative effects on future utility; as a result the discount rate drops out in deriving (25)-(29).

Condition (25) states that diversification, D_1, entails a cost by reducing anticipated production ($\partial Y/\partial D_1 < 0$) in both non-drought and drought years. These losses, weighted by 1 and ϕ for the non-drought and drought years, respectively, are offset by the marginal utility benefit accrued in drought years in the form of a reduced income shock ($\partial u/\partial D < 0$).

Condition (26) states that the expected marginal benefit of labor use in agricultural production is equated at the margin with its opportunity cost, the 'effective' marginal returns to off-farm labor, i.e., the market wage rate weighted by the expected marginal utility of wealth. This condition reiterates the intuitive result that riskiness in agricultural production makes (certain) off-farm wage income more attractive, leading to a reduction in the use of labor on farm.

According to condition (27), the marginal cost of savings is the value of output foregone by diverting resources from production to liquid reserves. The marginal benefit is the weighted non-drought- and drought-year utility value of marginal savings carried into the next period.

Condition (28) states that the marginal cost of the hypothetical insurance will be the production foregone by diverting resources to pay for the insurance premium. With p as the premium rate, output will be reduced by p times the productivity of the marginal unit of capital diverted from production. The benefit of insurance will be the drought-year utility derived from the marginal unit of indemnity received.

Insurance benefits and costs closely resemble those associated with savings; in fact, savings can be interpreted as an indigenous insurance scheme. The relative cost efficiency is, however, *a priori* ambiguous. Using (27) and (28), it is seen that insurance will be cost-efficient relative to savings only if

$$(1-p)\pi Y'_{k_1}[1+\phi(1-u)] > 1 \tag{30}$$

The marginal cost associated with borrowing in period 1 is the reduction in weighted non-drought- and drought-year marginal values of resources available to finance consumption in period 2. The reduction in resources will, at the margin, depend on the slope of the repayment schedule, h'. The marginal benefit of borrowing is the utility value of the marginal productivity of capital used in production. The intuition behind this equilibrium condition is that borrowing to finance current consumption helps to keep an equivalent amount of capital in productive use, which at the margin increases output at its current level of productivity. If borrowing is used to finance production, e.g. buying fertilizer, then the marginal benefit of borrowing in terms of the marginal productivity of capital is more transparent.

The efficiency of risk-management strategies to mitigate drought risk can be indicated using the parameters in (25)-(29). To evaluate the efficiency of an insurance scheme of the type considered here, note that (27) and (28) imply

$$p = \frac{\phi}{(1+\phi)} \tag{31}$$

which is the premium rate at which a household will be indifferent between purchasing insurance and holding liquid reserves. It is simple to verify that while a household which has efficiently diversified its risks, or is risk-neutral, will be indifferent between purchasing and not purchasing an actuarially fair insurance[6], it will be willing to purchase drought insurance at a subsidized rate, i.e., at a premium rate less than q. It is also straight-forward to confirm the intuitive result that more risk-averse households will be willing to pay a larger insurance premium

$$\frac{\partial p}{\partial \psi} = \frac{q}{1-q}\frac{1}{(1+\phi)^2} > 0 \tag{32}$$

where the strict inequality follows from the assumption of a strictly positive probability of drought in each time period, i.e, $q > 0$.

Empirical Application

The empirical approach adopted here follows from a literature which infers risk attitudes from risk-avoidance behavior in agricultural production (Moscardi and de Janvry, 1977; Antle, 1987,1989). We depart from such studies in that we directly use information on drought shocks experienced by households in a structural model of farm income risk. In addition, we incorporate the use of non-farm risk smoothing in household risk management strategies to test for the latent demand for drought insurance.

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[6] Since $\psi = V_{2d}'/V_{2n}' = 1$ implies (from (24)) that $\phi = q/(1-q)$, which in turn implies $p = q^u = q$.

Data

The data used for the empirical application come from to the IFPRI-TNAU household survey conducted over the period 1982-84 (see Hazell and Ramasamy, 1991, for a detailed description of the data, the survey design and of the study region). Initially designed for one year (1982-83), the survey was extended for an additional year (1983-84) after the first year turned out to be a severe drought year[7].

A two-stage sampling approach was adopted: in the first stage 11 representative villages were identified, and in the second stage a stratified random sample of households was drawn from these villages. The first-year survey covered a total of 345 rural households. Due to resource constraints the resurvey was planned to cover only 75 of the original households from 5 villages that were most affected by the drought. Of this sub-sample, 36 were agricultural producers; complete panel information, however, is available only for 32 households. This is the sample used for the empirical analysis.

All survey villages lie in the North Arcot district in the northwest of Tamil Nadu state in southern India. The region is densely populated (350 persons per square kilometer) and poor - both absolutely and relative to other regions in India - with an annual income equivalent of US$95/capita compared with the national average of US$260/capita. The region is dominated by small, family farms averaging 1.2 hectares. Paddy and groundnut are the main crops, followed by millet, sorghum and pulses.

The district enjoys two monsoons: the southwest monsoon from June to September and the northeast monsoon from October to December. The northeast monsoon is relatively more important, providing about 60 percent of the total annual rainfall. In harmony with these rainfall patterns, the agricultural year (June-May) is divided into three cropping seasons, namely *samba*, *navarai* and *sornavarai*. The *samba* (rainy season) crop is the main crop, sown in July-August and harvested in December-January. The *navarai* crop coincides with the dry season and depends entirely on irrigation.

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[7] Annual rainfall for 1982-83 was 751 mm as compared to the average rainfall of 1032 mm over the period 1961-62 to 1984-85. It has also be described as one of the 9 worst rainfall years since 1901 (Rodgers and Svendsen, 1991).

It stretches from December-January to May. The *sornavarai* crop extends from June to September and encompasses the light, southwest monsoon.

Almost all households in the retained sample have access to irrigation. The main sources of water are tanks or small reservoirs (33 percent) and wells (60 percent). Access to irrigation allows almost continuous cropping of the land throughout the year. Ironically, this dependence on irrigation accentuated the effects of the 1982-83 drought. While 1981-82 was a normal year, it was insufficient to recharge groundwater reserves after the drought of 1980-81, making even the households that rely on irrigation prone to drought. Thus the insurance offered by irrigation was limited in 1982-83.

Access to irrigation makes delineating seasons difficult because of overlapping crop cycles. While it is possible to separate out the *navarai* crop from the rest because of the distinct gap in the planting periods, it is difficult to separate the two rainy-season crops. Part of the problem also lies in the starting and ending dates of the two survey periods. Considering the short time between the planting dates of *sornavarai* and *samba* crops, there is considerable overlapping in the crop cycles of the two crops. The allocation of land for the two seasons is thus likely to be jointly determined.

For the present purposes, the two rainy season crops are treated as a single stage I crop and referred to as the *samba* season for convenience. Stage II of the sequential household planning problem thus includes the *navarai* season and extends from January to May of the agricultural year. Total *samba* production is thus estimated as the value of production from all land planted prior to the month of January in each survey period. Total labor and capital inputs, and gross cropped area are also aggregated accordingly for the purposes of production function estimation. Diversification is defined over area allocated to different crops over the season. The agricultural production shock is calculated using the value of total *samba* output for the two years.

It is probable that households respond to shocks in total income rather than to the prospect of production shocks alone. Accordingly, an alternative estimate of drought shocks is used to estimate household behavioral response, based on total (farm and non-farm) income. Annualized household income is used to proxy stage I total income for lack of a more appropriate estimates.

Econometric Specification

To specify the essential parameters for estimation it is sufficient to concentrate on equations (25), (26) and (27). Equation (28) pertains to conditions of hypothetical insurance; as such a market did not exist in the study area, it provides no insights to observed behavior and hence is treated here as an analytical tool. Equation (29) requires knowledge of repayment schedules for households as well as data on borrowing. Since such information is not available, equation (29) is dropped from the empirical model.

To estimate the remaining system, information is required on technology of agricultural production, Y(.), and expectations of income shocks u(.) held at the beginning of stage I. The former requires estimating a production function and the latter the estimation of a 'shock' equation. Given data on a single pair of drought and non-drought years, a two-step estimation procedure is adopted that optimizes the use of data. In the first step, a shock equation is estimated as a function of pre-determined drought-year variables (i.e., initial endowments and fixed farm characteristics). Using the estimated parameters, predictions for shocks anticipated at the beginning of the non-drought year are obtained using the non-drought-year values of pre-determined variables. In the second step, these predictions are used along with production data for the non-drought year to estimate the remaining parameters.

Assuming that non-drought year farm income is representative of the long run expected income, drought shock is defined as

$$u = \frac{\pi Y_n - \pi Y_d}{\pi Y_n} = 1 - \frac{\pi Y_d}{\pi Y_n} = 1 - \tilde{u} \qquad (33)$$

where πY_n is income for a non-drought year and πY_d is income for a drought year. Earlier, u(.) was hypothesized to be a function of diversification. Since diversification is an endogenous choice variable, reflecting anticipated shocks among other things, a simultaneous equation system is required to estimate the structural relationship between the two variables. Although such a relationship would be useful by itself, it is not essential for the purposes of this analysis. Accordingly, the shock equation is estimated as a reduced form using available fixed and pre-determined variables. The main advantage of doing this is that it avoids imposing structure on an instrumenting regression which makes predictions of expected shocks more straightforward.

The last equality in (33) is used to estimate $\tilde{u}$, which represents drought year output as a ratio to non-drought year output. We use the logarithm of the output ratio $\tilde{u}$ as the dependent variable. The explanatory variables used for this regression include village dummies and opening stocks (of variable inputs and food commodities), fixed capital, family size, and farm characteristics as of the beginning of the drought year. Using the estimated coefficients and the values of the respective variables at the beginning of the non-drought year yields an estimate, $\widehat{\ln\tilde{u}}$, from which the anticipated shock for the non-drought year, $\hat{u}$, is calculated as $1-\exp(\widehat{\ln\tilde{u}})$.

The production function is specified with a Cobb-Douglas functional form:

$$\log(Y) = \sum_i z_i G_i + \alpha\log(L_{fl}) + \beta\log(k_1) + \theta\log(1-D_1) + \nu\log(A_1) + \epsilon \quad (34)$$

where Y is the value of anticipated (non-drought) output; L_{fl} is total labor used on-farm; k_1 is working capital input; A_1 is area cultivated; D_1 represents diversification; G_i is a dummy variable for village i; z_i, α, β, θ and ν are parameters, and ϵ is a random error term. A Simpson index[8], defined over area allocated to different crops, is used to measure on-farm diversification, D_1.

Given production function (34), the behavioral relations of interest, i.e., equations (25), (26) and

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[8] A Simpson index of diversification over x_i, for all i, is defined as $D(x)=[1 - \Sigma_i(x_i/\Sigma_i x_i)^2]$.

(27), can be rearranged to derive the following estimable equations

$$\log\left[\frac{wL_{fl}}{Y}\right] = \log(\alpha)+\log(1+\phi(1-\hat{u}))-\log(1+\phi)+\omega_L \tag{35}$$

$$\log\left[\frac{k_1}{Y}\right] = \log(\beta)+\log(1+\phi(1-\hat{u}))-\log(1+\phi)+\omega_k \tag{36}$$

$$\log(D_1) = \log(\gamma)+\log(1+\phi(1-\hat{u}))-\log(\phi)+\omega_D \tag{37}$$

where $\hat{u}$ is the predicted shock, $\gamma=\theta/u'_D$ and ω_L, ω_k and ω_D are disturbances (with standard Gauss-Markov assumptions) associated with (35), (36) and (37), respectively. The left-hand-side variables of equations (35) and (36) are logarithms of the shares of labor and capital in total value of output, respectively, and the left hand side of (37) is the logarithm of the diversification index. Given that the production errors enter multiplicatively in (34), and that the hypothesized drought shock is also multiplicative in (15), it is assumed that optimization, specification or data-related errors are likely to affect conditions (25)-(27) multiplicatively rather than additively. Besides being more robust to specification errors, this structure also simplifies estimation somewhat.

These three equations together with the production function (34) yield a simultaneous system. Across-equation restrictions are necessary to identify all of the system parameters. Parameters α and β are held as constants across the production function (34) and equations (35) and (36), respectively. The risk coefficient, ϕ, is similarly restricted to be identical across equations (35), (36) and (37). The coefficient on the specialization variable, θ, is estimated unrestricted and is expected to be positive[9].

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[9] Note that diversification, D, is expected to have a negative effect on output. However, taking logarithms is not possible for observations on households that do not diversify (i.e. have D=0). Hence, the variable included in the specification is (1-D) which represents specialization. Accordingly, θ, the coefficient on log(1-D), is expected to be positive.

Parameter γ in equation (37) is also estimated freely. As derived from the first order conditions above, $\gamma = Y_D'/u_D'$. It represents the ratio of the marginal effect of diversification on expected output to the marginal effect of diversification on output shock. Since both effects are hypothesized to be negative, γ is expected to be positive.

Labor, capital and diversification are variables endogenous to the system (34)-(37) and hence instrumental variable estimation is necessary for consistent estimation. A three-stage least squares procedure, with appropriate cross-equation parametric restrictions, is used to obtain consistent and efficient estimates (Judge, et al., 1985). Household and farm characteristics including demographic variables and opening inventories are used as instruments. Labor and capital are normalized by area to avoid collinearity in the production function. The estimated coefficient on the log of area, thus, provides a direct test of constant returns to scale ($H_0: \nu = 1$).

Results and Discussion

The sample used in this study is admittedly small but the detailed information under drought conditions provides a rare opportunity to model the effects of drought on household incomes, making the data particularly useful for this analysis. As mentioned earlier, the following empirical results are intended to serve as an illustration. To corroborate the findings and to provide additional results, a companion study (Sakurai, et al, 1994) uses panel data collected by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) on rural households from Burkina Faso.

Simple statistics for the variables used in the estimations are given in Table 1. Regression results for the output ratio, $\tilde{u}$, are given in Table 2. Note from (33) that a larger ratio implies a smaller drought effect. In terms of explanatory power, the regression explains 58 percent of total variation. The lack of significance of most coefficients, however, suggests the presence of collinearity. This is verified by the regression results without village dummy variables, also reported in Table 2. Both qualitatively and quantitatively the results are consistent for the two specifications with the exception of a sign change in one insignificant variable, while the significance level of three key variables improves markedly when the village dummy variables are omitted. The R^2, however, falls considerably. The formal test of exclusion of the village dummy variables is significant at the 10% level[10]. Since the primary concern with this instrumenting regression is consistent prediction, the specification with village dummy variables is used to predict anticipated drought shocks for estimating the main parameters of interest (in the second step).

It should be noted that there are no clear theoretical priors for the asset variables. The dependent variable is realized shock, and hence will be a function of both the choice behavior of the household (e.g., the shock may increase with wealth indicating a large risk-bearing capacity of the wealthier households) and the efficacy of measures adopted by the household (the shock is expected to decrease with protective measures).

The results show that households owning a greater number of wells experience a smaller production shock, as may be expected. The number of owned fragments also tends to reduce the shock. Fragmentation implies spatial diversification which is likely to be positively related to diversification and hence the expected positive effect on the drought-non-drought output ratio (i.e., a negative effect on production shock). Value of total land owned has a positive effect on the output ratio, i.e., a negative effect on the shock, although, it is relatively insignificant. Opening stocks have a similar effect. Larger food stocks are positively correlated with diversification. This suggests that stocks induce households to diversify their crop portfolio which in turn helps cushion the effects of drought on total production. Households with larger fixed farm capital experienced a greater production shock as reflected by the large and relatively significant negative effect on the output ratio. This is perhaps because a large proportion

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[10] The F statistic for the exclusion of the four village dummies is $F(4,20)=2.41$ which is significant at the 8% level.

of fixed capital is in the form of irrigation equipment. While such equipment yields large returns in non-drought years, the shock is also pronounced in drought years when such equipment is of little use. An increase in the average distance of owned land (from the village) reduces the output ratio, i.e., it tends to increase production shocks. This may reflect greater care being given to plots that are closer to home, reducing the effects of drought. Finally, family size has an insignificant effect.

Table 3 presents results for the total income shock equation. Note that the dependent variable for this regression is the total household income ratio in drought and non-drought years and that the specification includes two additional variables, value of owned business capital and a dummy variable for illiterate households.[11] Overall, the regression for total income shock performs better than the one for production shock, with an R^2 of 0.72. The number of owned wells again has a significantly positive effect on the income ratio (i.e., it reduces total income shock). Number of fragments owned has a negative effect on the drought-non-drought income ratio or a positive effect on the income shock. This reflects a scale effect: the number of land fragments is positively correlated with total land owned. A larger share of agriculture in total income and a greater ability to bear risks perhaps explains this effect. The same is also suggested by the significantly negative effect of owned land value and opening stocks on the income ratio, i.e., a positive effect on the income shock. Farm fixed capital, *ceteris paribus*, has a positive effect on income ratio (negative effect on income shock). It should be noted that total income includes income from the *navarai* (irrigated) crop grown in the latter half of the agricultural year. With irrigation equipment included in farm fixed capital, this result is not surprising. An increase in the distance of plots from the village tends to increase income shocks, as in the case of production shocks. Family size, however, has a negative effect on the income ratio, or a positive effect on income shocks, as does the value of owned business capital. These signs, although insignificant, probably reflect the

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[11] These two variables were omitted from the production shock equation because of their lack in explanatory power.

widespread effects of drought on the local economy. With agriculture as the main activity in the study area, a severe drought has a depressing effect on all activities via intersectoral linkages. This is also reflected in the large and highly significant negative coefficient on the dummy for illiterate households who are likely to rely more heavily on unskilled wage labor (Hazell, et al., 1991). Finally, one of the village dummies is highly significant and consistent in sign with the village effects on production shocks, while the others are insignificant. Thus there appears to be some regional variation in the effects of the drought.

Turning now to the main parameters of interest, Tables 4 and 5 give the results for the model represented by equations (34)-(37) using predicted shocks for *samba* production and total income, respectively. Using crop production data for the non-drought year 1983-84, Tables 4a and 5a present results with dummy variables for four of the five villages in the production function specification (34), while Tables 4b and 5b present results without the dummy variables. Given the small sample size, this is done to check the robustness of behavioral and technology parameters against village-specific effects.

In the production function, logarithms of variable inputs, labor and capital, and the crop specialization index (i.e. 1-D) are treated as endogenous. The estimation results for the first-stage instrumenting equations for these variables are presented in Appendix B, Tables B.1-B.3. The results of these regressions are not discussed since they are of not of immediate interest. As is evident, with R^2s of about 0.70, 0.85 and 0.57 for the three variables, respectively, the instruments appear to explain a substantial proportion of observed variation. However, a limited number of observations combined with moderate collinearity generates large standard errors making it difficult to establish the importance of individual variables as identifying variables.

The production elasticity parameters for labor and capital are highly significant, and appear to be robust to the production function specification with and without village dummy variables as well as to production and income shock estimates. The coefficient on area is positive and insignificantly different from 1 in all specifications.

The specialization index, although positive in all regressions, is sensitive to village dummy variables in the production shock specification. The positive sign is as expected, suggesting that specialization (diversification) increases (decreases) expected output. The estimate is significant in the regression without village effects, but is insignificant in the regression with village effects. This suggests that diversification is correlated with village-specific effects. The significance of the coefficient on the specialization index in the two total income shock specifications follows a similar pattern, although in magnitude the estimates are close to the production shock specification estimate without village dummy variables.

The ratio of the marginal effect of diversification on expected production to its marginal effect on production shock, γ, is positive in all regressions as expected. It is also significantly less than one in all cases, indicating that the 'benefit' of diversification (i.e. the reduction in shock) is greater than its 'cost' (i.e., the reduction of output). This parameter, however, is also sensitive to village-specific effects in the production shock specification.

Finally, the parameter of chief interest in this study, the risk coefficient, ϕ.[12] The estimate is 0.50 (significant at the 5% level) in the specification with village effects, and 0.25 (significant at the 10% level) in the specification without village effects in the specifications using predicted *samba* production shocks (Tables 4a and 4b). The change in the magnitude of the coefficient suggests an omitted variables bias in the specification without village fixed effects, considering that at least one village dummy is quite significant (at the 6% level). The rest of the discussion is restricted to the specification with fixed effects.

In the specification using predicted total household income shocks in Tables 5a and 5b, the

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[12] The reported ϕ is estimated as a constant and interpreted as the sample mean. Alternative specifications were tried making ϕ a linear function of household wealth as well as other household characteristics such as family size, age of household head, dummy variable for illiterate households and owned business capital. None of the household characteristics attained significance. A quadratic specification in initial wealth was also tried with similar results. Since these regressions do not add much to the discussion, they have not been presented.

estimates of ϕ are 0.39 and 0.34, respectively, with both significant at the 5% level. The insignificance of village effects reflects the insensitivity of the coefficient to the two specifications. It should be noted that despite the differences in the instrumenting equations for the two shock variables, the risk parameter estimates using total income shocks are within one standard error of each other as well as of the estimate using production shocks (with village effects), indicating that the ϕ estimate is robust across the different specifications. Since total household income is likely to be less sensitive to weather shocks, one might expect a lower estimate for the risk coefficient using the total income shock specification. As can be seen, even though the difference is statistically insignificant, the estimates using total income shock are quantitatively smaller than the estimate using production shocks.

One way to interpret this coefficient, as noted earlier, is as a ratio of the marginal-utility-weighted probabilities of drought (q^u) to non-drought ($1-q^u$) outcomes. The ϕ estimates of 0.50 and 0.39 imply values of q^u of about 0.33 and 0.28, respectively. These probabilities should be compared with the actuarial probability of drought using historical data. As noted earlier, risk neutrality or complete insurance against drought shocks (i.e., for which $W_{2d}=W_{2n}$), imply q^u will be equal to q, and households will not exhibit any unmet demand for insurance. On the other hand, a $q^u > q$ would indicate such a demand.

Using annual rainfall data from 1961-62 to 1984-85, mean annual rainfall is estimated at 1031 mm with a standard deviation of 223 (Ramasamy et al., 1991). The definition of drought used is one developed by the Indian Meteorologic (*sic.)* Department: a drought is "... a situation occurring in any area in a year when annual rainfall is less than 75% of normal" (quoted from Rodgers and Svendsen, 1991). Using this definition, the probability of observing a drought in any given year is 0.124 (or 12.4%). The utility weighted probability estimates of 0.33 and 0.28 are both substantially higher and strongly suggest an unmet demand for insurance against drought shocks.

To put these numbers in perspective, consider the proportional risk premiums (PRP) associated with each q^u. A PRP is defined as the difference between actuarial expected income and utility-weighted expectation income as a proportion of the actuarial expected income. Calculating utility-weighted expectation as $Y^{ue}=\{(1-q^u)Y_{2n}+q^uY_{2n}(1-\hat{u})\}$ and actuarial expectation as $Y^e=\{(1-q)Y_{2n}+qY_{2n}(1-\hat{u})\}$, the PRP can be simply calculated as $1-(Y^{ue}/Y^e)$, which reduces to $\{(q^u-q)\hat{u}/(1-q\hat{u})\}$. With the mean production shock experienced by sample households of 0.74, and the mean total income shock of 0.61, the PRPs are estimated at 0.17 and 0.13, respectively, for the corresponding q^u's. This indicates the sample households would be willing to pay 13-17% as the premium to purchase external insurance. Note that this 'premium' is in excess of the pure risk-cost of 0.124 that a risk-neutral or a fully insured household would be indifferent to for an actuarially fair insurance. Thus allowing for reasonable program costs (5-10%), such an insurance may be commercially viable.

Binswanger and Sillers (1984) report mean proportional insurance premia using data from Binswanger's experimental study in southern India (Binswanger, 1981). These range from 0.09-0.20 (for 'low' to 'high' payoff games where 'low' payoffs were Rs. 5 and high payoffs were Rs. 500). Similar mangnitudes of risk premia (with a population mean relative risk premium of 0.14) have also been reported by Antle (1987) for South Indian Rice producers using econometric risk attitude estimates. The estimated risk premia from this study are quite comparable.

The results indicate that agricultural households in the sample exhibit significant risk-avoidance behavior. This suggests there is a latent demand for better smoothing mechanisms. Subject to the caveats of sample and functional form specificity, based on the mean proportion of income that the households are currently 'paying' as insurance against drought outcomes, it may be concluded that there is a potential market in the study villages for additional (external) insurance against droughts at unsubsidized premium rates. Since the premiums calculated here are at sample means, it is likely that there would be some uptake if a scheme such as a drought or rainfall lottery were to be introduced.

The analysis in this paper is restricted to agricultural households. Given the predominance of agriculture in rural economies, droughts are likely to have a significant effect on non-agricultural activities as well. It is thus possible that non-agricultural households (e.g., agricultural wage earners and local business operators) will also exhibit demand for insurance against droughts. Based on exogenous variables such as rainfall levels, as opposed to endogenous variables such as production shortfalls, such insurance can be readily made accessible to non-agricultural households as well.

In drawing policy conclusions, it is important to keep two issues in mind. First, the definition of the objective probability of drought. Note that the estimated risk-response coefficients do not depend on the actual probability of drought; it is their interpretation in determining the demand for insurance, i.e., the marginal premium the households will be willing to pay, that requires a precise definition of drought. The results indicate that households will be indifferent to purchasing insurance at actuarially fair premiums for insurance based on objective drought probabilities of up to 33% and 28% (based on estimates of production shocks and total income shocks, respectively).

Second, the non-drought year which is used to determine the latent demand for insurance followed a drought year. It is possible that risk coping mechanisms of households were exhausted by the end of 1982-83 (the drought year) and, hence, household behavior in 1983-84 (the subsequent non-drought year) may reflect greater risk avoidance than may be observed in other circumstances. Thus, measured demand may be an over-estimate of the long-run average demand for insurance. This is a generic issue with a path-dependent historic event. Nevertheless, the results are indicative of the inability of households to absorb drought shocks when they do occur. Considering that droughts are a recurrent event, one may argue that there is a real, perhaps fluctuating, demand for smoothing mechanisms against droughts outcomes.

Summary

This paper develops a dynamic household model to examine the efficiency of existing drought management strategies used by peasant households. An attractive feature of the method is that it exploits actual production (input-output) data without having to deal with the usually unreliable data on household consumption and leisure activities.

The model is applied to a two-year panel of data on households from five villages in the North Arcot district of Tamil Nadu (South India). Although sample is small, the data are special in that one of the two years for which data are available was a severe drought year. This provides an opportunity to apply the model developed in this paper. Subject to the assumptions about the structure and functional forms of the relationships used in this study, as well as the limitations imposed by the sample, the conclusions must be viewed as indicative rather than definitive. The key parameters, nevertheless, are estimated with sufficient precision and the implied risk premia are plausible in comparison with existing evidence based on experimental estimates of risk-aversion for households in similar circumstances.

The results indicate that agricultural households exhibit significant risk-avoidance behavior, and that even though they may use a range of risk management strategies, there still remains an unmet demand for insurance against drought risks. The study did not estimate the likely costs of supplying drought insurance, but the latent demand in the study region is found to be strong enough to more than cover the break-even rate of approximately the pure risk-cost (the probability of drought) plus 5 percent administration costs.

The findings confirm the inadequacies of traditional strategies of coping with droughts in poor rural areas. Because of catastrophic and simultaneous effects of droughts on all households over large areas, there is limited scope for spreading risks effectively at the local level. Either households must increase their savings significantly (a problem with low average incomes and an absence of safe and convenient savings instruments), or more effective risk management aids are needed that can overcome

the covariation problem. Improved financial markets (with both credit and savings facilities) could be helpful, particularly if they intermediate over a larger and more diverse economic base than the local economy. Alternatively, formal drought insurance in the form of a drought (or rainfall) lottery might be feasible, and the results suggest that it could be sold on a full-cost basis. These conclusions support a case for further research on other areas and for using more reliable data to provide further evidence on the latent demand for insurance in poor rural areas.

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Table 1: Sample Descriptive Statistics[1]

Variable	Mean	C.V.
Samba Agricultural Production (Rs.)	9136	121.2
Labor Share	0.299	55.5
Capital Share	0.325	56.0
Cultivated Area (Acres)	5.488	141.1
Labor/Acre (Rs.)	572.5	53.8
Capital/Acre (Rs.)	621.9	57.4
Specialization Index	0.702	33.9
Samba Agricultural Production Shock	0.737	35.3
Total Household Income Shock	0.612	35.6
Annual Agricultural Production (Rs.)	12041	118.5
Total Household Income (Rs.)	9354	125.4
Initial Wealth (Rs.)	67948	114.5
Opening Stocks (Rs.)	803.7	166.4
Owned Livestock Value (Rs.)	1720	65.9
Farm Fixed Capital (Rs.)	6493	228.7
Value of Total Land Owned (Rs.)	45526	123.6
Value of Owned Business Capital (Rs.)	4059	323.4
Proportion of Total Area Irrigated	0.395	88.1
No. of Owned Wells	1.063	53.1
No. of Owned Fragments	4.750	84.2
Avg. Distance of Owned Plots from Village (Km.)	0.807	108.6
Dummy for Illiterate Household	0.153	240.5
Age of Household Head (years)	47.90	18.2
Family Size	6.031	28.1

[1] Values reported are for the year 1983-84 with the exception of shock variables which are as defined in the text.

Table 2: *Samba* Production Shock Equation Estimates[1]

Variable	With Village Effects	Without Village Effects
Constant	-2.052 (0.847)[2]	-2.836 (0.795)
Village Dummy 2	-1.299 (0.726)	
Village Dummy 3	-0.145 (0.803)	
Village Dummy 4	0.288 (1.026)	
Village Dummy 5	-0.809 (0.740)	
Value of Land Owned/10000	0.011 (0.039)	-0.029 (0.041)
No. of Fragments Owned	0.041 (0.073)	0.075 (0.050)
No. of Wells Owned	0.561 (0.437)	0.821 (0.377)
Farm Fixed Capital/10000	-0.274 (0.143)	-0.374 (0.150)
Avg. Plot Distance	-0.306 (0.333)	-0.183 (0.245)
Opening Stocks/1000	0.101 (0.250)	0.183 (0.243)
Family Size	0.069 (0.096)	0.071 (0.101)
R^2	0.589	0.392

[1] Dependent variable is log of the ratio of drought to non-drought year total value of *samba* crop output. The explanatory variables are drought year values (in levels).
[2] Standard errors reported in parentheses.

Table 3: Total Income Shock Equation Estimates[1]

Variable	Estimate
Constant	0.382 (0.530)[2]
Village Dummy 2	-1.438 (0.444)
Village Dummy 3	0.306 (0.524)
Village Dummy 4	-0.294 (0.556)
Village Dummy 5	-0.404 (0.443)
Value of Land Owned/10000	-0.059 (0.026)
No. of Fragments Owned	-0.063 (0.045)
No. of Wells Owned	0.652 (0.322)
Farm Fixed Capital/10000	0.133 (0.182)
Avg. Plot Distance	-0.157 (0.199)
Opening Stocks/1000	-0.029 (0.178)
Family Size	-0.058 (0.062)
Owned Business Capital/1000	-0.112 (0.675)
Dummy for Illiterate HH	-1.686 (0.445)
R^2	0.724

[1] Dependent variable is log of the ratio of drought to non-drought year total annualized household income. The explanatory variables are drought year values (in levels).

[2] Standard errors reported in parentheses.

Table 4a: Effect of Anticipated *Samba* Production Shock on Input Decisions - with Village Effects

Variable	Parameter	Estimate	Std. Error
Constant	z	3.059	0.701
Village Dummy 2	$z2$	0.011	0.258
Village Dummy 3	$z3$	0.101	0.243
Village Dummy 4	$z4$	0.324	0.201
Village Dummy 5	$z5$	0.428	0.213
Labor	α	0.331	0.049
Capital	β	0.381	0.046
1-Diversification	θ	0.059	0.473
Area	ν	0.899	0.093
$(\partial Y/\partial D)/(\partial u/\partial D)$	γ	0.292	0.118
Risk Coefficient	ϕ	0.504	0.229

Table 4b: Effect of Anticipated *Samba* Production Shock on Input Decisions - without Village Effects

Variable	Parameter	Estimate	Std. Error
Constant	z	3.764	0.499
Labor	α	0.291	0.037
Capital	β	0.343	0.035
1-Diversification	θ	0.477	0.229
Area	ν	1.006	0.059
$(\partial Y/\partial D)/(\partial u/\partial D)$	γ	0.156	0.084
Risk Coefficient	ϕ	0.251	0.145

Table 5a: Effect of Anticipated Annual Total Income Shock on Input Decisions - with Village Effects

Variable	Parameter	Estimate	Std. Error
Constant	z	3.804	0.513
Village Dummy 2	$z2$	-0.015	0.296
Village Dummy 3	$z3$	0.049	0.276
Village Dummy 4	$z4$	0.057	0.203
Village Dummy 5	$z5$	0.225	0.205
Labor	α	0.291	0.036
Capital	β	0.336	0.032
1-Diversification	θ	0.439	0.526
Area	ν	0.946	0.107
$(\partial Y/\partial D)/(\partial u/\partial D)$	γ	0.217	0.088
Risk Coefficient	ϕ	0.394	0.191

Table 5b: Effect of Anticipated Annual Total Income Shock on Input Decisions - without Village Effects

Variable	Parameter	Estimate	Std. Error
Constant	z	3.838	0.443
Labor	α	0.287	0.034
Capital	β	0.334	0.030
1-Diversification	θ	0.467	0.227
Area	ν	1.008	0.062
$(\partial Y/\partial D)/(\partial u/\partial D)$	γ	0.194	0.081
Risk Coefficient	ϕ	0.343	0.165

APPENDIX A

DROUGHT INSURANCE

Crop Insurance:

Several countries have publicly operated crop insurance programs that provide insurance against drought as one of many insured yield perils. But without exception, these programs have required massive subsidies from government and they have not proved particularly effective in protecting farm incomes against droughts.

The basic reason why most publicly-operated crop insurance programs lose money is because they insure yields against a wide range of perils, many of which are subject to severe moral hazard and adverse selection problems. This problem is typically compounded by features of institutitonal and program design that increase the insurer's risk exposure (e.g., the insurance portfolio is tied to agricultural credit programs, realistic deductibles are not equired, and indemnitites are valued on the basis of shortfalls from target yeilds rather than on actual crop damage); see Gudger (1991) and Hazell (1992) for recent reviews of public crop insurance.

Commercial crop insurance, which has to be financially viable to survive, is invariably limited to very specific perils that satisfy four insurability conditions: (i) the likelihood of the event must be readily quantifiable; (ii) the damage it causes must be easy to attribute and value; (iii) neither the occurrence of the event nor the damage it causes should be affected by the insured's behavior (i.e., absence of moral hazard); and (iv) the event should not occur so frequently that farmers canot realistically afford the required premiums.

Crop losses due to extreme droughts can be insurable when judged by these criteria, particularly if the damage is total. In fact, private insurers do offer drought insurance in a number of countries, though because of the high administration costs incurred when insuring small-scale farmers, it is rarely extended to other than large-scale, commercial farmers. Insurance of less extreme shortfalls in rainfall is more problematic, since losses are only partial and moral hazard and adverse selection problems can arise. For example, if the shortfall is due to poor rains after planting, the farmer can affect the amount of damage through fertilization, weeding and harvesting practices.

In order to harness drought insurance as a more general risk management aid for drought-prone regions, several objectives must be met.

First, the insurance must be readily accessible to all kinds of households; small and large farmers, landless laborers, shopkeepers, agricultural merchants and processors, artisans, etc. This means that insurance contracts cannot be tied solely to crop or livestock production.

Second, the insurance must be affordable, particularly by poor people. This implies that administration costs must be kept very low; and that only drought events that occur with some infrequency (say 1 or 2 in 10 years) can be reasonably insured.

Third, since drought damage within a region tends to be highly covariate, drought insurance will only be fiancially viable if a mechanism exists to spread the risk beyond the insured region. In a large country, this might be achieved by insuring many regions, particularly if these have low or even negatively correlated rainfall patterns. But more generally, it is necessary to establish arrangements for reinsurance or contingent loans with the government or with private banking and insurance institutions.

New forms of drought insurance can be designed which meet thse objectives whilst satisfying essential insurability conditions.

A New Approach to Drought Insurance

The drought insurance envisaged here would be weather-station specific, and all persons insuring against the rainfall at a specific station would pay the same premium and receive the same indemnity per dollar of insurance. Indemnities would be paid whever the station's cumulative rainfall for some specified period of the year (say an agricultural season) fell below an agreed 'drought' level (elel, 70 percent of average). Premiums would be calculated on the basis of the probability of a drought occurring, on the size of the indemnity to be paid, and on administration costs. For example, for a station faced with a one year in ten drought and an insurance administration cost of 10 percent, a $1.00 insurance ticket would pay out approximately $9.00 in the event of a drought (i.e., the expected premium collected over ten years minus the 10 percent administration cost). The calculation is approximate because no allowance has been made for expected interest earnings on accumulated premiums held by the insurere, or for reinsurance costs.

Drought insurance tickets could be marketed rather like lottery tickets, employing low-income people to sell the tickets on a commission basis. Unlike standard insurance, however, all ticket holders for a given weather station would receive an indemnity in a drought year, but no indemnity would be given in non-drought years. If the scheme is managed by a commercial bank, then the indemnitites could be issued through its local brance offices after suitable announcements in the lcoal press, radio and television.

Since all participants would pay the same premium and receive the same indemnity, drought insurance avoids all moral hazard and adverse selection problems. Moreover, since the insurance is not tied to agricultural output, participation does not have to be restricted to farmers. In fact, many types of rural households might find it attractive. Nor need the emergence of a secondary market be discouraged, since this would enable cash-strappped individuals to obtain their expected prizes (albeit, at a discount) prior to the end of the monitored raifall period. Finally, since thei nrance does not require any contract wirting with individuals, or any field inspections or loss assessments, administration costs could be kept very low (perhaps at 2 to 3 percent of the ticket value).

There are at least three potential problems with the proposed insurance. First, its value as a drought-coping aid depends on whether catastrophic income outcomes for most households coincide with severe droughts at nearby weather stations. This is more likely to be true the greater a region's dependence on agriculture, but it also depends on the number and geographic dispersion of the weather stations used in defining the insurance. NOte that since individual households would be free to purchase tickets for any insured weather station, they would have considerable scope to exploit less than perfectly correlated drought risks to tailor insurance portfolios to their individual income risks.

Second, there could be difficulties in measuring the cumulative rainfall over the specified period if large numbers of local people have an interst in a low reading. Guarding the weather stations is expensive, nor would it necessarioly be successful since the guards might acquire a financial interest themselves. The problem might be reduced by narrowing the time period over which readings must be taken to key periods in growth of important lcal crops. Some recent work at ICRISAT, for example, suggests that the date of onset of the monsoon is an excellent indicator of the agricultural production value of the ensuing monsoon. This could be a very insurable event. Another promising approach is to use soil-moisture content readings as a proxy for rainfall deficiency, perhaps even defining drought in terms of soild moisture contnet rather than in terms of cumulative rainfall. Soil moisture readings could be randomly sampled in much the same way that crop-cutting methods are used to estimate regional yields.

Third, the drought insurance proposed here faces an even more extreme covariability problem than conventional drought insurance. This is because all the participants receive the same indemnity per dollar of ticket and at the same time. Under these conditions, an insurance for a single weather station is almost equivalent to a group savings scheme in which households save in non-drought years and simply receive their money back in drought years. However, there are two important differences. First, in a pure savings scheme, the amount of money available in a drought year is determined solely by the cumulated savings since the last drought. But with the insurance, the available funds depend on the expected value of the total savings that can be accumulated between droughts; that is, the indemnities from the insurance do not depend on the order in which drought years occur. This feature of the insurance can only work if the insurer either runds a number of weather station insurances that are less than perfectly correlated, or has access to reinsurance or contingency loan arrangements. Either approach effectively expeands the reserves available to be tapped in drought years. SEcond, if the insurer is adequately diversified or reinsured, the amounts of liquid reserves that need to be carried can be considerably less than with a private savings shceme. This increases the scope for earning larger returns on the nonliquid share of toal reserves.

If the insurance is to succeed in helping the poor cope with droughts, it would be especially important to market the tickets to this clientele. To the extent that the poor are overtly more risk averse, then the insurance should be partly self targeting. However, since poor people often might not be able to afford the premium, subsidized tickets would enhance their attractiveness. Such subsidies might be funded by diverting some government funds from existing crop insurance or drought relief programs.

Appendix B: First-Stage (Instrumenting) Equations

Table B.1: Labor Input[1]

Variable	Estimate	Std. Error
Constant	6.046	0.770
Village Dummy 2	-0.054	0.426
Village Dummy 3	0.476	0.419
Village Dummy 4	-0.038	0.369
Village Dummy 5	-0.280	0.398
Value of Land Owned/10000	-0.093	0.017
Proportion Area Irrigated	0.128	0.412
Farm Fixed Capital/10000	0.163	0.053
Livestock Value/10000	1.590	0.839
Family Size	0.085	0.056
No. of Owned Fragments	-0.008	0.031
Average Plot Distance	-0.451	0.126
Age (of Household Head)	-0.0002	0.007
Dummy for No Education	0.060	0.294
R^2	0.875	-

[1] Dependent variable is log of labor input per acre.

Table B.2: Capital Input[1]

Variable	Estimate	Std. Error
Constant	4.773	0.781
Village Dummy 2	0.147	0.432
Village Dummy 3	0.410	0.424
Village Dummy 4	1.033	0.375
Village Dummy 5	0.689	0.403
Value of Land Owned/10000	-0.073	0.017
Proportion Area Irrigated	0.117	0.427
Farm Fixed Capital/10000	0.125	0.053
Livestock Value/10000	2.990	0.851
Family Size	0.109	0.564
No. of Owned Fragments	0.010	0.031
Average Plot Distance	-0.313	0.127
Age (of Household Head)	0.006	0.008
Dummy for No Education	0.200	0.298
R^2	0.768	-

[1] Dependent variable is log of capital input per acre.

Table B.3: Crop Specialization Index[1]

Variable	Estimate	Std. Error
Constant	-1.017	0.672
Village Dummy 2	0.126	0.372
Village Dummy 3	0.109	0.365
Village Dummy 4	0.409	0.322
Village Dummy 5	0.491	0.347
Value of Land Owned/10000	-0.022	0.014
Proportion Area Irrigated	0.575	0.359
Farm Fixed Capital/10000	0.012	0.046
Livestock Value/10000	0.418	0.732
Family Size	-0.006	0.048
No. of Land Fragments (owned)	0.022	0.026
Average Plot distance	-0.201	0.109
Age (of Household Head)	0.006	0.007
Dummy for No Education	-0.061	0.257
R^2	0.596	-

[1] Dependent variable is log of crop specialization index. Crop specialization is defined as 1-D, where D is a Simpson index for crop diversification.

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