CSAE Working Paper WPS/1993-02

Risk, Crop Choice and Savings: Evidence from Tanzania

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1. Introduction[1]

Rural households engaged in agricultural activities face considerable risks in their income process. These income risks are especially important if they result in consumption fluctuations. This is likely if insurance and credit markets are absent. One possible strategy for household is to take up low-risk activities, even if they imply lower returns. Such response cannot be viewed independently from the other options available to households to reduce consumption fluctuations. This paper focuses on the importance of liquid asset formation for risk-taking behaviour by households. An intertemporal model of consumption under liquidity constraints is developed in which households can choose between income activities with different returns and riskiness. It shows that if liquid asset holdings are large, providing a buffer for consumption shortfalls, then households will be more willing to take up high risk activities. Evidence based on survey data from Shinyanga District, Tanzania is presented, consistent with this prediction.

Income uncertainty can result in considerable cost on households. The standard theoretical and empirical analysis of the cost of risk and instability such as in Newbery and Stiglitz (1981) assumes incomplete markets: credit or insurance markets are absent. Insurance markets in developing countries are notably incomplete and imperfect (e.g. Hazell et al.(1987)). Their absence can be explained by problems of asymmetric information between lender and borrower, causing incentive problems such as moral hazard and adverse selection, as well as through the covariance of risks in agricultural societies which limit the scope for risk trading. Informational problems and covariate risks also limit the development to credit markets (e.g. Binswanger (1987), Lipton (1979)). While in many developing countries informal credit markets are thriving, they are typically fragmented. Insider's knowledge seems to be the main barrier of entry: inside the community, kinship group or geographical area, information flows freely and credit is generally available but individual credit markets are not integrated with other credit markets (Bell (1988), Hoff and Stiglitz (1990)). Important differences exist between the extent of the credit markets between developing countries. In Kenya for example rural credit markets tend to be confined mainly to tribal and kinship groups (e.g. Collier and Lal (1986)). In West-Africa informal credit markets are quite widespread, but even so Udry (1990) found that in Northern Nigeria almost all credit given was within the village or kinship group. This segmentation of credit markets implies that only non-covariate income risks and fluctuations can be insured through credit, limiting the scope for consumption smoothing. Even in areas in which non-

[1]The author wishes to thank Pramila Krishnan, Paul Collier and John Hoddinnott. All errors remain the author's responsibility.

resident lenders and institutions provide a large share of total credit, this segmentation remains pronounced with respect to consumption loans (see e.g. Siamwalla et al. (1990) on Thailand).

The absence of complete credit and insurance markets does not imply that rural households have no strategies left to cope with income uncertainty. There is a vast literature documenting insurance strategies employed by rural households to offset the adverse effects of income shortfalls and entitlement failures (e.g. Walker and Jodha (1987), Corbett (1988), Chambers (1989), Alderman and Paxson (1992)). Alderman and Paxson classify these responses into risk management strategies and risk coping strategies. The former aim to reduce income risk, while the latter aim to cushion the effects of income risk on consumption, intertemporally through savings and across households through mutual support networks as a risk-sharing device.

Considering income risk management strategies, agricultural crop producers often use adjustments within the cropping system with the specific purpose of reducing the production risk of a particular crop. Examples are spatial scattering of plots, staggering of planting and other operations, moisture conservation measures such as ridges and furrows, and irrigation systems (Ruthenberg (1976), Jodha and Mascarenhas (1983)). Institutional arrangements such as different forms of tenancy contracts could influence the riskiness of the income process, by shifting some of the risk towards or away of the tenant (e.g. Newbery and Stiglitz (1979), Walker and Jodha (1987)). A common strategy for households to alter the income risk they face through diversifying their income sources, and skewing the risk distribution by focusing on low risk income sources. Its effectiveness as a strategy to reduce total income risk depends on the covariance between the different income sources: the lower the covariance, the lower the total riskiness of the process. In farm societies the cultivation of different crops and often combining crop and livestock farming are important diversifying strategies. The choice of agricultural activities can be induced by varying attributes in terms of maturity period, drought tolerance, timing and quantities of labour and other input needs, etc.

Other income diversifying strategies can be the hiring out of human labour and bullocks, earnings and remittances from migrated members of the extended family - in general off-farm income, and on-farm non-agricultural income such as earnings from handicrafts. It is not necessarily true that income diversification will reduce the riskiness of the joint income process: crop outputs in a non-irrigated smallholding tend to have positive, not zero, covariance (Lipton (1979)), just as local off-farm income earning opportunities might especially be limited when a region experiences a general crop failure. Evidence on Burkina Faso and India would however suggest that non-agricultural based income diversification tends to be more effective as a risk-reducing strategy, since these income sources tend to be less correlated with crop income than different crops with each other (Walker and Ryan (1990), Reardon, Delgado and Matlon (1992)).

Income risk management strategies cannot be viewed independently of risk coping strategies: the opportunities available for consumption smoothing can be expected to influence the ways in which households respond to income risks (Alderman and Paxson (1992)). Rosenzweig and Binswanger (1993) found that in semi-arid India the wealth of the household increased the riskiness of the activities portfolio to which productive assets were allocated. Eswaran and Kotwal (1990) analyzed the effects of credit constraints on the risk behaviour of households. Both studies refer to the increased consumption smoothing possibilities with higher wealth and access to credit as a rationalisation for the observed risk-taking effects. The evidence provided by Rosenzweig and Binswanger uses the data set collected by ICRISAT (see Walker and Ryan (1990)). Due to the panel nature of the data set and its detail on farming systems, it would seem at present the only data on developing countries which would allow to test convincingly the interaction between risk behaviour and consumption smoothing possibilities. In this paper an attempt is presented to investigate aspects of this relationship for Tanzania, on a, admittedly, much poorer data set. It is based on a sample survey conducted in 1990 in Shinyanga District in Western Tanzania, part of an area often referred to as Sukumaland. The specific circumstances of the region's rural economy allow however certain simplifications in the analysis, partially compensating for the data constraints.

Tanzanian rural households cannot rely on credit for consumption smoothing since both formal and informal credit markets are very limited. The formal credit market is geared exclusively towards the public sector, while informal credit is, if available, only available from within villages (Due (1983), Collier and Gunning (1991), Amani et al. (1987), Bevan et al. (1992)). Traditionally, village based mutual support networks exist in Sukumaland (Malcolm (1953), Cory (1953)), but their effectiveness will be limited to non-idiosyncratic risk (Alderman and Paxson (1992)). Self-insurance through liquid asset accumulation and depletion forms the main way of mitigating the consumption consequences of income fluctuations (Hankins (1974)). Models of consumption under liquidity constraints can therefore be expected to capture the main characteristics of risk coping strategy used by households in Sukumaland. The effectiveness of savings in buffering consumption has been analyzed in Deaton (1990, 1991, 1992). Important factors include the return and the liquidity of the assets, as well as the covariance of the asset values with income.

The traditional liquid store of wealth in the Western regions is livestock. In fact, about a third of the national herd of cattle in Tanzania is kept in Sukumaland, mainly by agro-pastoralists (Marketing Development Bureau (1987)). Few households have specialised into livestock rearing, and most use it as a store of wealth providing a useful supplement in mixed farming systems, providing

both an important return as well as a safety net for bad years[2]. Livestock markets are quite well developed and have been liable to very little intervention in Tanzania since the 1960s, except for a brief and largely unsuccessful attempt to control prices between 1969 and 1971 (Mackenzie (1973), Frankel (1982), Marketing Development Bureau (1989)). Other assets are rarely used as part of a consumption smoothing strategy, mainly because no obvious high return alternatives to livestock exist. Financial assets in particular virtually absent in rural Tanzania: very little savings occur in cash or savings deposits (see e.g. Von Rotenhan (1966), Amani et al. (1987)). This is not surprising given the negative returns obtained on financial assets since the mid-1960s. Inflation has for example consistently been between 25 and 40 percent in the 1980s, and financial repression has meant that returns on savings deposits did not compensate for this. A traditional Sukuma saying sums it up: "Shillings do not breed" (Malcolm (1953)). Land investment is also limited in the area: even though since the restrictions of the 1970s some form of land market seems to have developed, they remains very limited[3]. Consequently, total liquid assets households can be well approximated by valuing the livestock herd, and this will be done in the paper below.

The main traditional risk management strategy within the farming system in the particular area considered is the devotion of some part of the farming land to the cultivation of sweet potatoes (Malcolm (1953), Von Rotenhan (1966)). Sweet potatoes have a low yield risk since it is very drought and locust resistant and provides a stock of food locked up in the soil which can be depleted in case of food shortages. Its characteristics are very comparable with cassava, but in the particular area the latter is much less popular. A disadvantage of the crop is its low protein content, even though high in energy. Furthermore their economic return is limited by the lack of its marketability due to the bulkiness of the crop (Marketing Development Bureau (1987)). High transport and post-harvest storage losses imply that prices are fairly low. Consequently sweet potatoes are a low return, low risk crop.

It can be expected that the extent to which (risk-averse) households will use sweet potatoes to reduce their overall income risk will depend on the other alternatives available to reduce their income risk and its consumption consequences. Given the limitations on the data available, the analysis in this paper will focus on the role played by the main alternative identified, the use of liquid

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[2]According to the 1990 survey data used in this paper, about 68 percent owned some livestock (cattle, goats, sheep or chicken), with about half of these households considering livestock as one of their two main income sources (including livestock products as subsistence income and live cash sales). For most of these households it is however only a supplementary source of income: only about 20 percent of livestock owners derive cash mainly from livestock products and live sales.

[3]In the survey, only 9 percent had acquired any land via purchase and 3 percent were hiring land. The rest had acquired all their land through inheritance and from the government.

assets in the form of livestock to buffer consumption. In particular, it can be expected that households with higher liquid asset holdings will be willing to allocate their resources to higher risk activities, since the consumption risk consequences of such decision are less costly than for households with fewer liquid assets. As a consequence, the former are likely to grow less of the low risk, low return crop.

In the next section, a model is developed in which this is formalised: households faced with liquidity constraints will attempt to combine income generating activities which are optimal in terms of mean and riskiness. The possibility of savings will however affect in each particular period the amount of income risk a household is willing to take up: the more liquid assets available as a buffer the more risk the household is willing to take up. The basis is a model of consumption under liquidity constraints as in Deaton (1991). The main difference is that income is not exogenous, since its mean and riskiness can be determined by the household. Formally, the model can be viewed as a simplified version of Roe and Graham-Tomasi (1986), retaining the central problem of the simultaneity of consumption decisions in last period and production decisions in the present period, but introducing liquidity constraints explicitly. The conclusions of the model are similar to Eswaran and Kotwal (1990), even though the specification of the problem is somewhat different. The reason is that the emphasis is on obtaining an estimatable model. In section 4 the model is tested on data from a 1990 survey conducted by USAID in Shinyanga District (1990); section 3 will first discuss the data used[4]. In section 5, some of the implications of the analysis are discussed.

2. Modelling Income Skewing and the Role of Assets

Suppose the household has access to two crop income sources with different means and riskiness in each period t and it can allocate proportions of its total available labour time L to each activity according to its objectives, such that the sum of the proportions equals one. For a particular combination of the two income sources, access to an asset would reduce the consequences of income uncertainty related to this joint income process. Consequently, it can be expected that the household might well be willing to take up more risk in its income process if assets can be used to smoothen consumption. To show this result formally, consider a multi-period model in which the household has to make decisions at the beginning of each period how much labour to allocate to two crops. Production takes place by allocating one production factor, labour, to each of the crops under constant

[4]For more details on the survey, its design and shortcomings see USAID (1990) and Dercon (1992).

returns to scale. The activities yield a return of r_1 and r_2 in each period per unit of labour, with p_t being the proportion of labour allocated to the activity 1 with return r_1 in period t (with $0 \leq p_t \leq 1$). Income from the first crop in period t, y_{t1}, equals $p_t.L.r_1$ and is certain. The return on the other activity, r_2, is risky, resulting in income from that growing the crop, y_{t2}, equal to $(1-p_t).L.r^1_2$ with a probability of q, and to $(1-p_t).L.r^2_2$ with probability (1-q) (with $0 \leq q \leq 1$). It will be assumed that $r^1_2 < r_1 < r^2_2$, and that the expected return per unit of labour from the second activity, $E(r_2)=q.r^1_2+(1-q).r^2_2$, is assumed to be larger than r_1. Consequently, riskiness will be weighed against the expected value of income in the household's choice of joint income process. The risk-averse household maximizes intertemperal expected utility and has constant relative risk aversion $(1-\rho; \rho < 1)$, implying an instantaneous utility function of the form $v(c_t)=c_t^\rho$, as shown in equation (1):

$$u = E_t\sum_{t=0}^{T} (1+\delta)^{-t}.c_t^\rho \tag{1}$$

with δ the rate of time preference and c_t consumption at t. The functional form of the utility function implies a precautionary motive for savings: they are kept in response to risk to buffer consumption such that an increase in risk will increase savings (Deaton (1991)).

First, consider the situation in which the household has no access to credit nor assets such that consumption in each period is simply equal to income, i.e. $c_t = y_t = p_t.L.r_1+(1-p_t).L.r_2$. In that case, the intertemporal nature of the problem is irrelevant. The model is a simple static portfolio choice model, but it will provide a useful comparison later on. The problem can then be written as:

$$\begin{aligned} \max\ : u &= E_t\sum_{t=0}^{T} (1+\delta)^{-t}.(p_t.L.r_1 + (1-p_t).L.r_2)^\rho \\ s.t.\ 0 &\leq p_t \leq 1 \end{aligned} \tag{2}$$

From the first order conditions of this problem it follows that if p_t is smaller than one - it pays the household to grow some of the risky crops - then the condition for optimal choice of p_t becomes:

$$\begin{aligned} \frac{\partial u}{\partial p_t} &= E_t u'(c_t).(L.r_1-L.r_2) \\ &= E_t\,(\rho.(L.r_1-L.r_2)(p_t.L.r_1+(1-p_t)L.r_2)^{\rho-1}) \\ &= L^\rho.\rho.[q.(r_1-r_{21})(p_t.r_1+(1-p_t)r_{21})^{\rho-1} + \\ &\qquad (1-q).(r_1-r_{22})(p_t.r_1+(1-p_t)r_{22})^{\rho-1}] \leq 0; \\ \frac{\partial u}{\partial p_t}.p_t &= 0 \end{aligned} \tag{3}$$

As long as the condition is satisfied with strict inequality, the household will find it optimal only to grow the risky crop. If the condition is satisfied with strict equality, then expression for the proportion p_t of labour time allocated to the activity with return r_1 can be found as:

$$
\begin{aligned}
p_t &= \frac{B}{(D-1).r_{21} - B} \\
&= \frac{B}{D(r_{11} - r_{21}) + (r_{22} - r_{12})} \\
\text{with } D &= \left[\frac{(1-q).(r_{22} - r_{12})}{q.(r_{11} - r_{21})}\right]^{\frac{1}{1-\rho}} \\
B &= r_{22} - D.r_{21} \\
0 &\le p_t \le 1
\end{aligned}
\tag{4}
$$

The interpretation of this first result is fairly straightforward. From the assumptions about the relationship between the returns on both activities, and since the coefficient of relative risk aversion, $(1-\rho)$, is strictly positive, it follows that D is always strictly larger than one. Also, the denominator of the expression is always strictly positive. Consequently, as long as B is strictly positive, p_t will lie between zero and one. This implies that the household will diversify by allocating some labour to the low risk crop. The larger B, the more of the low risk activity will be taken up. A larger spread between the 'good' and the 'bad' return on the risky activity - implying a higher riskiness - would increase B, as would a lower D. The latter could follow from a higher risk-aversion or from a lower mean return on the risky activity relative to the safe activity. If B is negative then it follows that equation (3) will only be valid with strict inequality and no safe crop will be grown. Constant returns to scale imply that the proportion of labour allocated to the safe crop is independent of the amount of labour available.

The introduction of the possibility of savings (with borrowing constraints) will affect this outcome: assets can be built up in good years to provide a buffer for bad years. The problem can then be expressed as:

$$
\begin{aligned}
&\max : u = E_t \sum_{t=0}^{T} (1+\delta)^{-t} c_t^{\rho} \\
&s.t. \qquad A_{t+1} = (1+i).(A_t + y_t - c_t) \ge 0 \\
&\qquad y_t = y_{t1} + y_{t2} = p_t.L.r_{11} + (1-p_t).L.r_{12} \\
&\qquad 0 \le p_t \le 1
\end{aligned}
\tag{5}
$$

with A_t the total liquid assets at the beginning of period t and the i the (certain) rate of return on savings. If the household allocates some of its labour to the risky activity, then income y_t is uncertain. The household now has two decisions to take based on the present income outcome y_t and its present asset stocks A_t: how much of its total liquid means to consume (c_t, determining A_{t+1}) and how much

of its total labour supply to devote to the low risk activity in the coming year (p_{t+1})[5]. Defining L as the Lagrangean function for the dynamic programming problem and λ and γ the Lagrangean multipliers related to A_{t+1} and p_{t+1}, the first-order Kuhn-Tucker conditions can be written in general as:

$$
\begin{aligned}
&\frac{\partial L}{\partial c_t} = u'(c_t) - \frac{1+i}{1+\delta}.Eu'(c_{t+1}) - \lambda \leq 0; \quad \frac{\partial L}{\partial c_t}.c_t = 0 && (6i)\\
&\frac{\partial L}{\partial p_{t+1}} = \frac{1}{1+\delta}.Eu'(c_{t+1}).(L.r_2 - L.r_1) - \gamma \leq 0; \quad \frac{\partial L}{\partial p_{t+1}}.p_{t+1} = 0 && (6ii)\\
&\frac{\partial L}{\partial \lambda} = A_t + y_t - c_t \geq 0; \; \lambda.\frac{\partial L}{\partial \lambda} = 0 && (6iii)\\
&\frac{\partial L}{\partial \gamma} = 1 - p_{t+1} \geq 0; \; \gamma.\frac{\partial L}{\partial \gamma} = 0 && (6iv)
\end{aligned}
\qquad (6)
$$

Condition (6i) is the well-known result of the analysis of consumption under liquidity constraints (e.g. Deaton (1992)): as long as the liquidity constraint is not binding presently, (ie. (6iii) holds with strict inequality) so that λ is equal to zero, present and expected future marginal utilities will be equalised. If the liquidity constraint (6iii) is binding ($c_t = A_t + y_t$), then λ may be positive. The expected discounted marginal utility of future consumption will then be lower than the marginal utility of consumption today: the household would have wished to have had higher consumption, implying lower marginal utility but this is impossible given the liquidity constraint. γ will only be positive if (6iv) holds with strict equality, ie. if p_{t+1} equals 1 - all labour is allocated to the low risk crop. In that case, (6ii) shows that it would have been preferred to move even more labour to low risk crop according to (6ii). Condition (6ii) will only hold with strict inequality if p_{t+1} is equal to zero: no allocation of labour to the low risk crop at all. γ will then obviously be zero following (6iv): any marginal increase in p_{t+1} would according to (6ii) result in a decrease in optimal utility. In that case, there is clearly no point to allocate anything to the low risk crop. The interpretation of these corner solutions are quite self-evident. If p_{t+1} is however not equal to zero and smaller than one (ie. (6ii) holds with equality and (6iv) with inequality) then it is possible to find a more specific solution for p_{t+1}. With constant relative risk aversion and the assumptions about the income process, condition (6ii) becomes:

[5]The model can be viewed as a simplified version of Roe and Graham-Tomasi (1987), with production determined by one input with fixed endowment and absent market, and binomial risk. Also, the utility function is defined over consumption goods only. Their central conclusion, the lack of separability of consumption and production decisions, is maintained. Their model is expanded through the introduction of liquidity constraints.

$$\frac{\partial L}{\partial p_{t+1}} = \frac{1}{1+\delta}.\ E\ [(L.r_1 - L.r_2).\rho.((1+i)(A_t + y_t - c_t) + p_{t+1}.L.r_1 + (1-p_{t+1})L.r_2)^{\rho-1}] = 0$$

(7)
$$= \frac{1}{1+\delta}\ [(q.\rho.(L.r_1 - L.r_{21}).((A_{t+1}^{*} + p_{t+1}.L.r_1 + (1-p_{t+1}).L.r.y_{21})^{\rho-1}) +$$
$$(1-q).\rho.(L.r_1 - L.r_{22}).((A_{t+1}^{*} + p_{t+1}.L.r_1 + (1-p_{t+1}).L.r_{22})^{\rho-1})]$$

in which A_{t+1}^{*} is the amount of assets to be carried over between t and t+1, and is determined by the consumption at t, the other choice variable in the problem and therefore denoted with an asterisk. Reworking (7), an expression can be found for the proportion p of labour time allocated to activity one:

$$p_{t+1} = \frac{B}{(D-1).r_1 + B} - \frac{(D-1).A_{t+1}^{*}}{L.[(D-1).r_1 + B]}$$

$$= \frac{B}{D(r_1 - r_{21}) + (r_{22} - r_1)} - \frac{(D-1).A_{t+1}^{*}}{L.[D(r_1 - r_{21}) + (r_{22} - r_1)]}$$

(8)
$$with\quad D = \left[\frac{(1-q).(r_{22} - r_1)}{q.(r_1 - r_{21})}\right]^{\frac{1}{1-\rho}}\ (\geq 1)$$

$$B = r_{22} - D.r_{21}$$

$$0 \leq p_{t+1} \leq 1$$

Comparing equation (8) with equation (4), it can be seen that to (4) an asset term has been added. Since D is larger than one and the denominator positive, a household with positive assets will always reduce its allocation to the safe crop. If zero assets are kept, then the result is the same as in (4). In equation (8), the asset is also weighted by the amount of inputs available to the household - the scale of operations will inform the value the household attaches to a particular amount of assets as a means of insurance against bad income outcomes. For an individual household i, facing constant returns to the different activities, with particular preferences and with endowments of labour L_i, the choice of p at t+1 can be rewritten as a linear equation of assets per unit of inputs with a constant, as in equation (9), with D and B defined as above.

$$p_i = \alpha_0 + \alpha_1 . \frac{A_i^{*}}{L_i}$$

(9)
$$with\quad \alpha_0 = \frac{B}{(D-1).r_1 + B}$$

$$\alpha_1 = -\frac{(D-1)}{[(D-1).r_1 + B]}$$

Equation (9) is not an optimal solution of the problem in terms of the exogenous variables: the choice variable c_t is implicitly still present through the levels of assets at the beginning of year t+1, A_{t+1}^{*}. Finding an optimal level of consumption from the Kuhn-Tucker conditions in (6) is

however not straightforward given the liquidity constraints. Deaton (1991) argued that an explicit functional form for the optimal consumption function in a similar model with exogenous income was unlikely to be found, so he used a numerical approach to find the shape of the consumption function for particular values of the parameters of the model. The approach taken in this paper to get around the problem is essentially econometric.

The fact that in equation (9) assets at the beginning of the period is determined by a choice variable, endogenous with the left hand side variable, would imply that, in principle, a bias would result when using least squares estimation. Instrumental variables estimation could be used to deal with this problem, but its drawback is that some efficiency would be lost if the bias caused by least squares estimation is relatively limited (Nakamura et al. (1981)). Therefore, first the Wu-test based on Hausman (1978), as in Nakamura et al. (1981), is used to check the significance of the endogeneity problem. To do so, a model determining assets has to be estimated, using its prediction as the basis of the test in equation (9). The model and its estimation results are discussed in the appendix.

The essential point of this asset model is that the level of assets for a particular household will depend on its ability to generate surpluses, besides its risk and time preferences and 'luck'. Assuming that the mean of income is constant, its random nature implies that in some years income outcomes are above 'mean' or 'permanent' income. Assuming multiplicative risk, the extent of such surpluses will depend on the mean of the income process. Since asset holdings are the accumulation of positive surpluses, they can be thought of as being related to the factors determining the mean of income. With incomplete land, labour and credit markets, the mean of income can be modelled as being determined by household land and labour endowments. If the Wu-test shows that endogeneity is a problem, then the predicted values of the asset model will be used to allow least squares to be used, since this predicted value will be independent of the errors.

A final point to be made is that for an individual household α_0 and α_1 in equation (9) can be considered to be constant, as long as the options available to the household and its preferences remain unchanged. In the cross-section this may not be true. For example, different attitudes towards risk across households would imply non-constancy of the parameters in equation (9). Effectively, there would be missing variables in the equation, as in a random coefficient model. The errors in the regression would then show heteroscedasticity. The Breusch-Pagan test will be used to check the presence of heteroscedasticity. If present, the heterogeneity of the households is not easily resolved using cross-section data. The approach taken will be to attempt to model explicitly the structure of the heteroscedasticity, assuming a multiplicative form.

3. Empirical Results

In the area of the 1990 Shinyanga District survey, sweet potatoes was widely grown: 71 percent of the 77 households interviewed grew this low risk crop. As discussed in section 1, this is the local low risk, low return crop. The analysis will try to test whether the allocation of inputs to this crop is determined by the relative consumption safety provided by liquid asset stocks[6]. The model in the previous section considered that the choice faced by the households was between two alternatives. In reality, more alternatives are available to the households. The main point is however that sweet potatoes is the only low risk alternative available. Other typical low risk alternatives, such as non-agricultural wage employment, are not present for the households in the sample. A significant number of households participate in agricultural wage employment on local farms. With covariate climatic risk, this type of activity is relatively less available in 'bad' years, providing limited consumption protection. Consequently, it ought not to be considered as a low risk activity. The estimation will therefore keep the stylised fact of one low risk activity versus a (group of) higher risk alternatives.

Equation (9) suggested that the proportion of inputs allocated to the cultivation of the low risk crop (p_i) was a linear function of assets per unit of inputs available. Total liquid assets (A_{i*}) were defined as the total value of livestock at present market prices, and livestock kept were cattle, goats, sheep and chicken (scaled in '00 000 Tanzanian Shillings). No other significant liquid assets could be identified in the sample. The mean herd size in the sample was about 14 head of cattle, 3 goats, 2 sheep and 4 chicken, presenting a value of 132060 TSh on average per household. Cattle is by far the most valuable asset, with a value on average 6 times as high as for goats and 10 times the average value of a sheep.

A significant number of households earn income from agricultural wage employment (25 percent), and about half the households earn (relatively small amounts of) income from non-agricultural business income. This would suggest that the labour endowment (L_i) should be used to as a deflator in equation (9): with a land constraint, labour can also be allocated to (risky) non-agricultural activities. The relative security offered by assets and governing the move into low risk activities will then be measured relative to the total labour endowment of the household. The total labour endowment of the households is measured by the number of adults above 15 years of age (with on average about 3.3 adults per household in the sample). Some experimentation with more

[6]Four farmers also grew some cassava, an alternative low risk, low return crop, with similar marketing and storage characteristics. The (small) areas cultivated with this crop were added to the sweet potatoes acreage.

sophisticated measures, such as weighing the contribution of children under 15 years of age and the elderly, turned out to make no significant difference in the results. Ideally, one then would like to measure the allocation to sweet potatoes in terms of labour as well. Unfortunately, no crop specific labour input data were available, so the proportion of land allocated to the low risk crop is used as the independent variable in the estimation.

First, ordinary least squares was used to estimate equation (9). The results are reported in table 1 as 'Basic regression'. As can be seen the results are not encouraging: assets per adult are not significant in explaining the allocation of land to the drought resistant crop sweet potatoes. Joint significance tests are not significant. The estimation procedure ignored however the problem of endogeneity of assets and the possible heteroscedasticity of the errors. These will be dealt with in turn.

Heteroscedasticity was put forward above as one of the possible consequences of differences among households. These could for example be related to differences in risk preferences or differences in returns on activities. Differences in returns could follow from differences in endowments and technology. For example, differences in soil quality will affect the returns obtained by individual farmers and could be important to explain why they grow a particular crop or not, but unfortunately no data which could proxy soil quality are available. Also, differences in technology availability and use will affect returns. As it turned out in the survey, virtually all farmers in the sample were using hand hoes and ploughs, suggesting little difference between farmers in technology available. Finally, household composition, and the quality of labour could also affect the returns households can obtain from activities.

Homoscedasticity was tested against the alternative of multiplicative heteroscedasticity. The latter was related to a general formulation based on land and household labour supply characteristics[7]. In particular, the variables included were the farm size ('Farmsize', in ha), the age, the gender and education of the head of the household ('Agehead' - in years; 'Genderhead' - one if male; 'Education head' - in years) and the number of male and female adults in the household ('Males' and 'Females', above the age of 15 years). The resulting econometric model is shown as equation (10).

[7]Further household composition effects, such as the number of children in various age groups were initially also included, but these did not change any of the conclusions reached.

$$p_i = \alpha_0 + \alpha_1 \cdot \frac{A_i}{L_i} + \epsilon_i$$

(10)
$$\epsilon_i \sim N(0, \sigma_i^2)$$
$$\sigma_i^2 = \sigma^2 . Z_i^{\gamma}$$
$$= \sigma^2 . (Farmsize^{\gamma_1} . Genderhead^{\gamma_2} . Males^{\gamma_3} . Females^{\gamma_4} . Agehead^{\gamma_5} . Educationhead^{\gamma_6})$$

The results of the estimation (using maximum likelihood) are reported in table 1. First at the bottom the Breusch-Pagan test is reported, rejecting convincingly the null of homoscedasticity against the alternative of multiplicative heteroscedasticity. Assets per adult has a negative sign and has become significant at 5 percent, even though its parameter value is barely different from the basic regression, suggesting that heteroscedasticity contributed to low efficiency of the OLS estimation. The higher the value of assets per adult kept by the household, the lower the allocation to low risk activities, supporting the model predictions from the previous section. The land and labour supply characteristics all seem to contribute to the explanation of the heteroscedasticity, except for the educational level. Also, a pattern can be detected: households with large farm sizes, and/or which are male headed with a large number of males have a lower variance of the errors than households which are female headed, with many female adults and an older head of the household. An explanation for this may be that the larger the household's endowment in terms of farm land or male (high return) labour, the easier the household will find it to adjust its input allocation to low risk crops to its optimal level, given its asset holdings. A household with a female or old household head, and with relatively more female adults may well find it more difficult to adjust itself. For example, female headed households often depend on other households to do certain activities such as the clearing and ploughing of the land. This dependence may make them less flexible to reach the optimal land allocation.

An alternative explanation for the poor performance of the basic regression is related to the endogeneity of assets with the choice of activities. A Wu-test based on Nakamura and Nakamura (1981) was performed to test the endogeneity of assets. For this, an auxiliary regression model was estimated to yield predictions of assets per adult, and is reported at the bottom of table 1. Its specification and estimation is discussed in the appendix. Land holdings and male labour endowment is found to be significant in explaining accumulated liquid assets holdings. Entering the predictions from equation (14) (in appendix) into the basic regression yielded as significant estimate with a t-value. This value is the Wu-test statistic, which is t-distributed under the null hypothesis that the predicted values do not add to the explanation of the dependent variable, or that the explanatory variable is independent from the dependent variable. Given the high t-value reported in table 1, it

would suggest the endogeneity of assets per unit of inputs, with the allocation decision towards the low risk activity.

The third column reports the results of the basic model corrected for the endogeneity, i.e. in which the actual asset levels per adult were replaced by the predicted value from the auxiliary model. The fourth column reports the results for the heteroscedasticity model with a correction for endogeneity. Both equations have a high joint significance and strongly significant estimates of the predicted negative sign of the effects of assets on low risk activity choice. The fourth equation for example implies that a household with an average livestock holding (i.e. worth 37285 TSh per adult) would have a proportion of land allocated to sweet potatoes which is 25 percent smaller than a household with no liquid assets. Using the predicted rather than the actual values of assets increases also the extent of the effect. The Breusch-Pagan test statistic, rejecting homoscedasticity, suggests that the model with multiplicative heteroscedasticity is to be preferred. The variance increases again for female headed households or with older household heads, and with relatively high number of female adults; and decreases for male headed or households with large farms. As before, this could be explained by the difficulties faced by households with lower endowments to adjust to the optimal allocation.

Table 1:

Estimation Results

	Basic Regression	Basic with Hetero-scedasticity	Basic with Endogeneity	Endogeneity with Hetero-scedasticity
constant	0.095	0.062	0.132	0.088
	(7.34)**	(8.01)**	(7.85)**	(7.09)**
assets per adult	-0.014	-0.013	-0.113	-0.059
	(0.89)	(2.25)*	(3.28)**	(4.24)**
heteroscedastic form:				
farm size		-0.174		-0.245
		(3.17)**		(4.47)**
gender head		-1.194		-0.894
		(2.63)**		(1.97)*
males		-0.291		-0.162
		(1.73)*		(0.96)
females		0.564		0.394
		(3.07)**		(2.14)*
education head		-0.078		-0.089
		(1.08)		(1.24)
age head		0.028		0.024
		(2.07)*		(1.74)*
F-joint	0.78		10.73**	
Chi-joint	0.80	40.13**	10.30**	34.02**
Breusch-Pagan		50.83+		33.07+
Wu-test	3.17**			

* significant at 5%
** significant at 1%

\+ rejecting homoscedasticity at 99%
\- not rejecting endogeneity at 95%
\-- not rejecting endogeneity at 99%

The absolute t-value is given in brackets

Auxiliary Regression for Wu-test for endogeneity (see Appendix)

Assets/adults = 0.143 + 0.084 farmsize + 0.191 males - 0.154 females
(0.377) (3.018)** (2.329)** (1.717)*

0.139 genderhead + 0.004 educhead - 0.003 agehead
(0.632) (0.105) (0.406)

R^2=19% F[6,70]=2.67* (joint significance test)

** significant at 1 percent
* significant at 5 percent
(t-values in brackets)

4. Conclusions

Households use different strategies to mitigate income risk and its consequences. This paper provided an analysis of one such strategy, the cultivation of a low risk, low return crop, and the extent to which it is related to the household's consumption security provided by liquid assets stocks. A model was developed in which it was shown that risk-taking behaviour is positively related to the household's liquid asset stock: with high asset levels the consumption consequences in 'bad' years are much less important than if liquid assets are low, encouraging high return, high risk activities. One crucial feature of the model is however that the choice of activities and consumption decisions in an intertemporal setting are endogenous. Decisions about what kind of income risk to take and what to consume from past incomes and assets can not be separated. Consequently, the choice of activities at t and the stock of assets to be carried over from t-1 are endogenous.

The model was applied on cross-section data from Shinyanga District in Western Tanzania. The distinguishing features of the area considered is that credit markets are absent, liquid assets take traditionally and virtually exclusively the form of livestock and that the traditional low risk, low return activity is the cultivation of sweet potatoes. An econometric model was specified in which the proportion of land allocated to sweet potatoes was related to the stock of liquid assets held by the household per adult. To deal with the endogeneity problem, the stock of accumulated liquid assets were predicted using the underlying endowments of the household, and endogeneity could not be rejected using the Wu-test. Also, given intra-household differences, including with respect to land and labour supply characteristics, and household preferences towards risk and the timing of consumption, heteroscedasticity could be expected. The presence of homoscedasticity was rejected when tested relative to multiplicative heteroscedasticity related to household composition and labour and land endowments. The regression results of models taking into account heteroscedasticity and/or endogeneity showed the significance of the predicted relationship between sweet potatoes input allocation and assets per adult. From the regression taking into account heteroscedasticity and endogeneity, it could be found that a household without liquid assets would cultivate about 9 percent of its land with sweet potatoes. An additional cow of average value per adult reduced the allocation of land to sweet potatoes by about 7 percent (i.e. just over 8 percent of its land would be cultivated with sweet potatoes).

One notable result was the signs on variables implied by the estimation of the variance to account for heteroscedasticity. Endowments in the form of land and male labour, and dummy for male headed households resulted in negative signs, while female labour and the age of the household head

in positive signs. In other words, the variance for households which are female headed, with mainly female adults or with older household heads is typically higher than for other households. This could well be related by the relatively bigger difficulties for the former group to allocate its resources optimally. For example, female headed households or elderly households rely on other households to do certain land-related activities such as clearing and ploughing. This may well give them less flexibility to allocate optimally than households with plenty of male labour.

Several lessons can be drawn from the analysis. First, from a modelling point of view, it reiterates Roe and Graham-Tomasi (1986)'s point that the choice of activities in a risky environment with missing markets cannot be analyzed in a static framework, but has to be viewed in a dynamic context with emphasis on the consumption consequences of decisions. It also provides evidence from Africa on the relationship between risk management strategies (to reduce income risk) and risk coping strategies (to reduce the consumption consequences of income risk). Up to now, this relationship had mainly been addressed using the ICRISAT data set (Alderman and Paxson (1992)).

Furthermore, this evidence is to some extent disconcerting if one is interested in rural growth without exacerbating rural inequality, since it shows the existence and the mechanisms of a 'poverty trap'. Similar as in for example Rosenzweig and Binswanger (1993), wealthier households can engage in more risky but higher return activities than households with a poor asset base. The latter engage relatively more in lower return activities to provide for their consumption security requirements, increasing over time the wealth gap with the richer households. However, by focusing on the interaction of risk management and coping strategies lessons can be learned for targeting the poor. First, campaigns to promote the cultivation of drought resistant crops as were conducted in Tanzania throughout the 1970s and part of the 1980s - and still promoted by aid agencies - could well be ill conceived. Households grow these crops because alternative consumption security mechanisms such as off-farm employment or liquid assets are not sufficiently available to them. Encouraging farmers to enter into the low risk activity may be appropriate if no other means can be created, but its consequence is that expected returns are low as well, thereby encouraging 'poverty traps' to develop with permanently low incomes. Alternative policies could be the creation of alternative safety nets, such as temporary and targeted employment, which would not jeopardize mean incomes. Another alternative could be the creation and propagation of appropriate liquid assets for the poorer households, by encouraging savings in 'good' years and guaranteeing relatively high returns and easy liquidation. Such mechanisms may both provide a safety net for 'bad' years as well contributing to the development of a higher asset base for the poorer households through accumulation.

Appendix: A model of asset accumulation

The evolution of assets in the model can be written as (see (5)):

$$A_t = (1+i)(A_{t-1} + y_{t-1} - c_{t-1}) \geq 0 \qquad (11)$$

Under the assumptions of the model, (in particular the precautionary savings objective), assets perform the role of a buffer stock. Concave marginal utility implies that the household prefers smooth to unstable consumption. It therefore dislikes to be confronted with binding liquidity constraints. Given income uncertainty and liquidity constraints, the way for the household to achieve reasonable consumption stability is to use 'good' income draws to build up assets to cope with 'bad' income draws. Asset accumulation can then *inter alia* be seen to be the result of a sequence of 'good' income draws.

Consider now a household with sufficient positive assets at present, such that it is not facing binding liquidity constraints. This household will choose to consume according to its 'permanent' income, minus some precautionary savings to deal with possible future liquidity constraints (see Deaton (1991)). The marginal increase in assets it will choose to carry over to next year t can be denoted by η_{t-1}. With some manipulation, equation (11) can then be rewritten, using the lag operator L, as

$$\begin{aligned} A_t &= \beta.(A_{t-1} + \eta_{t-1}) \quad (with \quad \beta = (1+i)) \\ &= \frac{\beta}{1-\beta L}\eta_{t-1} \\ &= \beta(1+\beta L+\beta^2 L^2+ \ \ldots \ +\beta^{n-1}L^{n-1})\eta_{t-1} \\ &= \beta\eta_{t-1}+\beta^2\eta_{t-2}+\beta^3\eta_{t-3}+ \ \ldots \ +\beta^n\eta_{t-n} \\ &= \sum_{j=1}^{n} \beta^j \eta_{t-j} \end{aligned} \qquad (12)$$

in which t-n is the first period in the beginning of which assets were positive. The present level of assets can then be seen as a sequence of shocks above the household's optimal consumption level. Cumulatively, these shocks are overwhelmingly positive, resulting in positive present asset levels and therefore higher consumption security.

Equation (12) describes assets for an individual household: the extent of shock η are not necessarily the same for different households. For the households considered incomes are mainly linked to agricultural activities facing climatic risk. One implication is that an assumption of constant proportional risk may well be realistic - a bad year makes different farmers lose a similar proportion of the harvest. The coefficient of variation is then constant across households with the same

combination of income sources even at different scales of production. It is then possible to write the shock η at t for household i as $\eta_{it} = \mu_i u_t$ and u_t is distributed with mean zero and variance σ^2. This implies that η_{it} has a mean of zero and a variance of $\mu_i^2\sigma^2$, and the coefficient of variation of y_{it} is σ. Since climatic risk can be expected to be highly covariate across households in a small geographical area as considered in this paper, u_t can be assumed to be the same across households as well as t-n, the first period of the sequence of cumulatively positive shocks. Equation (12) can then be rewritten as a linear function of the mean of the income process for each household[8], or

$$A_{it} = \gamma.\mu_i \quad with \quad \gamma = (\sum_{j=1}^{t} \beta^j u_{t-j}) \tag{13}$$

The mean of the income process enters in equation (13), but this variable is not directly observable in the cross-section data for one year. To approximate the mean of the income process, the factors underlying income will be considered. With incomplete land and labour markets, these can be expected to depend on the households endowments: in particular, the quantity and quality of the available labour and land. Unfortunately, the data do not contain full information about all these variables, in particular about the quality of land and labour supply. Total farm size ('Farmsize'; in ha), as well as household characteristics will be used to approximate the endowments, determining the mean of the income process faced by the household. The latter include the gender of the head ('Genderhead'; one if male), the number of male adults (above 15 years of age) ('Males'), the number of female adults ('Females'), the age of the head ('Agehead'; in years) and the education in years of the head ('Educationhead').

$$A_i^* = \delta_0 + \delta_1 Farmsize_i + \delta_2 Agehead_i + \delta_3 Genderhead_i + \delta_4 Males_i + \delta_5 Females_i + \delta_6 Educationhead_i + u_i \tag{14}$$

To be in line with the rest of the analysis in sections 2 and 3 in the main part of the paper, to estimate equation (14), assets per adult were used as the left hand side variable. This equation was estimated using Ordinary Least Squares, and the results are reported in table 1 in the main text. It can be seen that endowments in the form of farm land and male labour availability add positively and significantly to the value of assets per adult. Female adults on the contrary reduce the number of assets per adult kept. The latter result may be understood as referring to a lower return to labour by females than by males: the composition of the adult labour endowment matters for the extent of the

[8]Some problems exist with this specification. First, it assumes that preferences are similar across households. The extent of patience or impatience on the part of the household, measured by the rate of time preference δ (see equation (1) in the main text) is important in determining at what level of liquid means the household will start savings. Implicitly it is assumed to be constant across households in this paper. Further, the access to assets and the return on assets is also assumed to be the same across households. For a discussion and an attempt to deal with this problem when modelling assets, see Dercon (1993).

surpluses generated and therefore for asset accumulation. From the regression it can also be seen that measures of the 'quality' of the labour force, relating to age, gender and education of the household head do not add significantly. This may suggest that the quality of the total labour available in the household and not just that of the household head will be important. Better measures of the quality of labour available were unfortunately not collected in the survey.

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