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**Dynamic Portfolio Management Under Risk and
Subsistence Constraints in Developing Countries**

By

**Frederic Zimmerman and
Michael R. Carter**

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Dynamic Portfolio Management Under Risk and Subsistence Constraints in Developing Countries

Frederic Zimmerman and Michael R. Carter[*]

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ABSTRACT—

This paper presents a model that endogenizes asset-based risk-coping in an environment of unmediated risk and subsistence constraints. It uses an individually-rational, stochastic dynamic programming model to explore intertemporal portfolio decisions in an environment in which both yield risk and endogenous asset-price risk exist. The results show that agents pursue one of three distinct investment strategies, depending on their initial wealth levels. Agents who are too poor to support subsistence at a sustainable level eventually stock out, driving their asset base to zero. Agents who have more than a certain threshhold level of highly productive assets continue to accumulate those assets. Agents who fall somewhere in between, with an intermediate level of assets, adjust their portfolios to maintain both their yield risk and their price risk at a tolerable level.

The paper compares the portfolio management strategies of the intermediate group ("poor") and the wealthy group. It is found that the poor pursue strategies that involve smoother income but less smooth consumption than is the case for the wealthy. This result at once provides a theoretical explanation for recent empirical findings of a positive correlation between wealth and rates of return on portfolios in South India, and at the same time suggests that a common explanation for this phenomenon—that of decreasing relative risk aversion—is probably inaccurate.

1. Introduction

This paper models portfolio management among heterogeneously endowed rural agents facing subsistence constraints and risk to both asset yields and asset prices. This risk is assumed to be less than fully mediable by either formal markets or informal risk-sharing, so that agents must use both the composition and levels of portfolios to cope with their residual risk autonomously. Such a situation arises frequently in developing countries, particularly among poor and remote populations. The paper's contribution is to complement a considerable body of research on the use of portfolio adjustments in coping with risk by extending the analysis to allow for agent heterogeneity. The model accordingly sheds light from a theoretical perspective on the role of wealth levels in determining portfolio composition and portfolio management, and, by extension, returns on portfolios. This theoretical insight is important for understanding poverty, accumulation and poverty policy in developing countries.

A great deal of research has in recent years been brought to bear on the issues of income- and consumption-smoothing in the risky environments of developing countries. This research has in general shown that most agents in most situations have smoother consumption than income, and smoother income that what

a risk-neutral agent would achieve. (See Christina Paxson, 1992 and 1993; Angus Deaton, 1991; Christopher Udry, 1994 and 1995; Susan Lund, 1996. See also the reviews by Jonathan Morduch, 1995; and Anjini Kochar, 1995). Research on the risk-coping strategies of households is important for determining the value and appropriate form for risk management policy. If households are sufficiently able to smooth consumption ex-post of income shocks, then various income-stabilization policies may not be a high priority for beneficiaries. If, on the other hand, consumption-smoothing is either not easily achieved, or achieved mainly by smoothing income, then policies that reduce risk or attenuate its impact may indeed be important.

In an important recent article, Deaton (1991) shows that households facing borrowing constraints are able to smooth income fairly successfully with relatively low average holdings of assets. His intertemporal model incorporates stochastic labor income and a single, non-productive asset (such as grain or cash). For a reasonable set of parameters, the numerical solution to this model suggests that households holding an average stock of assets equal to the standard deviation of income are able to reduce the standard deviation of consumption to half that of income.

When the storage asset is also a productive asset, as for Mark R. Rosenzweig and Kenneth I. Wolpin (1993), who model the accumulation of bullocks in South India, households are similarly able to buffer consumption. Unlike the Deaton case, however, the fact that the buffer asset is also a productive asset means that smoothing consumption has adverse implications for production efficiency. This buffering now comes at a cost: borrowing-constrained households in the Rosenzweig and Wolpin simulation hold on average about half of the optimal level of bullocks.

Rosenzweig and Hans P. Binswanger (1993) complement these theoretical studies by an empirical study of South India, in which they explore how households allocate investments across a variety of assets distinguished by both the mean and the variance of their yields. Furthermore, and in contrast to the approaches of Deaton and of Rosenzweig and Wolpin, Rosenzweig and Binswanger explicitly examine how households with different wealth levels solve the mean-variance trade-off differently. Importantly, they find that poorer households tend to pursue portfolio strategies that emphasize assets with lower risk and lower return, while wealthier households choose portfolios more weighted toward higher risk and higher return assets.

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The discovery of different solutions by differently-endowed households to the same asset management problem raises two important issues: First, what is the theoretical justification for the multiple solutions to the portfolio-management problem as explored by Rosenzweig and Binswanger? And second, if the multiple solutions indeed exist and indeed are related to differences in wealth levels, might there be a "poverty trap" in which poorer households experience lower *rates* of return on their overall portfolio, to such an extent that their accumulation incentives are severely blunted? Answering these questions is the task of this paper. Doing so involves two innovations on the literature. First, agents facing the portfolio management problem are endowed with differing levels of wealth so that the dependence of the solution on wealth level can be explicitly considered. Second, asset prices covary endogenously with a local stochastic production shock–and hence with the need to use assets to buffer consumption.

As regards the importance of agent heterogeneity, several possibilities exist to explain the importance of wealth to portfolio management. First, access to markets–particularly goods and financial markets–could be stratified by wealth, so that a given level of consumption-smoothing could be more costly to obtain for poorer people than for wealthier people. However, although the stratified

access issue is an important one for production, it has not yet been spelled out how it would distort consumption-smoothing efforts, particularly when so much of consumption-smoothing in the developing world (e.g., self-storage or reciprocal claims) is premised on not transacting in local formal markets. Second, agents could have decreasing relative risk aversion. This explanation, however, is more mathematical than behavioral, and its reliance on unobservable properties of the utility function is unsatisfying. Thirdly, risk aversion among the very poor might not be so much about consumption-smoothing over a concave utility function as about the possibility of losing labor power–either through ill health or death–when consumption dips below a certain critical level. In this case, an intertemporal non-separability between consumption and production develops that exacerbates the utility penalty of low consumption. Several economists have written about this non-separability (Jere R. Behrman, 1990; Debraj Ray and Peter Streufert, 1993; Partha Dasgupta and Ray, 1990; Christopher Bliss and Nicholas Stern, 1978), but not explicitly in the context of its implications for consumption-smoothing and portfolio adjustment.

This third approach is adopted in this paper. Specifically, nutritional work suggests that very low levels of consumption result in lost labor power, and there-

fore lost ability to gain income in the future. (See Behrman and Duncan Thomas (1995) and the citations in Giovanni Andrea Cornia (1989)). Because low current consumption increases both the utility loss in the present as well as the probability of utility loss in the future, households close to the zone for which low consumption induces a future productivity problem will feel the loss of an adverse shock both because of current income and through (the discounted present value of) future income. Wealthier households, away from the subsistence danger zone, will feel an adverse shock only on current income, and not on future income. This distinction will make poorer households behave in ways that appear to be more risk-averse than for wealthier households even though the underlying utility parameters are the same for everyone.

Households in the developing world are exposed to both covariate and idiosyncratic risk. While opinions in the literature vary as to the relative importance of covariate versus idiosyncratic risk, a point that has not been stressed frequently enough is that the distinction between covariate and idiosyncratic risk has an important endogenous or at least policy-sensitive element. What is important is the extent to which a shock affects in similar ways many of the members of a given risk-pool. That risk-pool may be defined by social group for informal risk-sharing

arrangements, or by a market, for asset-based risk coping. The high degree of risk covariation in Africa reflects not just common dependence on rainfall shock, for example, but also the fact of a rain-fed, agrarian environment, with relatively isolated markets due to poor infrastructure and an undiversified economy. (See Michael R. Carter, forthcoming; Udry, 1994; Binswanger, John McIntire and Udry, 1989.) Rosenzweig and Wolpin (1993) assume they are dealing with idiosyncratic risk by assuming that their bullocks can costlessly move to markets unaffected by local risk outcomes. That assumption is dropped in this analysis. Local risk outcomes accordingly affect local asset prices. Such a dependence is both frequently observed in developing-world settings and also important to how households manage assets to protect themselves from risk.

The paper is organized as follows. Section 2 presents a dynamic, stochastic model of asset accumulation. This model incorporates three features that are characteristic of developing country environments, and that drive some of the results discussed below. These features are unmediated risk, subsistence constraints and endogenous asset prices. The model is first developed and presented analytically. Because of the sensitivity of the qualitative results to specific functional forms and levels of risk, the model is solved numerically using data from West Africa.

Results of the model are presented in Section 3. Three stable attractor points in asset space emerge as optimal portfolio strategies. One of these strategies is a grain-rich and land-poor strategy pursued by less-wealthy agents. Another is a land-rich and grain-poor strategy pursued by wealthy agents. The poorer agents are found to have smoother income than the wealthy agents, but—importantly— less smooth consumption. Section 4 briefly describes how agents move from their initial endowments toward the stable attractor points. Conclusions, including suggestions for further work in this area and some tentative conclusions for policy, are presented in the final section.

2. A Dynamic, Stochastic Model of Asset Accumulation Under Risk and Subsistence Constraints.

Several features are important to an understanding of asset accumulation among poorly-endowed agents in developing countries. These features include pervasive and unmediated risk, the existence of sometimes binding subsistence constraints, and endogenous asset prices that are frequently correlated with aggregate, or village-level, risk outcomes. (See Rosenzweig and Binswanger, 1993; Binswanger, McIntyre and Udry, 1989; Thomas Reardon, 1992; Reardon, Peter Matlon and

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Christopher Delgado, 1989; Rosenzweig and Wolpin, 1993; Carter, 1995; Gerhard Glomm and Michael G. Palumbo, 1993; Mukesh Eswaran and Ashok Kotwal, 1990). In such environments, the presence of binding consumption constraints is an important determinant of inter-temporal optimization (Glomm and Palumbo, 1993; Dasgupta and Ray, 1986; Ray and Streufert, 1993).

The consumption-productivity link is captured by specifying a minimum subsistence level of consumption. Agents who fall below this subsistence level receive zero utility for that period and for every period thereafter. Although this representation is not sophisticated, it does capture the most important intertemporal utility implications of extremely low consumption levels[1].

Formally, the utility of consumption in period t (c_t) is defined as:

$$u(c_t) = \begin{cases} (c_t)^\varepsilon & if \ c_t \geq R_0 \ and \ c_s \geq R_0 \quad \forall s \in \{1, 2, ...t - 1\} \\ 0 & otherwise. \end{cases} \quad (2.1)$$

Here R_0 is the subsistence minimum, and ε is the utility curvature parameter. Note that it is a formal convenience to define the non-separability across periods

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[1]This specification is similar to that of Rosenzweig and Wolpin (1993).

in terms of utility, instead of in terms of production. One could as easily define y_t equal to zero in periods following (by any distance) zero-consumption periods. Zero-consumption under such a specification would have similar inter-temporal implications to the specification articulated here, and the results of the analysis would be substantially the same[2].

Other features of the model follow the standard, infinite-horizon utility maximization problem. There is one consumption good (c), and two assets: a risk-free but low return asset (grain, for example) and a risky, but higher-return asset (land, say, or livestock).

Assets in this setting are distinguished by three properties: their yield-risk; their asset-price risk; and their mean rate of return. Clearly, portfolio management involves a trade-off across all of these properties. In rural areas of the developing world, properties of assets in these three dimensions tend to coincide, so that high-return assets also tend to be those assets with high levels of variance in their returns and high levels of negative covariance between their prices and any consumable good price[3]. One implication of such an environment is that a

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[2]As represented below, however, the modeling technique would be greatly complicated by having zero-consumption imply only zero income–rather than zero utility–in future periods.

[3]This coincidence of properties arises because of two features. First, there are very few assets whose returns are negatively correlated with each other, so that the mean-variance trade-off is the primary criterion for choosing assets. Put differently, there are no reasons to accept any

two-asset model adequately captures the full set of portfolio choices available to households. The assets could be anything, but they can usefully be thought of and will henceforth be referred to as "grain" (represented by M, and a low price risk, low return, low yield risk asset) and "land" (represented by T, and a high price risk, high return, high yield risk asset). This representation follows, and is a simplification of, the Rosenzweig and Binswanger (1993) empirical exploration.

A number of non-portfolio methods exists to manage risk, from social sharing schemes to formal insurance. (See Stephen Coate and Martin Ravallion, 1993; Caterine Coquéry-Vidrovitch, 1985; Marcel Fafchamps, 1992; Jean-Philippe Platteau, 1989; Carter, 1995; Reardon, Delgado and Matlon, 1992.) However none of these methods can eliminate all risk, and the nearly universal existence of portfolio methods (including grain storage) speaks to the need for individual risk management The risk representations of this model have been carefully parameterized to reflect exposure to risk *ex-post* of the effects of institutions such as social reciprocity, labor diversification, and optimal crop management.

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asset that is stochastically dominated by another asset, and therefore, all assets tend to fall along the mean-variance frontier. Second, consumption assets are not generally productive, and productive assets are not generally consumable. Therefore, assets either have a high return or have low price risk (i.e., in the conversion to food), but rarely both.

2.1. The Household Utility-maximization Problem.

The model follows the lines of a standard dynamic programming model. Production is a simple function that represents output as a diminishing-returns function of land. This specification follows the literature that finds an inverse farm-size/farm-productivity relationship.

$$F(T_t, \theta_{it}, \theta_{vt}) = \theta_{it}\theta_{vt}D \cdot (T_t)^{\sigma} \tag{2.2}$$

Here T_t is the household's land holding in period t; D is a land productivity parameter; and σ is an output elasticity parameter which represents decreasing returns.

Production risk is the product of two distinct shocks: an idiosyncratic shock, θ_i, which captures those risks which affect household "i" only, such as health problems during the work season, or localized flooding or erosion; and a village-level shock, θ_v, that represents primarily weather-related shocks that affect an entire village. In a model of consumption and asset accumulation, both covariate and non-covariate risks are important to the process of balancing short-term consumption vs. long-term investment. Covariate shocks drive both asset price risk and yield risk, whereas idiosyncratic shocks drive yield risks alone.

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The budget constraint which households face is:

$$c_t \leq F(T_t, \theta_{it}, \theta_{vt}) + \mu M_t - P_{Tt}(T_{t+1} - T_t) - (M_{t+1} - M_t) \qquad (2.3)$$

Here M_t is the household's holding of the non-productive asset ("grain") in period t; and μ is the rate of return on grain. P_{Tt} is the price of land in period t. Units are defined so that the prices of grain and the consumption good are equal and numéraires.

Agent heterogeneity can be defined both over total wealth level and over the mix of assets. The budget constraint accordingly reflects possibilities of both consumption versus investment choices as well as portfolio composition choices.

Agents maximize the present value of their utility over the infinite horizon. The function is additively separable, with a fixed discount parameter:

$$\max_{\{\underline{c}_0, \underline{T}_1, \underline{M}_1\}} E_0 \left\{ \sum_{t=0}^{\infty} \delta^t u(c_t) | F(P_{Tt}, \theta_{vt} | \Omega_t) \right\} \qquad (2.4)$$

$$\underline{c}_s = \{c_s, c_{s+1}, c_{s+2}, ...\}$$

$$\underline{T}_s = \{T_s, T_{s+1}, T_{s+2}, ...\}$$

$$\underline{M}_s = \{M_s, M_{s+1}, M_{s+2}, ...\}$$

Subject to (1), (2) & (3) and given T_0, M_0, θ_{i0}, θ_{v0}.

Here δ is the discount factor. $F(P_{Tt}, \theta_{vt}|\Omega_t)$ is the joint distribution of the asset price and the covariate shock. This joint distribution will depend on the land distribution at any given point in time. Agents do not know what this joint distribution will be, but will have rational expectations about it. Because of the possibility of major structural shifts in the distribution of assets over time, it is important to the integrity of the model that asset prices be fully endogenous.

The magnitude of this covariance depends on several features of the local economy. First, the covariance will be greater the more people are forced—given an adverse shock—to alienate assets to buffer consumption. In general, this will depend on how low average consumable asset stocks are relative to the variation of income. Second, it will depend on the price elasticity of demand for land in the economy. Finally, it will depend on the relative size of the contribution of covariate (as opposed to idiosyncratic) shocks in overall income shocks. In this model, only the third factor is exogenous, and the first two arise out of the endogenous intertemporal choices made by households. Since the covariance itself is one feature these households take into consideration in making such choices, the model will look for a fixed point in the covariation.

The discussion of risk underscores the importance of an intertemporal model. Not only is portfolio choice (including the possibility of food storage) inherently intertemporal, but agents make their decisions with rational understanding of the process of asset price formation, and in particular of asset price risk.

2.2. The Dynamic Programming Model

Models of intertemporal optimizing are distinguished according to whether the problem is separable in time. Time-inseparable models must be solved simultaneously for all time periods, and for that reason, the complexity of the problem grows exponentially with the number of time periods involved. Time-inseparable models of many periods are therefore generally not feasible. On the other hand, because time-separable models can be solved period-by-period, the complexity of the problem grows only arithmetically with the number of periods involved. For a model of asset accumulation in which risk interacts with long-term shifts in the distribution of assets through endogenous asset-price risk, a model of several periods is required. Accordingly, a computationally tractable, time-inseparable model is not available. Yet, as was presented in the Introduction, such a model is exactly what is required to adequately represent the intertemporal non-separability

of production and consumption that drives the reluctance of the poor to invest in risky assets. The challenge, therefore, is to articulate a model that has the important features of time-inseparability, yet the computational tractability of a time-separable model.

The simplest way of accomplishing this is to add a state variable that captures the important effects of past actions on the structure of current (and future) problems. Define this state variable (L_s) as zero if the agent has had zero-consumption in the past (i.e., before period s), and one if not. Although the complexity of even time-separable models grows exponentially with the number of state variables, adding a zero-one variable only doubles the complexity of the model. Note that it is in part the irreversibility of $L_{s+1} = 0$ that makes the complexity of the problem manageable.

The key trade-off to be captured in this model is that between present consumption and asset accumulation for future consumption. Capturing this trade-off is now straightforward because the infinite-horizon maximization problem (2.4) is additively separable in time, breaking into two parts representing present and future consumption. Because the state variable L reflects the intertemporal dependence of future utility on past consumption, it emerges as the problem (2.4)

is broken apart:

$$
\max_{\{c_0, \underline{T}_1, \underline{M}_1\}} \quad E_0 \left\{ \sum_{t=0}^{\infty} \delta^t u(c_t) \, | F(P_{Tt}, \theta_{vt} | \Omega_t) \right\} = \tag{2.5}
$$

$$
\max_{\{c_o, T_1, M_1, L_1\}} \left\{ u(c_0) + \delta \, L_1 \cdot E_0 \left\{ \max_{\{c_1, \underline{T}_2, \underline{M}_2, \underline{L}_2\}} \left\{ \sum_{t=1}^{\infty} \delta^t u(c_t) \, | F(P_{Tt}, \theta_{vt} | \Omega_t) \right\} \right\} \right\}
$$

$$
given \quad T_0, M_0, \theta_{i0}, \theta_{v0};
$$

The value of current consumption is reflected in the first part of equation 2.5, while the value of foregoing current consumption for the sake of investment is reflected in the second part of equation 2.5.

Since the second part of 2.5 can be considered the value of the problem in the future, a value function ($J(T, M, L)$) can be defined:

$$
J^*(T_0, M_0, L_0) \equiv L_0 \cdot E_0 \left\{ \max_{\{c_0, \underline{T}_1, \underline{M}_1, \underline{L}_1\}} \sum_{t=0}^{\infty} \delta^t u(c_t) \right\} \tag{2.6}
$$

Here $J^*(T_0, M_0, L_0)$ is the maximum expected discounted present value to be obtained from the asset combination (T_0, M_0) and the state variable L_0. Besides being defined over the domain of land and grain stocks, the true value function depends on all the functional parameters of the model, including the distributions

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of θ_i, θ_v. (Because the true value function expresses expected value, it does not depend on particular realizations of θ_{it}, θ_{vt}.) For the sake of simplicity, notation reflecting the dependence of the value function on the joint distribution of asset prices and covariate shocks has been suppressed.

Equation 2.5 then is rewritten:

$$\max_{\{c_0, T_1, M_1, L_1\}} \{u(c_0) + \delta J^*(T_1, M_1, L_1)\} \tag{2.7}$$

$$for \ t \ = \ 0 \ \ and \ \ given \ \ T_0, \ M_0, \ \theta_{i0}, \ \theta_{v0}.$$

If the true value function J* were known, then solving the agents' infinite-horizon problem would be straightforward. Agents allocate available resources in any period to consumption, land investment and grain investment, and thereby also determine L. The portfolio choice problem is solved by setting:

$$\frac{1}{P_{Ts}} J_1^*(T_{s+1}, M_{s+1}, L_{s+1}) = J_2^*(T_{s+1}, M_{s+1}, L_{s+1}) \tag{2.8}$$

The consumption-investment trade-off is solved by setting:

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$$u'(c_s) = \delta \frac{1}{P_{Ts}} J_1^*(T_{s+1}, M_{s+1}, L_{s+1}) \qquad (= \delta J_2^*(T_{s+1}, M_{s+1}, L_{s+1})) \qquad (2.9)$$

where J_i^* is the first derivative of J^* with respect to the ith argument.

Note that 2.8 and 2.9 can be equated in one of two ways. If consumption exceeds the subsistence minimum, so that $L_{s+1} = 1$, then the problem is straightforward. If $L_{s+1} = 0$, however, then all of the derivatives, u', J' are zero (except at the discontinuous point where $c_s = R_0$). Equations 2.8 and 2.9 still hold, but are zero on both sides. Agents compare these two solutions ($L_{s+1} = 1$ and $L_{s+1} = 0$) to see which of them yields greater utility.

Bearing in mind that J depends on the household's own assets, as well as the asset holding of all other households in the economy through their effects on prices and hence price expectations, a closed-form solution to the problem is not attainable. Accordingly, the model is simulated, parameterized to data to Burkina Faso. Following Deaton (1991), numerical methods were then employed to calculate the true value function. Details of this process are provided in Appendix B.

2.3. The Data.

Data were collected in three regions of Burkina Faso from 1981-1985 by the International Crop Research Institute of the Semi-Arid Tropics (ICRISAT). The survey encompassed six sample villages from three agro-climatically distinct regions of Burkina Faso, and is one of the largest and most comprehensive data-sets on West African agricultural production. These data were used to parameterize the initial distributions of the assets, the production function, and the risk structure. This parameterization is discussed in Appendix A.

The parameterization of the risk structure is based on empirical estimates of risk in Burkina Faso by Carter (1995), and is presented in Appendix A. This risk parameterization takes account of the fact that many forms of risk-mediation exist. Specifically, using the same data-set, Reardon, Delgado and Matlon (1992) find that the coefficients of variation of crop yields are 45%, 52%, and 67% for three regions of Burkina Faso. Households attempt to mediate this risk in two principal ways, viz., by pooling income and by diversifying sources of labor income. Ex-post of these two risk-coping mechanisms, the coefficients of variation are 12%, 49% and 53% for the three regions. Risk in this model is parameterized to have a coefficient of variation (of crop yields) of 25%. The level of risk in this model

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thus reflects very conservative assumptions about unmediable risk.

For the purposes of numerical solution a stylized village of 100 households (a typical number for Burkina Faso) was created, within which a land market cleared endogenously, generating a land price. Each household was endowed with land and grain at the beginning of the simulation according to empirically observed asset distributions in Burkina Faso. Each period of the simulation was characterized by a production cycle—in which households realized production according to (3)—and an asset-adjustment and consumption cycle—in which households solved the optimization problem (2) by allocating available resources to consumption and to land and grain accumulation or decumulation. This simulation was repeated for 20 periods, thereby creating a time series of endogenous prices.

2.4. Rational Expectations.

Rational expectations were achieved in the model by an iterative method. Agents were first endowed with a likely trajectory for prices and then the simulation was run for 20 periods to generate new price outcomes. These new price outcomes (or rather the price distributions which they were estimated to represent) then formed the basis for a second run of the entire 20-period simulation. This second

run generated in its turn new prices, whose estimated distributions formed the basis of a third run, and so on. This process was pursued until the actual prices realized in the simulation differed by no more than 2% from the price expectations which had generated the result. This process converged after about 10-15 runs of the simulation.

2.5. Parameter-Sensitivity Testing.

In the analyses that follow, the parameters specified in Appendix A were varied by 5-10% of their values, with no change to the substance of the results. (Interestingly, the results are highly sensitive to expectations over prices and the price-shock covariances, both of which are of course endogenous. Even small errors of 3% on average in price expectations affected the results in important ways).

3. Optimal Portfolio Management.

Optimal portfolio management strategies consist of the solutions to two distinct questions: What is the optimal way of using assets to buffer consumption against income risk in the steady-state, that is, given a constant mean level of assets

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and its concomitant stationary income process? And, what is the optimal way of moving through asset space from the starting endowment to the steady-state? This section answers the question of asset management in the steady state; the next section takes up the issue of the dynamics of reaching the steady-state.

Nothing about the model suggests that all agents will pursue the same portfolio management strategy. Indeed, given the presence of a fixed subsistence constraint and varying wealth levels, one would expect that differently endowed agents would find different portfolio combinations to be optimal. Wealthier agents are farther from the subsistence crisis line, and could be expected to be willing to bear more risk than poorer agents.

3.1. Steady-State Asset Management at Stable Attractor Points.

From a variety of starting positions, agents gravitate toward one of just three equilibrium strategies (including the (0,0) point). Figures 3.1 and 3.2 show income and consumption time-series for poor and for rich households at their stable attractor points. For agents who start the simulation with less than about 4 has. of land, a relatively grain-intensive point of (1.36 land; 7793 grain) is reached. for households who start the simulation with more than about 4 has. of land, a

relatively land-intensive point of (9.00 land; 1344 grain) is reached. For the poor household, there is no movement in land away from this stable point, and their income is accordingly stationary. Such an experience is typical of the households at this attractor point. Households at the more land-intensive stable point do have some movement away from the point in land space, but their portfolio tends to return to the stable point. This experience is also typical of the households at this attractor point.

Table 3.1 provides additional detail for these two optimal portfolios. Two important features of optimal portfolio strategies at the two different attractor points emerge from this table. First, although the maximum potential expected rate of return (ROR) is higher for poor agents (reflecting the decreasing returns to land), their realized ROR is much lower than for wealthy agents. The cost of risk-coping is about 25% for poor households, as against only 1% for rich households. This result is very stark, and it highlights the importance to the poor of smooth consumption. It is also in line with results from Rosenzweig and Wolpin (1993), who find investment in Bullocks to be only about half what it would be in a risk-free world. This result also sheds light on the empirical findings of Rosenzweig and Binswanger (1993), who find that the poor forego more potential income due
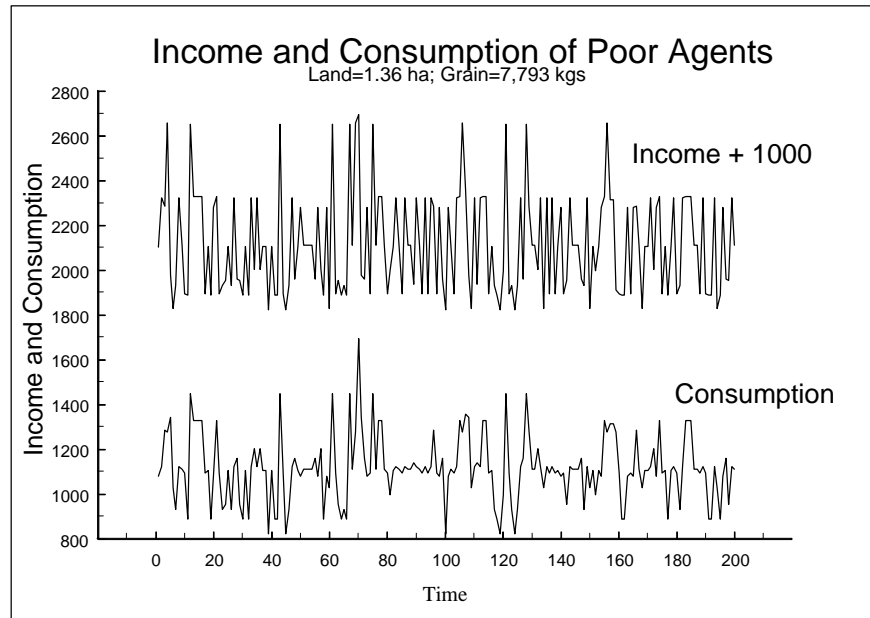
Figure 3.1: Income and Consumption of Poor Agents

to a safer investment strategy than do the rich. Moreover, the order of magnitude

of the loss to the poor is the same.

Second, both income and consumption are smoother for the poor than for

the rich, as would be expected. but although income for the poor is very much

smoother (the standard deviation of income for the poor is about one-sixth that

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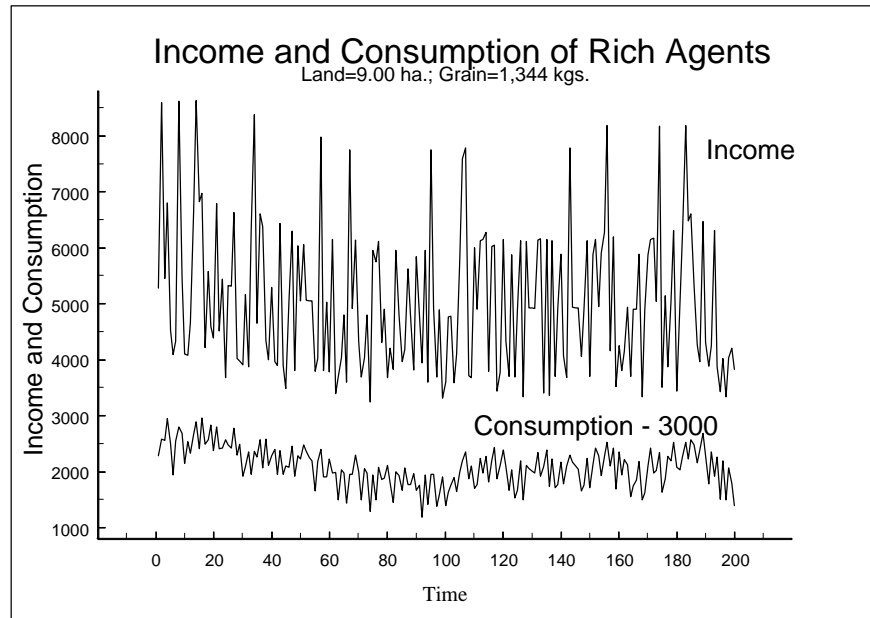
Figure 3.2: Income and Consumption of Rich Agents

of the rich), consumption for the poor is only somewhat smoother (the standard deviation of consumption for the poor is about one-half that of the rich). Indeed, adjusted for average consumption levels, the poor have *more variable* consumption streams than the rich, even though their income streams are more stable. The poor in effect are using consumption to buffer assets. In addition to Rosenzweig

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	"Poor"	"Rich"
	Land=1.36 has.	Land=9.00 has.
	Grain=7793 kgs.	Grain=1344 kgs.
1. Max. Expected ROR	0.0795	0.0743
2. CV of Max Exp{ROR} Portfolio	25.041 %	25.041 %
3. Mean ROR on Actual Portfolio	0.0599	0.0735
4. Cost of Risk-Coping (%)	24.65 %	1.07 %
5. Std. Dev. Of Income	222	1280
6. Std. Dev. Of Consumption	146	348
7. CV of Income	19.9 %	25.4 %
8. CV of Consumption	13.1 %	6.9 %
9. CV of Land Stock	0.53 %	4.5 %
10. CV of Grain Stock	1.28 %	63.3 %

(CV=coefficient of variation. Line 1 is what a risk-neutral fund manager could achieve.)

Table 3.1: Features of Optimal Portfolios

and Binswanger (1993), several writers have noted ways in which the dynamic implications of poverty differ according to asset levels of households. Michael Lipton (1993) has written of a "Micawber threshold," below which it is difficult for agents ever to accumulate assets. Reardon and Stephen A. Vosti (1995) write of asset poverty lines. In all instances, what is at stake is rates of return on portfolio that are positively correlated with wealth levels.

Although this result seems at first counter-intuitive, it is of course perfectly consistent with dynamic utility maximization. It is not, however, consistent with consumption-smoothing behavior, which is often assumed to be the axiomatic objective of dynamic optimizers facing risk. This distinction suggests that lit-

eratures emphasis on consumption-smoothing might not be capturing the full dynamic story of risk management–especially for poor agents.

Note that this result is incompatible with decreasing relative risk-aversion, which is frequently invoked to explain wealth-related differences in portfolio composition. Instead, the intertemporal non-separability drives the poor both to smooth income more than do the rich, and to take less of this stability in the form of consumption (and more in the form of protecting assets) than do the rich. Both of these theoretical explanations are difficult or impossible to observe directly. These results suggest a simple and direct empirical test of the competing explanations: If the poor simultaneously have smoother income and more variable consumption than the rich, then the appeal to decreasing risk-aversion in explaining wealth-dependent portfolios can be rejected.

4. Evolution of Household Asset Holdings Toward Optimal Portfolio Compositions.

The preceding discussion has described how heterogeneously endowed agents use assets to buffer risk around stable attractor points in asset space. Also of interest is the issue of the how agents move through asset space from their initial endowments

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to such points.

One situation in which a dynamic treatment of portfolio evolution would be particularly important is when institutions change, causing agents to have to rapidly adjust their strategies. Such an institutional change has occurred recently in West Africa as social sharing schemes have lost their effectiveness and importance. Households have therefore been thrust back onto their own, private risk-coping abilities. Part of such a strategy involves individually accumulating more grain than would have been needed under communal risk-sharing. Yet acquiring this grain can be difficult under given the non-fungibility of one of the main productive assets, land. This model shows how households would change their portfolio strategy when faced with an abrupt change in their individual exposure to risk as well as a change in the fungibility of their assets. The numerical results of this section are important, inasmuch as they show that each of these attractor points draw agents from meaningfully large portions of the asset space. These results suggest that multiple optimal portfolio strategies are of sufficient theoretical importance to warrant further empirical exploration.

Figure 4.1 shows the actual accumulation trajectories of agents over the course of the entire simulation (i.e., from periods 0 to 35). As can be seen, the trajectories

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of all of the agents can be grouped into three classes of movements. First, agents in the lower left portion of the asset space stock out over the course of the simulation. Note that even agents who begin the simulation with no land but with grain stocks several times the subsistence minimum eventually draw them down and stock out. Second, agents who begin the simulation with between 1-1/2 and 4 hectares of land readjust their portfolios in the direction of a greater grain-to-land ratio. Here it should be noted that in so doing these agents reduce the average rate of return on their overall asset portfolio, but also reduce its yield riskiness and increase its fungibility. Finally, agents who begin the simulation with more than 4 hectares of land increase their land stocks. Significantly, these agents hold very low levels of grain stocks, as their production levels in even a bad year enable them to avoid a subsistence crisis. These agents experience risk aversion only in the standard, utility-curvature way.

4.1. Efficiency and Asset Transactions.

Several sorts of agent heterogeneity could generate differences in the shadow prices of an asset across agents, and hence engender an asset transaction. These differences—related to capital access, human capital, skill and risk—in general un-
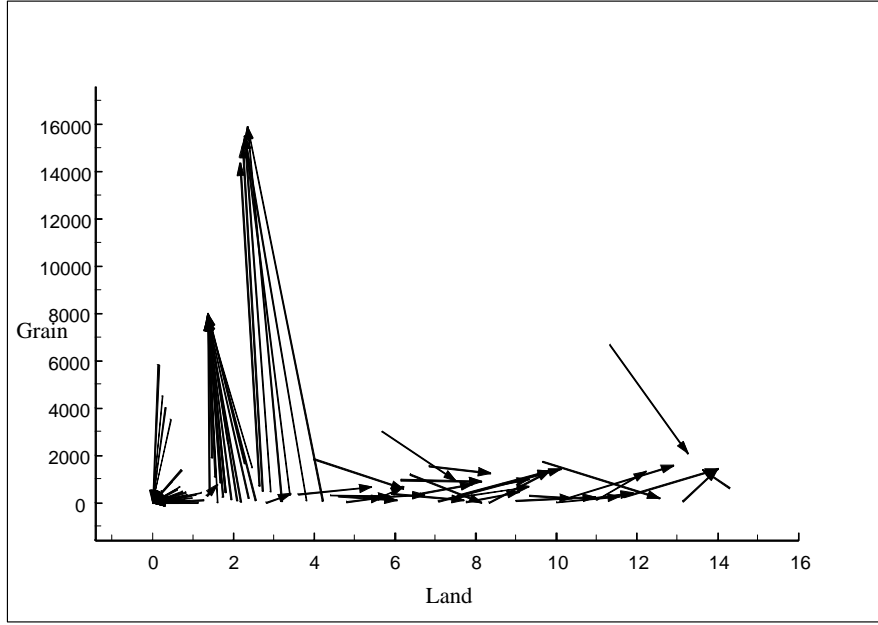
Figure 4.1: Evolution of Individual Portfolios

derlie a potential pareto improvement from an asset transaction that also implies

an increase in aggregate productivity. Risk is unique as a generator of heterogene-

ity in that it alone does not necessarily result in a demand for transactions which

enhance aggregate output. This odd feature of risk is due to the fact that house-

holds making asset accumulation decisions equate the ratio of present to future

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marginal utility of consumption to the ratio of the marginal productivity of the asset to its price (to within discounting and expectations operators). Transactions can therefore occur which, though pareto-improving, decrease aggregate output. In this model, land is not distributed in a fashion that maximizes aggregate output: The result portrayed in Figure 4.1 that agents with more than 4 hectares of land accumulate land despite the presence of decreasing returns to land provides evidence of just such a movement.

Table 1 provides fuller information on the characteristics of asset transactions in the simulation. As can be seen, the poorest agents, in the land holding size range of 1.5 to 4 hectares, decumulate assets over the course of the simulation, reflecting the stocking out phenomenon depicted in Figure 4.1. Note, however, that even among these agents fully 32% of transactions in the course of the entire simulation represent net increases in wealth. Clearly these agents are using asset transactions to buffer risk, even along the optimal path to stocking out. The agents in the wealthiest class (over 4 hectares) and the middle class (1.5 to 4 hectares) engage in the approximately equal numbers of transactions, with slightly greater emphasis on wealth-enhancing transactions.

Because some number of agents in the simulation are resorting to desperation

land sales that ultimately result in their stocking out, one might expect that the land price is low in the early period of the simulation. Indeed the land price (which is endogenous) rises steadily from a low of about 7000 in the early periods to a stable value around 9000 after about period 20. Because the low land price associated with the stocking out process might be considered an unreasonable epiphenomenon of the initial distribution (which includes some agents who have inviably low asset levels), results for the transactions are reported for periods 20 through 35–that is to say, after the shake-out has occurred and land prices have stabilized. Here the results are different than for the simulation as a whole in instructive ways. Transactions among the wealthy are almost evenly split among wealth-increasing, wealth-decreasing and wealth-neutral transactions. Because the wealthy are not net purchasers of land after period 20 but are over the course of the simulation, it must be that their accumulation comes during the period of low prices. The accumulation of land by the wealthy is therefore twinned with the process of stocking out among the poor.

	Full Simulation			After Period 20		
Land size:	0 - 1.5	1.5 - 4	> 4	0 - 1.5	1.5 - 4	> 4
1. Ratio of Buyers to sellers	0.11	1.02	2.78	0.08	0.09	1.36
2. Ratio of Grain accumulation to reductions	1.20	1.13	0.95	0.85	0.58	0.80
% of transactions in which						
3. wealth increases	32%	49%	42%	38%	16%	33%
4. wealth decreases	60%	32%	30%	62%	63%	36%
5. wealth changes by <100 kgs.	8%	19%	28%	0%	21%	31%

Table 4.1: Characteristics of Asset Transactions

5. Conclusions

This paper has presented a model that endogenizes asset-based risk-coping in an environment of unmediated risk and subsistence constraints. It has modeled individually rational, intertemporal portfolio decisions in an environment in which both yield risk and (endogenous) price risk exist. The results show that agents pursue one of three distinct investment strategies, depending on their initial wealth levels. Agents who are too poor to support subsistence at a sustainable level eventually stock out, driving their asset base to zero. Agents who have more than a certain threshold level of highly productive assets continue to accumulate those assets. Agents who fall somewhere in between, with an intermediate level of assets, adjust their portfolios to keep maintain both their yield risk and their price risk at a tolerable level.

Agents pursuing all three types of investment strategies also continually adjust their portfolios in response to transitory income shocks. The mid-level agents, however, complement this ex-post asset-based risk-coping with an additional ex-ante asset-based risk-coping. This ex-ante risk-coping is related at least in part to a desire to avoid driving their asset base below a sustainable level. The presence of a subsistence constraint therefore implies that risk-coping for these agents involves more than just smoothing consumption, but rather bespeaks a desire to protect asset levels.

Rosenzweig and Binswanger (1993) find empirically that agents willingness to abide profit risk is positively correlated with wealth. Two explanations present themselves for this phenomenon. It may be that for exogenous reasons poor agents have greater relative risk aversion in the utility function. Or, it may be that poor agents are less willing to abide risk because of a non-separability between current consumption and future productive capacity in the form of subsistence requirements. The simulation exercise in this paper provides some evidence for the subsistence-requirements explanation. It also suggests a simple empirical test. If, as suggested by the analysis of this paper, poor people smooth income more than rich people, but smooth consumption less (relative to their respective mean

levels), then the hypothesis of decreasing relative risk aversion can be rejected.

These results also provide some tentative suggestions for policy. First, the analysis here provides additional and novel support for *ex-post* consumption credit for low-income agents as a way not only of preventing desperation land or live-stock sales, but also of attenuating the tendency of the poor to pursue safer but lower-return asset portfolios ex-ante. Doing so would not only help with poverty alleviation objectives, but also with agricultural output objectives. Second, the role of risk in this analysis suggests that policies to reduce both the overall level of risk to which households are exposed, as well as policies to reduce the component of covariate risk in that overall level would be both equity- and efficiency-improving. Such programs would include insfrastructural investments in irrigation (to reduce yield risk) and in roads (to reduce asset price covariation), as well as in agri-cultural research (to reduce yield risk). Finally, the analysis here provides more support for the notion that markets for assets (including land) in general improve the ability of the poor and others to optimally cope with risk

A. Parameterization of the Model based on the ICRISAT Burkina Faso Data.

The Data from Burkina Faso were collected from 1981-1985 by the International Crop Research Institute of the Semi-Arid Tropics (ICRISAT). The survey encompassed six sample villages from three different agro-climatic regions of Burkina Faso, and is one of the largest and most comprehensive datasets collected on West African agricultural production. The survey results are well-suited for a basic parameterization of the model. The three regions are the Sahel, around Djibo, in the North; the Sudano-Sahel, around Yako; and the Guinea-Savanna, around Boromo. These regions vary considerably: Djibo is situated in a low-rainfall area where there are few trees and subsistence millet farming and itinerant cattle-herding dominate the agrarian economy. Boromo, by contrast, lies in the heart of the water-rich Burkinabè cotton belt, where corn, sorghum, and groundnuts are grown in relative abundance in addition to the cash crop, cotton. Yako lies between the other two, both geographically and in terms of its cropping system.

Table A.1 presents the land distributions for survey villages in the three re-

Hectares	Djibo	Yako	Boromo
0 - 0.5	.118	.007	.162
0.5 - 1.0	.059	.054	.147
1 - 2	.000	.101	.074
2 - 3	.059	.229	.103
3 - 5	.059	.322	.103
5 - 8	.176	.195	.147
8 - 12	.294	.067	.103
12 - 20	.235	.027	.147
> 20	.000	.000	.015

Table A.1: Distribution of Land per Household

Value of Livestock, Pensions, Cash(CFA Francs)	Proportion of households
0 - 5 000	.049
5 000 - 25 000	.146
25 000 - 50 000	.146
50 000 - 100 000	.110
100 000 - 150 000	.134
150 000 - 250 000	.146
250 000 - 500 000	.085
500 000 - 1 000 000	.098
> 1 000 000	.073

Table A.2: Distribution of Livestock and other Liquid Assets

gions, as well as for the simulation. Note that the Yako villages exhibit the most equitable distribution of land, whereas, the Djibo and Boromo villages are more unequal. The empirical distributions attempt to adjust for land quality differences where topography and placement (near or distant from the household compound) are concerned. Data on soil fertility were not recorded, and although different types of soil were recorded, there are so many soil types, and so few (relatively) fields, that a correlation between a soil type and its impact on land fertility was impossible to identify. It cannot be ruled out, therefore, that, especially in the north, the unequal land distribution is a reflection of the fact that some households have large amounts of relatively unproductive land, while others have smaller areas of highly productive land.

Table A.2 presents the distribution of livestock and other liquid assets used in the simulation, in kilogram-grain equivalents. Unfortunately, data on liquid assets was inadequately represented in the dataset. In particular, stored grain and cash savings were not recorded, and there were not sufficient observations on livestock holdings to permit the identification of a distribution of livestock holdings for each region separately. Moreover, Table A.2 represents only those households who hold signficant numbers of livestock, many of whom are herders.

Because of these problems, the simulation's liquid asset distribution was taken to be 1/20 the value of the distribution of livestock among those holding livestock. The justification is that the patterns of livestock holding among livestock holders would mirror–but be of greater magnitude–the patterns of grain holding among arable farmers.

The data show almost no correlation between land holdings and livestock. A simple OLS regression of livestock holdings on land had an R^2 of .002. Again, this lack of correlation may be due to the poor data on liquid asset holdings, rather than to any true independence in the asset portfolio. Nonetheless, it was an assumption that was maintained for the simulation.

The production parameter was estimated by computing mean yield. Again because of the variations in agroclimatic conditions across the different regions, these estimates were done separately for each region and crop. The mean yield for maize was considerably higher than that for sorghum and millet, doubtlessly because of the special conditions under which maize is so often grown (on small plots close to the house, benefiting from manure and even chemical fertilizers). Mean yields for sorghum and millet were about 1250 kg./ha. for the Boromo and Yako areas, and about 650 kg./ha. for the far North.

Labor hours hover around 2500 hrs. per household production unit. Taking this figure to represent the effort of four adult-equivalent workers per year, subsistence grain requirements can be estimated to average 1000 kg. per year. In addition, households need oil, vegetables, meat, eggs and spices. It is assumed that all of these components, together with about 200 kg. of grain requirements, can be met by non-farming income-generating opportunities.

Different household size was accounted for by normalizing land and livestock holdings to holdings per household member.

Carter (forthcoming) uses the same ICRISAT dataset to estimate production risk in both the Sahel region and the wetter Guinea-Savanna region. The risk parameterization of the model is a reasonable approximation of his findings.

B. Numerical Estimation of the True Value Function

The task of determining the true value function is as conceptually simple as it is computationally intense. First, a lower value function is posited, $J_o(T, M, L)$, which is a known underestimate of $J^*(T, M, L)$ over a grid of points in (T, M, L) space. For any given stochastic outcome $\theta_v \theta_i$, this J_o can then be updated for all

	Village-Level Shock: θ_v		
	Low	*Medium*	*High*
	θ_v=.75	θ_v=1	θ_v=1.25
	p=.3	p=.4	p=.3
Idiosyncratic shock: θ_i			
	θ_i=.9	θ_i=.8	θ_i=.7
Low: p=.2	$\theta_i\theta_v = .675$	$\theta_i\theta_v = .8$	$\theta_i\theta_v = .875$
	$p_{cell} = .06$	$p_{cell} = .08$	$p_{cell} = .06$
	θ_i=1	θ_i=1	θ_i=1
Medium: p=.6	$\theta_i\theta_v = .75$	$\theta_i\theta_v = 1$	$\theta_i\theta_v = 1.25$
	$p_{cell} = .18$	$p_{cell} = .24$	$p_{cell} = .18$
	θ_i=1.1	θ_i=1.2	θ_i=1.3
High: p=.2	$\theta_i\theta_v = .825$	$\theta_i\theta_v = 1.2$	$\theta_i\theta_v = 1.625$
	$p_{cell} = .06$	$p_{cell} = .08$	$p_{cell} = .06$

Table A.3: Risk Structure

values of T and M by applying Bellman's operator:

$$\tilde{J}_o(T., M., L. \,|\theta_i.\theta_v., F(\cdot)) = \max_{\{c., T_+, M_+, L_+\}} \{u(c.) + \delta J_o(T_+, M_+, L_+ \,|F(\cdot)\} \quad \text{(B.1)}$$

Here the notation $x.$ refers to the variable x in any given period, and the notation x_+ refers to the variable x in the subsequent period. Note that the form of the value function does not depend on time: the "o" subscript refers to the fact that J_o is an underestimate.

The conditional updated value function $\tilde{J}$ depends on $\theta_i.\cdot\theta_v.$ because the value of the constraints 2.3 and 2.2 depend on the specific realizations of the stochastic shocks. The objective of the iteration process is of course the unconditional value function, which expresses expected present value of utility from a given asset base. The unconditional value function is obtained by summing the conditional value functions over the set of stochastic shocks, and weighting by the appropriate

probabilities[4]:

$$\widetilde{J}_o(T, M, L \,|\, F(\cdot)) \quad = \tag{B.2}$$

$$\sum_{n=1}^{3} \sum_{m=1}^{3} \widetilde{J}_o(T, M, L \,|\, \theta_{in}\theta_{vm}, F(\cdot)) \cdot \Pr(\theta_i \quad = \quad \theta_{in} \,|\, \theta_v = \theta_{vm}) \cdot \Pr(\theta_v = \theta_{vm})$$

Since J_o is everywhere a (pointwise) underestimate of the true value function, and since it finds the maximum value—in terms of consumption and accumulation— over its domain, $\widetilde{J}_o$ will always be at least as large as J_o. By repeated applications of Bellman's operator, $\widetilde{J}_o$ eventually converges to the true value function, J^* (Streufert, 1990). However, since the $J_o(T, M, L)$ are numerical entities, it may not be obvious when they have converged to a limit. For this reason, Bellman's operator is also used to update an upper value function $J^o(T, M, L)$, a known overestimate of $J^*(T, M, L)$. Again, because J^o is (pointwise) higher than the true value function, successive applications of Bellman's operator will bring $\widetilde{J}^o$ down toward $J^*(T, M, L)$. When $\widetilde{J}_o(T, M, L)$ and $\widetilde{J}^o(T, M)$ differ by less than some epsilon for any (T, M, L) combination, then $J^*(T, M, L)$, which is always between the upper and lower value functions, has been identified to within that

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[4]Mathematically, summing across appropriately weighted stochastic outcomes is no different than summing across appropriately discounted time periods.

epsilon.

For this search for a fixed point in value function space to yield the true value function with certainty, the utility function and the production function must together constitute a dynamic problem that is biconvergent. In essence, upper-convergence means that if the largest feasible consumption possibilities are pushed ever further into the future, they matter ever less to present utility. Lower-convergence means that as the lowest feasible consumption possibilities are pushed ever further into the future, they would matter less and less. Upper-convergence and lower-convergence together constitute biconvergence (see Streufert, 1990). Biconvergence guarantees that the transversality condition is met, and that a solution to Koopmans' equation is the same as a solution to the infinite horizon utility maximization problem (i.e., that equation B.1 holds). The proof of biconvergence is straightforward, and is presented formally in Frederic Zimmerman (1994). Lower-convergence holds automatically because of the form of the utility function. The intuition behind the proof of upper-convergence is that since the profit function under ideal factor allocation is decreasing returns to scale, satiation (in the utility function) and impatience (in the discount rate) imply that agents will not want to infinitely accumulate land or wealth.

REFERENCES

Jere R. Behrman. The action of human resources and poverty on one another: What we have yet to learn. Living Standards Measurement Study Working Paper, no. 74; Washington, D.C.: World Bank, 1990.

Hans Binswanger, John McIntire, and Chris Udry. Production Relations in Semi-arid African Agriculture, in Pranab Bardhan eds., The economic theory of agrarian institutions Oxford; New York; Toronto and Melbourne: Oxford University Press, 1989.

Christopher Bliss and Nicholas Stern. Productivity, Wages and Nutrition: Part I: The Theory. Journal of Development Economics,1978, 5(4), pp. 331-62.

Michael R. Carter. Environment, Technology and the Social Articulation of Risk in West African Agriculture. Economic Development and Cultural Change,forthcoming.

Stephen Coate and Martin Ravallion. Reciprocity without Commitment: Characterization and Performance of Informal Insurance Arrangements. Journal of Development Economics,1993, 40(1), pp. 1-24.

Catherine Coquéry-Vidrovitch. Afrique Noire: Permanences et Ruptures. Paris: Payot, 1985.

Giovanni Andrea Cornia. Investing in Human Resources: Health, Nutrition

and Development for the 1990s. Journal of Development Planning,1989, (19), pp. 159-187.

Angus Deaton. Saving and Liquidity Constraints. Econometrica,1991, 59, pp. 1221-48.

Partha Dasgupta and Debraj Ray. Adapting to Undernourishment: The Biological Evidence and Its Implications, in Jean Dreze and Amartya Sen eds., The political economy of hunger Oxford; New York; Toronto and Melbourne: Oxford University Press, 1990.

Mukesh Eswaran and Ashok Kotwal. Implications of Credit Constraints for Risk Behaviour in Less Developed Economies. Oxford Economic Papers, N. S.,1990, 42(2), pp. 473-82.

Marcel Fafchamps. Solidarity Networks in Preindustrial Societies: Rational Peasants with a Moral Economy. Economic Development and Cultural Change,1992, 41(1), pp. 147-74.

Gerhard Glomm and Michael G. Palumbo. Optimal Intertemporal Consumption Decisions under the Threat of Starvation. Journal of Development Economics,1993, 42(2), pp. 271-91.

Anjini Kochar. Explaining Household Vulnerability to Idiosyncratic Income

Shocks. American Economic Review,1995, 85(2), pp. 159-64.

Michael Lipton. Growing Points in Poverty Research: Labour Issues, presented at the ILO Symposium: Poverty: New Approaches to Analysis and Policy, 1993.

Susan Lund. Informal Credit and Risk-Sharing in the Philippine Uplands, unpublished Ph.D. dissertation, Stanford University, 1996.

Jonathan Morduch. Income Smoothing and Consumption Smoothing. Journal of Economic Perspectives,1995, 9(3), pp. 103-14.

Christina H. Paxson. Using Weather Variability to Estimate the Response of Savings to Transitory Income in Thailand. American Economic Review,1992, 82(1), pp. 15-33.

Christina H. Paxson. Consumption and Income Seasonality in Thailand. Journal of Political Economy,1993, 101(1), pp. 39-72.

Jean-Philippe Platteau. Traditional Systems of Social Security and Hunger Insurance: Past Achievements and Modern Challenges, in Ehtisham Ahmad and et al. eds., Social security in developing countries Oxford; New York; Toronto and Melbourne: Oxford University Press, 1991.

Debraj Ray and Peter A. Streufert. Dynamic Equilibria with Unemployment Due to Undernourishment. Economic Theory,1993, 3(1), pp. 61-85.

Thomas Reardon, Christopher Delgado, and Peter Matlon. Determinants and Effects of Income Diversification amongst Farm Households in Burkina Faso. Journal of Development Studies,1992, 28(2), pp. 264-96.

Thomas Reardon, Peter Matlon, and Christopher Delgado. Coping with Household-Level Food Insecurity in Drought-Affected Areas of Burkina Faso. World Development,1988, 16(9), pp. 1065-74.

Thomas Reardon and Stephen A. Vosti. Links between Rural Poverty and the Environment in Developing Countries: Asset Categories and Investment Poverty. World Development,1995, 23(9), pp. 1495-1506.

Mark R. Rosenzweig and Hans P. Binswanger. Wealth, Weather Risk and the Composition and Profitability of Agricultural Investments. Economic Journal,1993, 103(416), pp. 56-78.

Mark R. Rosenzweig and Kenneth I. Wolpin. Credit Market Constraints, Consumption Smoothing, and the Accumulation of Durable Production Assets in Low-Income Countries: Investment in Bullocks in India. Journal of Political Economy,1993, 101(2), pp. 223-44.

John Strauss and Duncan Thomas. Human Resources: Empirical Modeling of Household and Family Decisions, in Jere Behrman and T. N. Srinivasan eds.,

Handbook of Development Economics Vol.IIIA. Amsterdam: Elsevier, 1995.

Peter A. Streufert. Stationary Recursive Utility and Dynamic Programming under the Assumption of Biconvergence. Review of Economic Studies,1990, 57(1), pp. 79-97.

Christopher Udry. Risk and Saving in Northern Nigeria. American Economic Review,1995, 85(5), pp. 1287-1300.

Christopher Udry. Risk and Insurance in a Rural Credit Market: An Empirical