Consumption Smoothing? Livestock, Insurance and Drought in Rural Burkina Faso*

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Abstract

This paper explores the extent of consumption smoothing between 1981 and 1985 in rural Burkina Faso. In particular, we examine the extent to which livestock, grain storage and inter-household transfers are used to smooth consumption against income risk. The survey coincided with a period of severe drought, so the results provide direct evidence on the effectiveness of these various insurance mechanisms when they are the most needed. We find evidence of little consumption smoothing. In particular, there is almost no risk sharing, and households rely almost exclusively on self-insurance in the form of adjustments to grain stocks to smooth out consumption. The outcome, however, is far from complete smoothing. Hence the main risk-coping strategies which are hypothesized in the literature (risk sharing and the use of assets as buffer stocks) were not effective during the survey period.

1 Introduction

Rural households in developing countries face substantial risk. Households living in these risky environments have developed a range of mechanisms to shield consumption from this risk, including income smoothing, self-insurance, and social insurance arrangements. There has been a good deal of work in recent years that examines the effectiveness of these formal and informal risk-sharing and consumption-smoothing arrangements (e.g. Alderman and Paxson, 1994; Fafchamps and Lund, 2003; Jalan and Ravallion, 1999; Townsend, 1994). The overall conclusion of this research is that most households succeed in protecting their consumption from the full effects of the income shocks to which they are subject, but not to the degree required by either a Pareto efficient allocation of risk (within local communities) or by the permanent income hypothesis (over time).

We examine the consequences of severe income shocks generated by drought for the food consumption of a sample of farming households in rural Burkina Faso. We find evidence of very little consumption smoothing. There are large fluctuations in aggregate consumption that closely track the aggregate changes in income associated with the drought and subsequent recovery. There is no evidence that livestock served as an effective buffer stock during this period, nor was there significant use of financial markets to smooth these aggregate shocks. Village-level risk pooling mechanisms were not effective. Conditional on aggregate shocks, we show that household consumption closely tracks the substantial idiosyncratic shocks to household income. None of the main risk-coping strategies that are hypothesized in the literature were effective during the crisis period we examine.

In the context of the Sahel region of West Africa, primary among these hypothesized mechanisms is the use of livestock as a buffer stock to insulate their consumption from fluctuations in income[1]. Yet empirical studies have consistently found a small or insignificant response of livestock sales to shocks in other income streams (Fafchamps, Udry, and Czukas, 1998; Fafchamps and Lund, 2003; Hoogeveen, 2002). This pattern of results suggests that net livestock sales may not compensate for losses in income from other sources. In the specific context of Burkina Faso, Fafchamps, Udry, and Czukas (1998) show that during some of the worst drought years in the recent history of the

[1] See for example Famine Early Warning System (1999) for how actual policy making is based on this assumption.

region, livestock sales compensated for at most between 15 and 30 percent of income fluctuations. Yet livestock holdings reported by most households at the end of the survey were large enough to compensate entirely for their income fall.[2,3]

In this paper, we examine three possible explanations for the apparent inconsistency between the commonly-shared belief that livestock is used as a buffer stock and the finding that there is little response of livestock sales to income shocks. First, it is conceivable that households were able to smooth consumption through other mechanisms, such as risk sharing or buffer stocks other than livestock. Empirically, this hypothesis implies that income shocks had little effect on consumption changes. Yet we find the contrary: during this crisis period, households' consumptions fell and rose with their incomes. Second, it is possible that the dynamics of livestock prices discouraged the use of livestock as a buffer stock. In particular, livestock mortality during the drought and reduced pressure on common grazing land afterwards may have resulted in higher expected prices in subsequent periods. This would raise the returns to current savings and reduce current consumption. However, we show that even comparing across households within villages (who share the same future price paths), those households who suffered idiosyncratic negative income shocks made no additional use of livestock sales to buffer their consumption. Third, liquidity constraints and a strong precautionary savings motive at low levels of asset holdings, particularly when combined with the need to maintain a reproductive herd may have resulted in positive livestock holdings as long as consumption was at least above subsistence level. We cannot reject this hypothesis as a component of an explanation for the minimal consumption smoothing we observe.

The paper is related to two main threads of literature. First, the paper is related to a growing literature which focuses on poor households' ability to draw on their savings or to enter in informal risk sharing arrangements to smooth consumption. In recent years, a large body of empirical research has consistently found that households in poor developing areas are able to protect consumption against a substantial fraction of income risks, but that full insurance is not achieved[4].

[2] Fafchamps, Udry and Czukas (1998) did not have data on consumption or non-livestock assets. They were not able to explore the possibility that consumption smoothing was effected via mechanisms other than livestock accumulation or decumulation.

[3] For West Africa's Sahelian countries (Burkina, Mali, Niger), livestock is one of the main sources of export revenues. Thus, the role of livestock as a buffer stock may also have macroeconomic implications.

[4] We can not here provide a review of this extensive literature. See Alderman and Paxson (1994); Attanasio and

Second, the paper is connected to the use of assets as a buffer stock when there are credit constraints (Deaton, 1991, 1992a; Banks, Blundell, and Brugiavini, 2001; Carroll and Kimball, 2001; Carroll, 1997). For example, Deaton shows that households subject to borrowing constraints are able to smooth consumption with relatively low asset holdings. Substantial changes in consumption arise only when stocks of assets are drawn down to near zero, which may happen infrequently. Rosenzweig and Wolpin (1993) depart from Deaton (1991)'s initial formulation by allowing a productive asset. In the context of rural India, bullocks are used as a source of mechanical power in agricultural production, but can also be sold to smooth consumption in the face of income shocks. Therefore, consumption is smoothed at the cost of crop production efficiency. The authors find that borrowing-constrained households keep on average half of the optimal level of bullocks.

However, unlike Rosenzweig and Wolpin (1993) we explore livestock as a buffer stock in the context of the WASAT, where animals are mostly used for (sales) consumption purposes rather than as a source of power in agricultural production. Therefore we focus more on the price dynamics and the livestock production processes which govern the offtake decisions and hence the ability to use livestock to smooth consumption. There is some evidence that households either have a precautionary savings motive, or are concerned about liquidity constraints that might bind in the future. We find that households whose landholdings make them more subject to future income fluctuations save more. However, we find no evidence that even the relatively wealthy households in our sample successfully accumulate or decumulate livestock to insulate their consumption from income shocks. This is true even for idiosyncratic income shocks (conditional on village $\times$ year effects) that have no influence on the future path of prices.

The second section describes the survey and summarizes the data used in the analysis. The third section examines the degree of consumption smoothing by the sample households and explores how exogenous income shocks affect herd management in the context of the Sahel. The fourth section concludes.

Szekely (2004); Bardhan and Udry (1999); Ersado, Alderman, and Alwang (2003); Kinsey, Burger, and Gunning (1998); Jalan and Ravallion (1999); Townsend (1994, for example). Dercon (2004) provides a useful recent entry into the literature.

2 Survey description and context

The data for this paper were collected in rural Burkina Faso between 1981 and 1985 by the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT). Approximately 25 households were randomly selected in each of six villages in three distinct agro-climatic zones for the survey. These zones vary in soil quality, annual rainfall patterns, and population densities. The Sahel in the north is characterized by low annual rainfall (480 mm per year on average), sandy soils, and low land productivity. The Sudan savanna has low rainfall (724 mm) and shallow soils. The Northern Guinea savanna in the southern part of the country is the most productive of the regions and has relatively high rainfall (952 mm). The survey collected detailed information on crop production, asset holding and asset transactions, transfers (money and in kind), grain stocks, consumption, and daily rainfall (Matlon, 1988; Matlon and Fafchamps, 1989).

The survey timing is of great importance to this study. The survey spans a period which was marked by some of the worst drought years ever recorded in the region. As shown in Table 1, in each of the six villages, rainfall recorded during the survey period was typically below its long run average; far below in several instances. Because of the predominance of rainfed agriculture, these rainfall fluctuations translated into enormous aggregate shocks. Figure 1 shows historical rainfall pattern in the region. It is apparent that the survey took place in the middle of a severe drought period and coincided with some of the lowest recorded rainfall levels for the region. Time series of annual rainfall in the west African semi-arid tropics are stationary, with the exception of a large downward shift in the mean of the distribution that occurred sometime in the late 1960s. In Table 2 we describe the simple time series properties of total rainfall in the three agroclimatic zones of the survey. This is the maximum likelihood estimator of the first-order autoregression of zone-specific rainfall with an (exogenously imposed) trend break in 1965. The estimate of the autocorrelation is small and insignificantly different from zero in each case, and the Durbin-Watson statistic accepts the null hypothesis of no autocorrelation. We strongly reject the hypothesis of no trend break in the mid 1960s. Each region experienced a large decline in annual rainfall at that point. The most severe decline occurred in the already very dry Sahel. By the time of the survey, households would have had more than a decade to incorporate the occurrence of this shift in the mean of rainfall into their expectations. Because of the dramatic consequences of droughts for welfare in the Sahel, climatologists have made a close study of rainfall patterns in this region of the world. Their conclusions accord with this brief description (Tapsoba, Hache, L. Perreault, and Bobee, 2004; Barbe, Lebel, and Tapsoba, 2002; Nicholson and Grist, 2001).

The ICRISAT survey did not collect consumption data directly until during the last two cropping years of the survey, i.e. 1984 and 1985. Detailed data on the use (net sales and gifts) of each crop (collected weekly), as well as seed use and stocks at the onset of each season are, however, available. Each plot owner was interviewed separately. This information can be used to generate household consumption data using the "flow accounting" identity (see Ravallion and Chaudhuri, 1997). The same consumption data have been used by Reardon, Delgado, and Matlon (1992). In our context, this method has both an advantage and a drawback. The main advantage is that a measure of own consumption of food, presumably the largest fraction of total household consumption, is readily available. This is particularly useful since households tend to underreport own consumption (Ravallion and Chaudhuri, 1997). The main drawback is that a spurious correlation between income and consumption may rise because of similar measurement errors in both variables (Ravallion and Chaudhuri). We believe, however, that our instruments allow an appropriate handling of this type of measurement error[5].

The sample consists of very low-income households. Table 3 shows that annual income and food consumption per adult equivalent varies across villages, but its overall mean is about CFA 20,000. Evaluated at the PPP exchange rate of the time of the survey (CFA 132 for $1), this food consumption level corresponds to less than $ .50 per adult equivalent per day. Line 1 of the table provides the proportion of the population of each village that consumes less than $1/day/adult equivalent, on the basis of the very conservative assumption that the food share of total expenditure is 50 percent.

This level of poverty is associated with very low levels of food consumption on average, and during the drought years many of these households experienced dramatic declines in their already

[5] Our identification strategy, which relies essentially on rainfall variation, is discussed later.

inadequate consumption. There are 184 household-year observations with negative consumption growth and for 167 (91 percent) of those observations, livestock holdings were positive. For the 20^{th} percentile of these observations with negative consumption growth, observed food intake was equivalent to 1770 kilocalories per adult equivalent per day. This corresponds to only about 60 percent of the recommended level of 2850 kilocalories for a moderately active adult (Expert Consultations, 1985). If each of these households had sold their livestock and purchased food at the local prices, their average consumption would have increased to 3300 kilocalories per adult equivalent a day. Calorie intake would have exceed the the recommended level in 43.5 percent of the cases[6].

We present summary statistics regarding livestock holdings in Table 4. Most households have positive holdings of cattle and small stock at the end of this period. There is no suggestion in this table that households that experienced consumption declines sold more livestock than other households. The number of cattle held by households tends to be small, indicating that indivisibilities in livestock holdings could inhibit their use to smooth consumption, although this is less of an issue for goats and sheep. To sum up, the summary statistics portray households with extremely low levels of food intake who choose to hold onto their livestock at the cost of further deterioration of their already inadequate nutrition[7].

3 Consumption Smoothing

Households in Burkina Faso during the drought of the 1980s faced substantial risk. In this section, we examine the extent to which people in the study villages were able to smooth their consumption over time, or to pool the risk they faced with others in the communities.

We consider communities v with risk averse households indexed by i, each of which maximizes an intertemporal expected utility, with instantaneous felicity u defined over the consumption of a single good c and leisure l. In each period t, states of nature $s \in S_t$ occur with fixed and known probability, and the history of states realized through t is denoted h_t. The preferences of household

[6] Moreover, in 55 percent of the cases, calorie intake would exceed 80 percent of the recommended norm which is the level of consumption used by previous studies to define food insecurity in the region (Reardon and Matlon, 1989).

[7] An important issue is how these costs are redistributed within the household. Unfortunately, our data are not well-suited to an examination of food reallocation within the household.

i in the first period are represented by the expected utility function

$$E \sum_{t=1}^{T} \beta^{t-1} u(c_{ivt}(h_t), l_{ivt}(h_t)), \tag{1}$$

where T is the common planning horizon, and the expectations operator is taken over the known probabilities of each history h_t in the set of potential histories through period t, denoted H_t. When markets are complete, household i in community v faces the budget constraint

$$\begin{aligned} &\textstyle\sum_{t=1}^{T} \sum_{h_t \in H_t} (1 + r_{vt}(h_t)) \left[p_{vt}(h_t) c_{ivt}(h_t) + w_{vt}(h_t) l_{ivt}(h_t) \right] \\ &= A_{iv1} + \textstyle\sum_{t=1}^{T} \sum_{h_t \in H_t} (1 + r_{vt}(h_t)) \left[\pi^*_{ivt}(h_t) + w_{vt}(h_t) T_{ivt}(h_t) \right]. \end{aligned} \tag{2}$$

The left hand side of (2) is the present discounted value of the household's consumption of goods and leisure, where $r_{vt}(h_t)$ is the discount rate between period 1 and period t in history h_t, and p_{vt} and w_{vt} are the village-specific state-contingent prices of the good and leisure in period t in history h_t. A_{iv1} is the initial wealth of household i in village v at the start of period 1, $T_{ivt}(h_t)$ is the time endowment of that household in period t of history h_t and

$$\pi^*_{ivt}(h_t) = \max_{L_{ivt}(h_t)} p_{vt}(h_t) f_{iv}(L_{ivt}(h_t); h_t) - w_{vt}(h_t) L_{ivt}(h_t) \tag{3}$$

is the value of farm profit in period t of history h_t.We presume that labor is the only input into farm production, and denote it as $L_{ivt}(h_t)$. The amount of land cultivated by the household is fixed and exogenous, and thus incorporated into $f_{iv}(.)$. Output is random; it depends on the realization of the state s in period t of history h_t. In our application, the key component of this state of nature is annual rainfall, but there are other dimensions as well that we do not observe. A standard separation argument ensures that the household chooses $L_{ivt}(h_t)$ to maximize the value of farm profits in each state of each period. Note that (2) incorporates the assumption that $A_{ivT+1} = 0$.

We proceed in three steps. First, we discuss the measurement of random shocks to farm production. Second, we examine self-insurance; that is, behavior under the assumption that period-by-period state-contingent markets do not exist. Are households able to smooth their consumption over time using credit markets or asset stocks? Finally, we examine risk-pooling within communities. Are insurance markets – or informal transfers that serve a similar purpose – operative within these villages?

3.1 Shock measures

In this section we use the data on rainfall deviations and the allocation of cultivated land across soil types to recover a measure of income shocks. To begin, village average income and consumption growth are presented in Figure 2. Two main features of the data are apparent from this figure. First there were enormous income shocks over the period (as expected by inspection of the rainfall data). Second, consumption tracked income closely at the village level; there is little evidence of effective smoothing of consumption over time in the face of aggregate shocks.

To proceed further, we quantify these shocks. From (3), we see that the value of farm profit $\pi_{ivt}(h_t)$ depends upon village-specific prices, the characteristics of the farmer's land, and the random shocks summarized by the state realized in history h_t. In particular, we exploit the strong dependence of farm outcomes on rainfall in the WASAT environment (Fafchamps, Udry, and Czukas, 1998).

We saw in section 2 that rainfall in this environment is stationary with the exception of the trend break in the late $1960s$, and that there is no evidence of autocorrelation in the series. To the extent that production on different types of land responds differently to similar rainfall levels, and land allocation is made at the beginning of the season when rainfall level is unknown, the cross-product of soil types and rainfall realization provides a measure of the income shock which is both exogenous and unanticipated.

We estimate an empirical analogue to (3):

$$\pi_{ivt} = z_{ivt}\alpha_1 + F_{vt}X_{ivt}\alpha_2 + \gamma_{vt} + \gamma_i + \varepsilon_{ivt}, \tag{4}$$

where π_{itv} is the farm profit (the value of output, net of all purchased inputs) of household i at time t in village v, z_{ivt} is a set of household demographic variables, X_{ivt} represents the area of plots of specific soil types cultivated by the farmer, F_{vt} is the current rainfall deviation from its long run mean (post 1960s trend break) measured in each village, γ_{vt} is a village-year fixed effect, γ_i is a household fixed effect and ε_{ivt} is an error term. We have dropped the history notation, because only the realized history is observed.

Estimates of regression (4) are reported in Table 5. The table shows separate results for poor and wealthier households, where a household is defined as wealthy if it posses animal traction at the start of the survey. The use of animal traction as wealth indicator is motivated by the survey design which sampled households stratified into those cultivating with animal traction and those cultivating with hand-tools (Matlon, 1988). This stratification reflects the common belief that there are systematic differences between households with and without animal traction. In fact, if animal traction requires disbursement of large amounts of cash or access to credit, then only well-off farmers will have access to that technology. Furthermore, in the context of the WASAT, animal traction represents a substantial technological shift, and therefore the stratification we use allows different responses to income shocks between households operating at different levels of technology.[8]

Beneath each column, we report the F statistic for the joint significance test of the interactions between the rainfall shock and the characteristics of the plots cultivated by the household. The null hypothesis that these interactions are jointly non-significant is rejected at the one percent level across all specifications (the F statistic ranges from 4.67 to 7.91). Rainfall affects income through its interactions with land topology and distance from the compound. The income of households with plots on lowland and near the compound is less sensitive to rainfall variations than that of those with plots in upland areas or distant from the compounds. In later sections, we will use these interactions between rainfall variations and plot characteristics as instrumental variables for income. Fafchamps, Udry, and Czukas (1998) and Matlon and Fafchamps (1989) show similar results.

We use regression 4 to assess the variation of income during the survey period. We predict idiosyncratic shocks using the interaction terms ($F_{vt}X_{ivt}\hat{\alpha}_2$) and aggregate shocks using the village-year fixed effects ($\hat{\gamma}_{vt}$). Table 6 shows the average over households within villages of the standard

[8]We also experimented with a wealth index based on farm areas, but the results did not change in any substantive way.

deviation of the shocks (taken over time, for each household), divided by mean income in the village. There is substantial rainfall-induced idiosyncratic risk in these villages. Our estimate of the magnitude of the idiosyncratic shock, moreover, is necessarily an underestimate, as it accounts for only that portion of that risk that is associated with $F_{vt}X_{itv}\hat{\alpha}_2$, and not any other source of idiosyncratic income variation. However, it is apparent that aggregate income volatility is an even more important concern, with a "coefficient of variation" about twice that of idiosyncratic shocks for most villages.

In Table 7 we present summary statistics on consumption, income and livestock holdings by quintile of the estimated transitory shocks. We see dramatic declines in calorie and food consumption for households subject to the most severe adverse shocks, despite their ownership of significant stocks of animals.[9] In summary, we are examining consumption by extremely poor households who were confronted with enormous exogenous income shocks. Yet these households chose to hold onto their main asset (livestock) at the apparent cost of more variation in consumption.

3.2 Self-insurance

In this subsection, we examine the degree of consumption smoothing over time with respect to income shocks. This is primarily an empirical exercise, although its interpretation can best be viewed within the simple life-cycle consumption smoothing paradigm. We temporarily consider a world with missing insurance markets but with well-functioning credit markets. In particular, households can borrow or save at a market interest rate, but have no access to cross-sectional insurance mechanisms. We first consider the simple PIH model, and then we test a buffer stock model more consistent with precautionary saving.

3.2.1 The PIH model

We specialize the budget constraint (2) to reflect the conventional assumptions of the permanent income hypothesis. Prices and wages are no longer state-contingent, and the interest rate is fixed.

[9] It can also be seen in Table 7 that the poorest region (the Sahel) was spared the worst of the shocks.

In each period t household i faces the budget constraint

$$A_{ivt+1} = (1 + r)A_{ivt} + \pi_{ivt} - c_{ivt} \tag{5}$$

For the moment, we also restrict preferences so that labor is supplied inelastically. Instantaneous felicity is now $u(c_{ivt})$, to match the bulk of the literature in the PIH tradition. This assumption will be relaxed presently. When T is sufficiently large, then this problem results in the standard permanent income result that the marginal utility of current consumption is equal to the discounted expected marginal utility of future consumption (Deaton, 1992b)

$$u'(c_{it}) = \beta(1 + r)Eu'(c_{it+1}). \tag{6}$$

If we assume that preferences are quadratic, separable across periods, and time invariant, and that the rate of time preference is constant and equal to the interest rate, then the changes in consumption from period to period can be expressed as a function of unexpected changes in permanent income. An empirical formulation would suggest that only shocks to permanent income would change optimal the consumption plan, and transitory shocks are smoothed (Deaton, 1992b). We base our estimates of transitory income shocks on (4). We define $\gamma_{vt} = \alpha_v F_{vt} + \tilde{\gamma}_{vt}$, and assume that $\tilde{\gamma}_{vt}$ is uncorrelated with z_{ivt} and X_{ivt}. We then estimate

$$\pi_{ivt} = z_{ivt}\alpha_1 + F_{vt}X_{ivt}\alpha_2 + \alpha_v F_{vt} + \gamma_i + (\tilde{\gamma}_{vt} + \varepsilon_{ivt}). \tag{7}$$

¿From (7), we define transitory income $y^T_{ivt} = F_{vt}X_{ivt}\hat{\alpha}_2 + \hat{\alpha}_v F_{vt}$, permanent income $y^P_{ivt} = z_{ivt}\hat{\alpha}_1$ and y^U_{ivt} as any residual unexplained variation in income. Equation (7) is less general than (4), but it permits us to examine the impact of aggregate (village level) rainfall shocks on consumption and saving choices.[10]

We begin by estimating a consumption function as in Paxson (1992):

[10] It would be an error to treat γ_{tv} in (3) as a transitory aggregate shock, because some if it may contain a permanent component. Nor do we want it all to be incorporated into y^U_{ivt} in equation (8), because that would leave only idiosyncratic variation in y^T_{ivt}.

$$c_{ivt} = \zeta_1 y^P_{ivt} + \zeta_2 y^T_{ivt} + \zeta_3 y^U_{ivt} + z_{ivt}\zeta + \lambda_i + \upsilon_{ivt}. \tag{8}$$

Where y^P is permanent income, y^T is transitory income, y^U is residual income, λ_i is a household fixed effect, υ_{ivt} is an error term and all other variables are as defined above. The PIH implies that ζ_1 is unity and ζ_2 is zero. Finally, to allow for systematic inter-household differences in the extent of consumption smoothing, we stratify our sample by household wealth, as in Table 5.

Estimates of this regression are shown in Table 8. In the first column we assume identical consumption responses to income shocks across all households, and in the second column we allow parameters to vary by wealth groups. Consumption increases with permanent income, although far from *pari passu*. The interpretation of the effect of y^P on consumption in this household fixed effect specification is difficult, because it is based on changes in the demographic structure of the household over time, which is likely to be largely predictable. The results that follow are robust to the exclusion of y^P from these equations, as can be seen in column 3.

About 55 percent of changes in transitory income are passed onto consumption. We see in columns 2 and 4 that neither rich nor poor households succeed in insulating their consumption from rainfall-induced transitory variations in income. However, the consumption of the poor is more sensitive to y^T than is that of the rich (the coefficients are statistically significantly different from each other). In columns 4 and 5, we restrict attention to the periods for which we have direct consumption measures, and do not rely on the flow accounting method of inferring consumption. The responsiveness of consumption to transitory income is even larger for this subperiod. Overall, the evidence indicates that changes in consumption track those in transitory income, which suggests that households are unable to smooth consumption in the face of year-to-year fluctuations in income. Such a pattern is incompatible with the standard permanent income model.

The estimates presented in Table 8 may be inconsistent because the model does not account properly for family labor. Crop income is measured as farm gross output minus hired input costs and minus the value of household labor used on the farm (imputed at period-village specific wages). In an agricultural economy characterized by well-developed labor markets and perfect substitutability between family and hired labor, this would be an appropriate procedure (Rosenzweig and Wolpin, 2000). However, hired labor is virtually absent our context (Fafchamps 1993). Overall, only 12% of labor used on farms in these villages is hired; most of that is used for harvesting cotton in only two of the villages. Apart from the cotton harvest, over 95% of the labor used on household farms is supplied by the households.

Therefore, it is more appropriate to examine the consequences for consumption smoothing of absent labor markets. Consider preferences as we originally defined them in (1), where felicity is

$$u(c_{ivt}(h_t), l_{ivt}(h_t)). \tag{9}$$

$u(c, l)$ is assumed to be concave and increasing in c and l. We also make the substantive assumption that $\frac{\partial^2 u}{\partial c \partial l} \leq 0$. This is a simple way of thinking about nutrition-productivity links. When households are working particularly hard (l is low), the marginal utility of consumption is high. Reflecting the evident absence of labor markets, the budget constraint is modified from (5) to

$$A_{ivt+1} = (1 + r)A_{ivt} + f(T_{ivt} - l_{ivt}, F_{vt}) - c_{ivt} \tag{10}$$

where $f(.,.)$ is farm output as a function of household labor input and the transitory random rainfall shock F_{vt}. In any period, consumption and labor choices satisfy

$$\begin{aligned} u_c &= \mu_{ivt} \\ u_l &= f_L \mu_{ivt} \\ \mu_{ivt} &= E_t \beta (1 + r_t) \mu_{ivt+1}, \end{aligned} \tag{11}$$

where $u_c \equiv \frac{\partial u}{\partial c}$, $u_l \equiv \frac{\partial u}{\partial l}$ and $f_L \equiv \frac{\partial f}{\partial L}$, and μ_{ivt} is the Lagrange multiplier on the budget constraint in period t. Consumption may no longer be unresponsive to transitory shocks. A transitory shock is defined in the context of perfect smoothing as one that does not influence μ_{ivt}. Imposing the assumption that $\frac{\delta \mu_{ivt}}{\delta F_{vt}} = 0$, equations (11) imply

$$\frac{dc_{ivt}}{dF_{vt}} = -\frac{\mu_{ivt} u_{lc} f_{LF}}{D_{ivt}} \tag{12}$$

where $D_{ivt} \equiv u_{cc}u_{ll} + \mu_{ivt}u_{cc}f_{LL} - u_{lc}^2 > 0$.[11] Even if there is perfect smoothing, consumption changes with transitory shocks depending on the effect of these shocks on the marginal product of labor. $u_{lc} < 0$, so consumption increases (decreases) if these transitory shocks increase (decrease) the marginal product of labor. Therefore, we can use our data on labor demand on household plots to examine the null hypothesis of perfect smoothing, even in the absence of complete labor markets.

Our IV estimate of the impact of transitory income shocks on consumption is

$$\frac{\frac{dc_{ivt}}{dF_{vt}}}{\frac{df_{ivt}}{dF_{vt}}} = \frac{-\frac{\mu_{ivt} u_{lc} f_{LF}}{D_{ivt}}}{f_F - f_L \frac{\mu_{ivt} f_{LF}(u_{ll} + \mu_{ivt} f_{LL})}{D_{ivt}}}. \tag{13}$$

where $f_{ivt} = f(1 - l_{it}, F_{vt})$. Similarly, we can examine the impact of the same transitory shocks on farm labor demand ($L_{it} \equiv 1 - l_{it}$). Under the null hypothesis of complete smoothing, the IV estimate of this coefficient is

$$\frac{\frac{dL_{it}}{dF_{vt}}}{\frac{df_{ivt}}{dF_{vt}}} = \frac{-\frac{\mu_{ivt} f_{LF}(u_{ll} + \mu_{ivt} f_{LL})}{D}}{f_F - f_L \frac{\mu_{ivt} f_{LF}(u_{ll} + \mu_{ivt} f_{LL})}{D}}. \tag{14}$$

Without further assumptions, in particular on the sign and magnitude of f_{LF}, we can not say much about either of these two quantities. However, their ratio is

$$\frac{\frac{\frac{dc_{ivt}}{dF_{vt}}}{\frac{df_{ivt}}{dF_{vt}}}}{\frac{\frac{dL_{it}}{dF_{vt}}}{\frac{df_{ivt}}{dF_{vt}}}} = \frac{u_{lc}}{(u_{ll} + \mu_{ivt} f_{LL})} > 0, \tag{15}$$

and thus they must have the same sign. If households smooth perfectly, consumption and farm labor demand must move in the same direction in response to transitory shocks.

[11] Where we extend our notational conventions so that $u_{lc} \equiv \frac{\partial^2 u}{\partial l \partial c}$, $f_{LF} \equiv \frac{\partial^2 f}{\partial L \partial F}$, $u_{cc} = \frac{\partial^2 u}{\partial c^2}$, $u_{ll} \equiv \frac{\partial^2 u}{\partial l^2}$, $f_{LL} \equiv \frac{\partial^2 f}{\partial L^2}$, and $f_F \equiv \frac{\partial f}{\partial F}$.

This restriction is strongly rejected in the data. We showed in Table 8 that $\frac{\frac{dc_{ivt}}{dF_{vt}}}{\frac{df_{ivt}}{dF_{vt}}} > 0$. In Table 9, we present results from estimating equation (8), with c replaced by L. We find that $\frac{\frac{dL_{it}}{dF_{vt}}}{\frac{df_{ivt}}{dF_{vt}}} < 0$, contradicting the null hypothesis that households are able to fully smooth the effect of transitory income shocks. In Column 1 of Table 9, we see that positive transitory shocks to income are strongly associated with declines in labor use on the household farm. A one standard deviation increase in income is associated with decline of about 335 hours of total labor, which is approximately 9% of total labor use. The decline in labor use is larger for poorer households. The decline in household labor on the farm associated with the same transitory shock is approximately 7% of total household labor use. This decline is evident for both men and women household members, though not for children. These declines are strongly statistically significant, and of moderate size.[12]

We find that consumption increases in response to transitory income shocks. At the same time, we find labor use on the farm declining in response to the same shocks. This contradicts the null hypothesis of perfect consumption smoothing. It is an unsurprising outcome under conditions of imperfect smoothing. Households with positive F_{vt} are temporarily well-off: some of this transitory utility shock is consumed in the form of c_{ivt}, some in the form of increased leisure.

3.2.2 Asset Stocks and Consumption Smoothing

We turn now to the mechanisms that might be used to smooth consumption over time. This serves as an important robustness check on the preceding results, because the data are partly independent of the information on consumption we have used to this point. There is no significant use of financial assets in these communities, so the primary assets that could be used to smooth consumption are consumer grain stocks, livestock holdings, consumer durables and tools. Unfortunately, we have no data on the evolution of holdings of consumer durables or tools. We focus our attention, therefore, on the two key assets of grain stocks and livestock.

The net savings functions for grain and livestock have the same form as the consumption function

[12] In a very different context, Kochar (1999) also finds hours working responds negatively to idiosyncratic income shocks. Much of the response she finds works through the off-household farm labor market.

(8) with c_{it} replaced by Δa_{it}, where a_{it} is holdings of either grain or livestock by household i in year t.

Estimates are presented in Table 10. Net savings in grain stocks appear to be a relatively important mechanism for smoothing consumption over time, as found by Udry (1995) in northern Nigeria. Put a different way, we found in the previous section that there is very little evidence of consumption smoothing. What smoothing there is appears to be effected though variations in grain holdings. The results indicate a positive response of grain saving to both transitory income and permanent income. This, however, appears to be the case only for relatively wealthy households (column 2). We have already noted that Fafchamps, Udry, and Czukas (1998) find very little responsiveness of net livestock sales to income fluctuations driven by rainfall shocks in these data. We reconfirm this finding in columns 3 and 4 of Table 10.

A source of concern with these results is uncertainty regarding the extent to which livestock price dynamics affect offtake decisions. Are households not selling livestock during this drought because current prices are low? If current prices are low, so that expected returns to holding livestock are temporarily high, livestock sales may be lower than what would be expected in the absence of price dynamics correlated with shocks. We temporarily defer this question, because it is best addressed in the context of an examination of within-village dynamics of livestock holdings, which is discussed in section 3.3.

Perhaps the estimated trivial responsiveness of livestock sales to transitory income shocks is related to the indivisibility of livestock. One cannot sell a fraction of a cow. It would be possible to sell a cow and purchase less expensive livestock, but transaction costs might inhibit such transactions. If a household holds only (say) a single head of cattle, and receives a moderate adverse transitory shock, it might decline to sell that indivisible asset. As a consequence, consumption may vary with transitory income shocks. To examine this hypothesis, we calculate expected consumption changes for each household in each year as

$$\Delta \hat{c}^e_{ivt} \equiv \hat{\zeta}_1 \Delta y^P_{ivt} + \hat{\zeta}_3 \Delta y^U_{ivt} + \Delta z_{ivt} \hat{\zeta} \tag{16}$$

or

$$\Delta \hat{c}^e_{ivt} \equiv \hat{\zeta}_1 \Delta y^P_{ivt} + \Delta z_{ivt} \hat{\zeta}, \tag{17}$$

treating y^U as permanent income in the first case, and as transitory in the second. We are interested in those household-years in which observed consumption rises less (falls more) than expected: $\Delta c_{ivt} < \Delta \hat{c}^e_{ivt}$. The number of such observations is reported in Table 11. Of those household-years in which there are abnormally high declines in consumption, almost 100 percent have positive asset stocks after the consumption decline. Almost 90 percent of households hold positive quantities of livestock after the consumption decline. Of those household-years in which an excess consumption decline is observed, about 80 percent hold some head of livestock for which the price is less than $\Delta c_{ivt} - \Delta \hat{c}^e_{ivt}$. These households could have sold that head of livestock to mitigate the consumption decline. There is a good deal of regional variation in this proportion, however. Very few households in the Sahel face potentially binding livestock indivisibility constraints. However, there are potentially binding indivisibility constraints for almost 30 percent of the household-years with surprisingly small consumption growth in the northern Guinean zone, because households in this area hold relatively few goats and sheep.

Therefore, in Table 12 we present estimates of the key consumption smoothing equations separately for households in the northern Guinean zone and in the rest of the sample. However, we see in columns 1 and 2 no evidence that households in the other regions are more successful in insulating their consumption from transitory income fluctuations than are households in the northern Guinean zone. Nor do the estimates presented in columns 3 and 4 provide support for the notion that households unaffected by indivisibilities make significant use of livestock sales to buffer the effects of transitory income shocks. Therefore, we do not find that indivisibilities in livestock drive our finding that households fail to smooth consumption.

3.2.3 Buffer stocks: Liquidity Constraints and the Precautionary Motive

If farmers in a risky environment face liquidity constraints, or if they have a preference-based precautionary motive for saving (or both), then the strict restrictions of the PIH no longer hold

(Banks, Blundell, and Brugiavini, 2001; Browning and Lusardi, 1996; Carroll, 1997; Carroll and Kimball, 2001; Deaton, 1991, 1992a; Zeldes, 1989). In these cases, farm households will not fully smooth transitory shocks. Instead, they may permit consumption to drop in the face of transitory shocks in order to preserve their buffer stocks against the possibility of future shocks. There is a very close connection between the precautionary savings motive and liquidity constraints, and they have very similar implications for the time series of consumption and income. In either case, we would observe current consumption (savings) being especially low (high) for those households that anticipate a higher variance of consumption in the future. As a consequence, we do not attempt to distinguish between these two complementary hypotheses for incomplete smoothing over time.[13]

Almost none of the now-substantial literature on buffer stock savings addresses the issues associated with possible nonseparabilities in preferences between consumption and labor supply.[14] It is clear that a full treatment would require explicit solution of the stochastic dynamic program facing these households. This extension is beyond the scope of the current paper. Instead, we note that the statistically-significant labor supply responses to transitory shocks revealed in Table 9 are relatively small. For the purposes of this first examination of buffer stock saving, we treat labor supply as inelastic.

We examine the possibility that there is important precautionary saving by adopting the method of Pistaferri (2001). He argues that observation of subjective expectations of future income variance provides a powerful test of this motive. Campbell's (1987) famous rainy day equation shows that under the PIH, saving depends on expected future changes in income. Does current savings depend,

[13]Zeldes (1989) shows that even if a household has no inherent precautionary demand for savings (because preferences are quadratic), liquidity constraints induce precautionary savings. An adverse income shock has a particularly negative impact on a household that faces a binding liquidity constraint, because the shock cannot be spread over time. The household engages in precautionary savings even when the liquidity constraint is not yet binding in order to reduce the chances of it binding in the future. Carroll and Kimball (2001) show that for quite general preferences the existence of liquidity constraints increases the demand for precautionary savings when asset holdings fall near the point at which constraints start to bind. Carroll and Kimball conclude that "the effects of precautionary saving and liquidity constraints are very similar, because both spring from the concavity of the consumption function" (p. 38).

[14]Despite the evidence that such nonseparabilities exist (Browning and Meghir, 1991). There is a significant amount of work that examines intertemporal labor supply in non-stochastic environments (following Heckman, 1974). Research on joint labor supply and savings choices in risky environments with liquidity constraints or a precautionary motive is much less well-established (see Blundell, Magnac, and Meghir, 1997; Low, 1999; Rust, Buchinsky, and Benitez-Silva, 2003, for a sampling of this literature). We know of no work to date that addresses the determinants of buffer stock savings in a context of nonseparabilities between consumption and leisure with absent labor markets and home production.

in addition, on higher moments of distribution of future income shocks? Therefore, we estimate

$$s_{ivt} = \gamma_1 y^P_{ivt} + \gamma_2 y^T_{ivt} + \gamma_3 y^U_{ivt} + \gamma_4 var(y^T_{ivt+1}) + \gamma z_{ivt} + \gamma_v + \varepsilon^s_{ivt}. \tag{18}$$

We assume that households have rational expectations concerning the distribution of income shocks due to rainfall that they can expect. Therefore, we estimate $\widehat{var}(y^T_{ivt+1})$ with the time series of rainfall variation, interacted with household land characteristics weighted by the estimates from equation (1). To be more specific, we combine our estimates $\hat{\alpha}_2$ and $\hat{\alpha}_v$ from (7) with historical rainfall data $\{F_{vt}\}$ and the land characteristics data from our sample to estimate the variance of rainfall-induced income shocks. If we let $\bar{X}_{iv} \equiv \frac{1}{5}\sum_{t=1981}^{1985} X_{ivt}$, then

$$\widehat{var}(y^T_{ivt+1}) = \frac{1}{16}\sum_{t=1965}^{1980}(F_{vt}\bar{X}_{iv}\hat{\alpha}_2 + \hat{\alpha}_v F_{vt} - (\bar{F}_v\bar{X}_{iv}\hat{\alpha}_2 + \hat{\alpha}_v\bar{F}_v))^2. \tag{19}$$

Table 13 summarizes our estimation results. In column (1), we see that conditional on current income shocks, households that have land characteristics that are associated with higher income variance save significantly more. A household with a one standard deviation higher expected future income variance saves CFA 4557 more (per adult equivalent). This is a moderately large effect on consumption and saving: the standard deviation of consumption is approximately CFA 13,000. As can be seen in column (2), there is no apparent difference in the absolute magnitude of the savings response of poor and rich households to expected future income shocks; hence, the responsiveness as a proportion of current consumption or assets is higher for poor households.

We have included only linear terms in income in the savings equation. The variance of income shocks might be correlated with omitted higher order terms in income. Therefore, in column (3), we test the robustness of these results to replacing the variance of income shocks with the coefficient of variation. The pattern of results is unchanged. A household with a one standard deviation higher expected coefficient of variation in income saves CFA 4140 more; almost the same sensitivity we find with the variance measure.

In the absence of time-varying measures of future income risk for our households, it is not possible for us to address the main empirical worry associated with this procedure, which is that we are assuming that landholdings are exogenous to other household characteristics, and in particular that they are uncorrelated with preferences over savings. It is of course possible that more risk averse households, or households that face more strict liquidity constraints, adjust their landholdings to reduce the volatility of income shocks. This possibility, along with the fact that we have not appropriately addressed non-separabilities between consumption and leisure in this context of very imperfect labor markets, implies that these results should be understood as preliminary rather than definitive.

3.3 Risk sharing

We turn now to an examination of the extent of risk pooling within these villages. Table 6 shows that in the context of the enormous aggregate income shocks associated with the drought period there is also significant idiosyncratic variation in income. While informal local risk sharing arrangements can do little to help households deal with the aggregate effects of the drought, they might permit households to efficiently pool the idiosyncratic variation within villages. We begin by considering the canonical model of fully efficient risk pooling within the village. The central implication of this model is that changes in individual consumption depend only on aggregate consumption, and are independent of a households' own shocks conditional on aggregate consumption.

We use a familiar specification to test the null hypothesis of complete risk pooling within villages (see Deaton (1990) and Ravallion and Chaudhuri (1997), for example). If the preferences in (1) are separable between consumption and leisure, then the complete village-specific state-contingent markets in (2) imply that the marginal utility in a given state in any period for a specific household is determined by an unchanging household-specific effect, and by a community-period specific effect, and not on the households own resources conditional on those two effects. Empirically, specifying CARA preferences implies that changes in individual consumption over time should be uncorrelated with changes in individual income conditional on a village-year effect:

$$c_{ivt} = \beta_1 + \beta_2 \pi_{ivt} + z_{ivt}\beta_3 + \xi_i + \xi_{vt} + \omega_{ivt} \qquad (20)$$

Where ξ_{vt} is a village×year fixed effect, ξ_i is a household fixed effect, and ω_{ivt} is a random error. Complete risk pooling implies $\beta_2 = 0$. We experiment with variants of equations (20), namely by instrumenting for income, and by accounting for potential endogeneity of the household composition. The instruments for income are described in 3.1, where we also present the first stage results.

Table 14 sets out estimation results of regression 20. OLS estimates are presented in columns (1) and (2), and IV estimates in columns (3) to (4). Column (5) shows results from the Arellano-Bond (AB) estimator, which treats both income and household size as endogenous and uses lagged variables as instruments (Arellano and Bond, 1991; Jalan and Ravallion, 1999). All regressions include village-year fixed effects to control for covariate shocks. In columns (2) and (4), we allow the degree of consumption smoothing to differ between rich and poor households.

Across all specifications, the income coefficients are positive and different from zero at any conventional level. Therefore, the null hypothesis of perfect insurance against idiosyncratic income risk is rejected.

The point estimates suggest that on average the effect of idiosyncratic income shocks on consumption ranges from 37 percent to 51 percent with OLS estimates, and from 31 percent to 44 percent when we instrument for income. The estimated income coefficient using the AB estimator is 43 percent, implying that the lack of risk sharing is robust to this alternative identification strategy for the income shocks.

We focus our interpretation on the IV results for two reasons. First, there is substantial evidence from other poor agrarian economies of nutrition-productivity effects that imply joint causation between income and consumption (Strauss, 1986; Strauss and Thomas, 1995). Second, it is plausible that there are measurement and/or imputation errors in the income variable. Measurement errors per se would tend to induce an attenuation bias that biases coefficients towards zero (Deaton, 1997; Ravallion and Chaudhuri, 1997). In this case, the OLS estimates provide a lower bound for the true parameters. However, imputation errors in the construction of both the consumption and the income variables may bias the income coefficients upwards (Deaton, 1997;

Ravallion and Chaudhuri, 1997)[15]. For positive coefficients, this bias is in the opposite direction of the standard downward attenuation bias due to measurement errors, so that the net effect cannot be signed *a priori.*

We test whether the extent of risk sharing differs between rich and poor households. The point estimates imply a stronger sensitivity of consumption to idiosyncratic shocks for poor households, but in our IV specification we cannot reject the hypothesis that the responsiveness is the same.[16] Thus, we cannot claim that the consumption of wealthier households is more protected against idiosyncratic income shocks than the consumption of poorer households, a finding which contrasts the results of Jalan and Ravallion (1999) in rural China. Overall, it is clear that a large proportion of idiosyncratic variation in income is uninsured for households at all levels of wealth.

In section 3.2.1 we saw that conventional treatments of the permanent income hypothesis can be misleading in a context in which preferences are not separable between leisure and consumption and labor markets are imperfect or absent. The same is true in the context of tests for efficient consumption insurance. Suppose as we did in section 3.2.1 that nutrition-productivity connections imply that the marginal utility of consumption is increasing in labor supply ($u_{lc} < 0$), and that production is based on household labor, due to absent labor markets. The implication (in a derivation almost identical to that of equation (15), so not repeated here) is that in an efficient allocation with full insurance, idiosyncratic consumption must move in the same direction as idiosyncratic labor use. The intuition is that conditional on aggregate labor and consumption, if labor supply increases for household h due to a change in the marginal product of labor on h's farm, then h's consumption must also increase to fully pool risk.

We can test this implication of full insurance by estimating an equation similar to (20), but with c replaced by $L-$ labor use on the farm. The results are presented in columns (6) and (7) of Table 14. We see that labor use is *declining* in farm output, conditional on household and village-year fixed effects. Households with positive idiosyncratic shocks consume more, and work less. This contradicts the null hypothesis of complete insurance, even with non-separabilities between

[15]This is critical in our context where most of the data on consumption is derived from an accounting flow.

[16]Note that the difference is statistically significant in column (2), i.e. using measured income. However, we have already argued that income may be endogenous.

consumption and leisure and absent labor markets.

In regression (20), all aggregate shocks are absorbed in the village-time fixed effects, making the test agnostic on households' ability to cope with aggregate shocks. Given the timing of the survey, a period characterized by severe drought, it may be informative to examine households ability to cope with aggregate shocks.

One option to examine the exposure to aggregate risk is simply to exclude the village-time fixed effects, which summarize the covariate shocks, from regression (20), and estimate the following regression:

$$c_{ivt} = \beta_1 + \tilde{\beta_2}\pi_{ivt} + z_{ivt}\beta_3 + \xi_i + \omega_{ivt} \tag{21}$$

The coefficient $\tilde{\beta_2}$ provides an estimate of consumption variability inclusive of both idiosyncratic and aggregate shocks. If aggregate shocks are important and there is substantial risk sharing, then $\tilde{\beta_2} > \beta_2$, and the difference $\delta = \tilde{\beta_2} - \beta_2$ summarizes the role of risk sharing (Deaton, 1990; Jalan and Ravallion, 1999).

Table 15 presents the estimation results, with income instrumented as discussed before. The implied $\delta' s$ are presented in the last row. From the estimates, it is apparent that risk sharing is not central to consumption smoothing. This means that households relied almost exclusively on self-insurance to smooth consumption during the survey period. This finding should be put in perspective with the timing of the survey discussed in section (2). In particular one might think that the persistence of negative aggregate shocks which resulted from a succession of drought years may have undermined existing social arrangements used to shared risk. Anecdotal evidence in Northern Burkina, where villagers have reported the break-ups of extended households and traditional reciprocity networks in the aftermath of the drought of the 1970's (Marchal, 1974), seems to support this hypothesis.

3.3.1 Mechanisms of risk sharing

To complement our previous tests on consumption smoothing, we look directly at mechanisms which households may use to cope with income risk. We first examine transfers, which could be an important mechanism for informal risk sharing. We estimate transfers response to income shocks using the following regression:

$$T_{ivt} = \beta_1 \pi_{ivt} + z_{ivt}\beta_2 + \gamma_{vt} + \gamma_i + \upsilon_{itv}^{trans}, \tag{22}$$

where T is net transfers defined as the difference between transfers received and transfers given. If complete risk pooling is implemented through transfers, we would expect β_2 to be -1. Conditional on aggregate consumption (γ_{tv}), a decrease of CFA 1 in income would be met with an increase of CFA 1 in transfers, and vice-versa. Estimates of (22) are reported in Table 16. The estimates imply that income risk has almost no effect on net transfers (the estimated coefficient is small in magnitude and not statistically significant). Thus, overall gifts giving within the village were not used to pool risk. This result is consistent with the evidence presented in Table 15. Moreover, the descriptive statistics (Table 3) indicated that transfers were too small to play any significant role in consumption smoothing.

To corroborate our finding of minimal risk sharing, we test how asset holdings (grain storage and livestock) respond to idiosyncratic, transitory shocks. In Table 17 we test the extent to which self-insurance mechanisms (grain storage and livestock sales) respond to idiosyncratic shocks, by estimating versions of regression 22 where the dependent variable is grain storage (columns 1 and 2) and livestock sales (columns 3 and 4), respectively. On average 41 percent of idiosyncratic shocks are passed onto grain storage (column 1) and only about 2 percent are passed onto livestock sales.

The most important reason for examining the responsiveness of livestock sales to idiosyncratic shocks is that it sheds light on the hypothesis that the reluctance of households to smooth consumption shocks with livestock transactions is related to the dynamics of livestock prices in drought situations. It is argued that livestock mortality during drought periods and reduced pressure on common grazing land afterwards lead to higher prices in subsequent periods because of local supply shortages (Fafchamps, Udry, and Czukas, 1998)[17]. Therefore current low rainfall may provide some incentives to hold onto livestock, and observed offtake will be lower than that would have prevailed in the absence of price dynamics. However, we see from columns (3) and (4) that within villages, households subject to transitory idiosyncratic shocks are no more likely to sell livestock than other households. Because these are conditional on village-year fixed effects, one cannot attribute the lack of livestock adjustment to shocks to differences in the expected future path of future livestock prices.

It is possible that indivisibilities in livestock are responsible for the lack of responsiveness of livestock transactions to idiosyncratic risk. We calculate expected consumption growth

$$\Delta \hat{c}^E_{ivt} \equiv \hat{\beta}_3(z_{ivt} - z_{iv,t-1}) + \hat{\gamma}_{vt} - \hat{\gamma}_{v,t-1} \tag{23}$$

using the estimates $\hat{\beta}_3$ and $\hat{\gamma}_{vt}, \hat{\gamma}_{v,t-1}$ from column (3) of Table 14. We compare this predicted consumption change to actual consumption changes in Table 18. We find once again that livestock indivisibilities are more likely to be an issue in the northern Guinean zone than in the rest of Burkina Faso. There is evidence that idiosyncratic income shocks are smaller than the value of livestock held by the household in almost 25 percent of the instances of lower than predicted consumption growth in the northern Guinean zone.

Therefore, we estimate (20) separately for the northern Guinean and the other two agroclimatic zones in our sample. Results are reported in Table 19, and we find no evidence that livestock indivisibilities play an important role in either our overall finding that household consumption closely tracks idiosyncratic income, nor our finding that livestock sales do not respond to idiosyncratic shocks. Consumption moves with crop income (instrumented, as before, with rainfall shocks interacted with soil characteristics) in both regions, but more strongly in the rest of Burkina Faso than in the northern Guinean zone. Livestock sales respond only trivially to idiosyncratic income shocks in both regions. There is some evidence that livestock sales respond more in the rest of Burkina Faso than in the northern Guinean zone, a qualitative relationship that is consistent with the idea

[17]See Sheets and Morris (1973) for a descriptive account of herd recovery after drought years in the Sahel in the mid-1970's.

that indivisibilities in livestock are particularly troublesome in the northern Guinea. However, even in the rest of Burkina Faso, where indivisibilities potentially bind in only 6 percent of instances of too slow consumption growth, livestock sales counteract less than 1 percent of idiosyncratic income variation.

3.4 Income shocks and herd management

A final prominent hypothesis for the apparent reluctance of many households to sell livestock to smooth consumption is based on livestock production technology. We start from the observation that in the absence of any consumption-smoothing motive (because there is no risk, or because there are efficient insurance markets) optimal herd management still implies periodic sales. This type of offtake, however, is governed only by profit objectives[18]. There may be a tension between these objectives and any desire of households to smooth consumption, reducing the usefulness of animal stocks for dealing with transitory risk.

To motivate our empirical model, consider the standard finite-horizon household model under complete markets. Each household (i) maximizes its utility, which is defined over state contingent consumption

$$u_i(c_{ist}).$$

The household's budget constraint is

$$\sum_{st} p_{st} c_{ist} \leq \sum_{st} \left[\pi_{ist} + q_{st} n_{ist} + w_{st} \left(E_{ist} - l_{st}(N_{ist}) \right) \right],$$

where p_{st} is the price of consumption, π_{ist} is i's farm profit, and E_{ist} is the endowment of labor of i in state s in period t. N_{ist} is the vector of animals of different ages held by household i in state s of period t. We can think of it as having A elements, each describing how many cattle of age a are held by the household at a particular moment; more generally it will record sex- and age-specific quantities held of all different types of livestock. l_{st} is the state- and period-specific labor

[18]Whether profit is defined in monetary or non-monetary (i.e. livestock may be also used to signal social prestige) would not affect the argument.

requirement of holding that vector of animals, which might depend on local pasture conditions. n_{ist} is the vector of net sales of livestock of different ages by i, and q_{st} are the prices at which those sales are realized. Livestock holdings evolve according to

$$N_{is't+1} = G_{st}(N_{ist}) - n_{ist}$$

where G_{st} describes the births, deaths, and aging of livestock from state s of t to s' of $t+1$.[19] Completing the model with the obvious non-negativity conditions and definition of farm profit, it is immediately apparent that the usual separability holds between production and consumption decisions.

It follows that the household problem is akin to maximizing profit, and then using the optimal profit in the budget constraint of the consumption problem. Under the complete market assumption, the household chooses an optimal sequence $\{n^*_{ist}\}$ that maximizes profit derived from livestock. This sequence of net sales is independent of household preferences, and uninfluenced by any desire to cope with risk: $\{n^*_{ist}\}$ is the same regardless of the degree of risk aversion in u_i.

We can say a bit more from the separable structure of the household's problem. The price sequences p_{st}, q_{st} and w_{st}, and the production functions $l_{st}(.)$ and $G_{st}(.)$ are all community specific. Conditional on the aggregate state at time t in a given community, they do *not* depend upon the idiosyncratic income shock of household i. As with the rest of this argument, this depends crucially on the completeness of factor markets in the community. It requires, for example, that pasture is open with a well-defined price (which is embedded in $w_{st}l_{st}(.)$ above) to all in the community. If this was not so, then rainfall shocks on household land might influence $\{n^*_{ist}\}$. This is just a particular example of the common and correct observation that separation of production and consumption decisions requires smoothly-working factor markets.

We now examine the null hypothesis that the sales of animals of particular ages are uninfluenced by the realization of idiosyncratic income shocks. We have data on the age, the type and the sex of each animal sold by sample households. We pool all animals (cattle, goat, and sheep) and calculate

[19]Without loss of generality, we have defined states such that conditional on state s of t these transitions are the same into any state s' of $t+1$.

for each animal j sold by household i in period t its standardized age (s_{jit}) based on the average life expectancy of each type of animal. We estimate

$$s_{jit} = \tau_1 y_{it} + \tau_2 z_{it} + m_{lsvt} + \upsilon_{jit}^{age} \tag{24}$$

where y_{it} is crop income, z_{it} is a vector of indicators of household composition, which we intend to capture variation across households in labor costs and m_{lsvt} is a livestock, sex, village, year dummy variable which captures local market and livestock production conditions. Note that these fixed effects will capture the effects of both current and expected future prices.

Optimal herd management implies that households choose the age at which each animal is sold based only on the local market and physical production conditions (m_{lstv}), which together determine the net profit per animal. The null hypothesis is that $\tau_1 = 0$. A positive τ_1 indicates that households who experience negative income shocks sell younger animals. That is, negative income shocks force household to deviate from the optimal herd management path. In all cases, y_{ht} is treated as endogenous and instrumented with interactions of rainfall shocks with household farmland characteristics, as in earlier tables. Note that the inclusion of m_{lstv} implies that our test can only reveal deviations from the null hypothesis caused by idiosyncratic variations in crop income; aggregate movements are captured in the fixed effect.

In Table 20, we report estimates of equation (24) with and without household fixed effects. We find no evidence of any sensitivity of livestock ages to income shocks in any of these specifications.

One interpretation of this failure to reject the null hypothesis is that the complete markets assumption is correct. This is implausible, since we have direct evidence of incomplete labor and insurance markets. The insensitivity of livestock ages at sale to income shocks is consistent with our overall finding that stocks of animals are not used to smooth consumption in the face of the dramatic income shocks faced by the sample households.

4 Conclusion

This paper has investigated patterns of consumption smoothing by rural households in the WASAT. These households experienced extreme aggregate income shocks during a period of severe drought. These aggregate shocks were accompanied by substantial idiosyncratic income variation. However, we found little evidence of consumption smoothing either over time or across households within villages. The small amount of consumption smoothing that we found was effected largely through the accumulation and decumulation of stocks of grain.

The size of these effects is important and surprising. Median calorie consumption per adult equivalent in these households was less than 2000, 30 percent below WHO recommendations for moderately active adults. They experienced substantial shocks to crop income as a consequence of rainfall variation. The standard deviation of these shocks was about half of mean crop income over the sample period. We estimate that over half of the value of these shocks was passed directly into consumption, and households also supplied more labor when faced with adverse shocks. About a quarter of these income shocks were smoothed via variations in stored grain. Changes in livestock holdings and within-village risk sharing were not used to smooth consumption.

The evidence uncovered suggests that households intentionally destabilized consumption in order to conserve livestock through the drought period, contradicting simple optimal saving theories. Two richer hypotheses about household behavior in this period seem particularly worth exploring.

First, households may systematically overestimate the probability that income shocks are persistent. Households might have misinterpreted the transitory adverse rainfall shocks that they experienced as a second long-term break in the pattern of rainfall (recall that an earlier persistent decline in average rainfall had occurred in the West African semi-arid tropics in the 1960s). As a consequence, they might have optimally reduced consumption and shepherded their assets. It does not appear feasible to examine this hypothesis using the data available from this drought experience. One promising avenue for research is a direct examination of farmer expectations about future weather (Gine, Larson, Townsend, and Vickery, 2005).

Second, household behavior appears to be more consistent with a buffer stock model than conventional risk sharing or PIH models. This conclusion is based on two complementary findings from our reduced form analysis. First, poor households already close to subsistence levels who were subjected to large income shocks endured drops in consumption in order to hold onto their remaining livestock. Second, households whose land characteristics implied higher future income variability saved more, conditional on current income shocks.

A next step in this research agenda, therefore, is to develop a more structural model that accounts for the key features that seem to be driving dynamic decisions regarding consumption and saving in this context. We believe that there are three such features. First, households are faced with potentially binding liquidity constraints, given current livestock holdings and the stochastic process that governs income in the area. Second, labor markets are virtually absent and there are important non-separabilities between the consumption of leisure and food. Finally, livestock sales and purchases involve significant transaction costs, and there are potentially important herd management considerations that influence the decision to modify the portfolio of livestock held by a particular household. We expect that a buffer stock model in the line of Deaton (1991) and Carroll (1997), extended to account for constraints raising from herd management considerations and nutrition-productivity connections may provide a more complete characterization of the data.

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Table 1: Village rainfall data

Villages	1981	1982	1983	1984	1985
Sahelian region					
Woure	362	324	441	302	201
	0.95	0.85	1.16	0.79	0.53
Silgey	444	314	425	295	234
	1.16	0.82	1.11	0.77	0.61
Sudanian region					
Kolbila	646	555	573	423	477
	0.99	0.85	0.88	0.65	0.73
Ouonon	504	525	401	533	469
	0.77	0.81	0.62	0.82	0.72
Northern-Guinean region					
Koho	666	770	725	783	877
	0.76	0.88	0.83	0.89	1.00
Sayero	865	561	634	676	664
	0.99	0.64	0.72	0.77	0.76

Rainfall data are yearly total rainfall in millimeters. The second row in each cell indicates the proportion of the long-run regional average rainfall (post 1965) received in a given year .

Source: Fafchamps, Udry, and Czukas (1998, p.284)

Table 2: Simple Time Series Properties of Annual Rainfall

	(1)	(2)	(3)
	Sahel	Sudan	Guinea
constant	627	793	994
	[35]	[32]	[32]
t > 1965	-245	-141	-119
	[42]	[44]	[60]
ar(1)	0.059	0.145	0.08
	[0.135]	[0.195]	[0.104]
σ	120	131	191
	[14]	[13]	[12]
n	50	58	78

std errors in brackets, ML ARIMA estimates

Table 3: Summary statistics

	(1)	(2)	(3)	(4)	(5)	(6)
	Sahel		Soudanian		Northern Guinean	
	Woure	Sigley	Kolbila	Ouonon	Koho	Sayero
Proportion of hh. consuming less than US 1 $ a day (PPP)	0.38	0.19	0.54	0.67	0.67	0.60
food consumption	32.98	27.57	22.82	15.78	17.92	19.42
	(17.23)	(12.44)	(13.31)	(6.36)	(8.83)	(11.61)
crop income	21.82	18.17	20.10	15.14	21.12	27.40
	(15.84)	(12.10)	(12.97)	(7.39)	(16.40)	(22.99)
income	26.25	21.21	22.72	16.83	25.57	31.54
	(17.93)	(16.87)	(12.80)	(8.45)	(17.32)	(24.30)
Change in food consumption	-6.23	-4.51	-1.08	2.38	2.85	0.65
	(25.67)	(18.38)	(16.81)	(7.54)	(13.61)	(13.53)
Change in crop income	-9.50	-5.84	-9.23	1.95	5.50	2.35
	(21.52)	(16.25)	(16.70)	(8.58)	(15.54)	(27.70)
Change in total income	-10.53	-5.29	-8.25	1.94	3.98	3.00
	(21.51)	(22.04)	(16.66)	(9.01)	(17.22)	(28.55)
Pubic Aid received	0.47	0.30	0.01	0.05	0.00	0.00
	(1.09)	(0.61)	(0.02)	(0.14)	0.00	0.00
Gifts from friends&relatives	0.78	0.61	0.22	0.16	0.27	0.05
	(1.31)	(1.60)	(0.68)	(0.35)	(0.68)	(0.17)
Gifts to friends&relatives	0.78	0.49	0.31	0.48	0.92	0.22
	(1.32)	(1.01)	(0.57)	(0.98)	(1.44)	(0.57)
Net transfers	0.49	0.16	-0.19	-0.23	-0.62	-0.20
	(2.54)	(1.72)	(0.62)	(0.96)	(1.18)	(0.63)
Cattle (head count)	0.91	0.60	0.02	0.44	0.55	0.23
	(1.58)	(0.86)	(0.08)	(1.18)	(1.06)	(0.46)
Sheep (head count)	0.59	0.49	1.31	1.05	0.44	0.32
	(2.62)	(0.84)	(1.16)	(1.28)	(0.61)	(0.93)
Goat (head count)	1.80	0.90	1.56	1.99	0.48	0.79
	(2.62)	(0.84)	(1.16)	(1.28)	(0.61)	(0.93)
Livestock	46.21	49.96	10.45	25.07	22.98	8.25
	(65.79)	(123.23)	(7.90)	(46.85)	(41.72)	(16.45)
Grain stock	4.32	1.42	6.05	2.95	2.12	1.88
	(8.22)	(2.34)	(9.11)	(4.36)	(7.78)	(11.84)
Total labor use (hours)	2132.64	2467.12	5222.17	2977.49	7142.18	4109.45
	(1464.21)	(1353.62)	(4231.70)	(2095.77)	(4995.85)	(2563.73)
Familiy labor use (hours)	2061.48	2381.78	4583.92	2849.43	5678.06	3456.62
	(1457.16)	(1331.09)	(3628.25)	(2017.27)	(3737.53)	(2169.65)
household size (adult equivalents)	7.43	7.60	9.75	8.54	12.71	8.21
	(4.62)	(4.04)	(5.45)	(5.23)	(7.96)	(5.37)
household size (head count)	9.78	9.93	13.11	11.64	15.95	11.07
	(6.15)	(5.52)	(7.45)	(7.29)	(10.75)	(7.41)

Standard deviations are in parentheses

All variables but calories expressed in CFA 1'000 per adult equivalent per annum.

Net transfers are gifts from friends/relative plus Public aid minus gifts to relatives/friends

Consumption per day (first line) is annual consumption converted in US $ – using the PPP exchange rate– divided by 365. The PPP exchange is taken from Penn World Tables.

Table 4: Livestock Holdings by Region and Year

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		Sahel			Soudanian			Northern-Guinean	
	1982	1983	1984	1982	1983	1984	1982	1983	1984
Cattle									
mean number	12.50	12.50	7.05	4.94	5.69	4.03	10.81	12.19	14.08
median number	4.00	4.50	2.50	0.00	0.00	0.00	0.50	1.00	2.00
mean increase for $\Delta cons > 0$		0.00	-5.33		1.44	-3.15		1.56	0.41
mean increase for $\Delta cons < 0$			-7.55		0.00	0.23		0.00	3.38
Average price	34.523	38.436	35.302	38.183	33.297	3.235	72.754	29.985	68.389
Goat& Sheep									
mean	36.44	30.41	17.08	39.22	38.61	24.61	11.54	11.38	10.02
median	16.00	14.00	10.00	27.50	26.00	19.50	7.00	6.50	5.00
Change for $\Delta cons > 0$		-6.79	-22.50		0.72	-16.70		-0.08	-0.53
Change for $\Delta cons < 0$			-13.35		-2.58	-8.31		-1.00	-2.27
Price	7.222	5.364	5.148	3.636	3.317	3.110	3.709	3.352	3.832

All variables except price in number of animals per household. Price in CFA 1000.

Table 5: Determinants of Income

	(1)	(2)	(3)
	Crop income	crop income-rich	Crop income-poor
Rainfall deviation interacted with			
Seno soil area	0.001	-0.109	0.059
	[0.04]	[2.45]*	[1.59]
Zinka soil area	0.014	0.031	-0.026
	[0.27]	[0.48]	[0.29]
Bissiga soil area	-0.004	-0.129	0.037
	[0.10]	[2.05]*	[0.73]
Raspuiga soil area	0.039	-0.022	0.076
	[0.71]	[0.32]	[0.21]
Ziniare soil area	0.016	-0.091	0.117
	[0.34]	[1.51]	[1.15]
Other soil area	0.041	-0.061	0.072
	[2.70]**	[2.28]*	[3.72]**
Low land area	-0.124	-0.111	-0.059
	[5.25]**	[3.14]**	[1.52]
Near low land area	-0.050	0.031	-0.096
	[2.57]*	[0.90]	[3.79]**
Midslope area	-0.036	0.052	-0.072
	[1.76]	[1.35]	[2.81]**
Near upland area	-0.038	0.157	-0.078
	[0.65]	[1.49]	[1.07]
Near home area	-0.108	-0.158	-0.065
	[3.74]**	[2.26]*	[1.63]
Distance to home	0.000	0.000	0.000
	[0.49]	[0.75]	[0.29]
Constant	8.264	31.166	-15.350
	[0.61]	[1.79]	[0.44]
Observations	464	203	261
Number of hh	126	55	71
R-squared	0.60	0.66	0.70
F test-rainfall interactions	7.91	4.67	6.41
F-test village-year dummies	20.13	7.5	12.47

Absolute value of t statistics in brackets

* significant at 5%; ** significant at 1%

Regressions also include demographic variables (adult males, adult females, boys, girls, household size, age of household head and age age of household head squared) but coefficients are not reported

Household and village-year fixed effects are controlled for

Table 6: Magnitude of Shocks Relative to Crop Income

Regions	Villages	Shock nature	Average Standard Deviation of Shock, over Mean Income
Sahel	Woure		
		Aggregate	0.50
		Idiosyncratic	0.27
	Silgey		
		Aggregate	0.67
		Idiosyncratic	0.33
Soudanian	Kolbila		
		Aggregate	0.46
		Idiosyncratic	0.27
	Ouonon		
		Aggregate	0.74
		Idiosyncratic	0.27
Northern-Guinean	Koho		
		Aggregate	0.53
		Idiosyncratic	0.24
	Sayero		
		Aggregate	0.23
		Idiosyncratic	0.33

Note: This Table presents the average over households of the standard deviation (taken over time within households) of the shock, divided by mean crop income in the village. Idiosyncratic and aggregate shocks are as defined in the text following equation 4.

Table 7: Summary Statistics by Quintile of Transitory Shocks

quintile	Calories	Δ Calories	Food Cons	Δ Cons	Crop income	Δ Crop income	Livestock
1							
Mean	2416.078	-434.618	25.287	-1.775	21.136	-14.667	17.600
Median	2078.648	-480.235	22.369	-2.379	19.771	-15.124	8.947
St dev	1533.980	2218.484	16.173	23.787	8.495	11.825	25.477
2							
Mean	2855.213	-932.761	26.847	-5.283	29.101	-9.126	15.526
Median	2275.466	-706.824	21.242	-5.254	21.354	-6.703	3.886
St dev	1639.200	1629.412	14.352	15.201	20.693	16.699	44.209
3							
Mean	2534.793	-126.628	22.107	2.717	25.670	-1.549	32.591
Median	2006.189	115.310	14.932	4.682	18.168	6.517	6.649
St dev	1701.442	1632.346	16.546	13.799	26.517	25.137	51.690
4							
Mean	1888.787	429.677	15.886	8.621	18.463	7.981	11.046
Median	1771.200	179.844	14.018	4.355	13.650	9.050	6.106
St dev	843.209	1239.252	7.885	11.696	19.536	19.432	16.164
5							
Mean	1824.999	802.881	14.828	11.529	14.908	12.647	21.794
Median	1659.919	450.347	13.015	9.094	11.751	8.676	7.441
St dev	831.847	1453.671	6.892	13.880	9.810	19.240	49.609
Total							
Mean	2190.543	146.220	19.522	5.138	20.434	2.296	20.284
Median	1825.972	75.664	15.678	4.567	16.131	4.603	6.432
St dev	1312.440	1694.555	12.874	16.511	18.256	21.787	41.154

Levels and livestock are values before the shock.

All variables but calories are expressed in CFA 1'000 per adult equivalent per annum

Table 8: Determinants of Consumption

	(1)	(2)	(3)	(4)	(5)
Permanent income	0.432				
	[0.183]**				
Transitory income	0.551		0.582	0.770	
	[0.059]***		[0.058]***	[0.065]***	
Unexplained income	0.481		0.484	0.544	
	[0.056]***		[0.057]***	[0.063]***	
Rich					
Permanent income		0.318			
		[0.195]			
Transitory income		0.499			0.635
		[0.096]***			[0.102]***
Unexplained income		0.515			0.709
		[0.093]***			[0.103]***
Poor					
Permanent income		0.863			
		[0.275]***			
Transitory income		0.593			0.827
		[0.079]***			[0.090]***
Unexplained income		0.500			0.472
		[0.074]***			[0.083]***
Constant	43.562	30.499	73.551	32.769	32.022
	[33.511]	[33.964]	[31.274]**	[37.627]	[37.422]
Observations	395	395	395	292	292
Number of hh	112	112	112	112	112
R-squared	0.42	0.43	0.41	0.58	0.59
Poor trans. Inc.=rich trans. Inc. F(2, 270)		41.61			

Standard errors in brackets

* significant at 10%; ** significant at 5%, *** significant at 1%

Income in columns 1 and 2 is net of imputed value of household labor

Regressions also include demographic variables (adult males, adult females, boys, girls, household size, age of household head and age age of household head squared) but coefficients are not reported

Columns 1, 2 and 3 use the full sample. Columns 4 and 5 use the sample of directly observed consumption

Household fixed effects are controlled for.

Table 9: Labor Response to Income Shocks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Total labor	Total labor	hh labor	hh labor	hh male labor	hh female labor	hh child labor
Transitory income	-35.244		-25.529		-18.264	-9.598	2.333
	[12.047]***		[9.755]***		[5.997]***	[4.669]**	[2.618]
Unexplained income	-5.804		-3.72		-2.357	-0.149	-1.214
	[6.376]		[5.163]		[3.174]	[2.471]	[1.386]
Rich							
wyt		-30.413		-19.372			
		[14.454]**		[11.687]*			
wyu		-8.667		-7.727			
		[9.353]		[7.563]			
Poor							
pyt		-44.718		-36.939			
		[23.093]*		[18.673]**			
pyu		-4.941		-2.174			
		[9.405]		[7.605]			
Constant	2585.720	2532.470	2428.302	2355.050	907.898	1443.653	76.751
	[1927.334]	[1938.200]	[1560.683]	[1567.254]	[959.370]	[746.967]*	[418.837]
Observations	343	343	343	343	343	343	343
Number of hh	126	126	126	126	126	126	126
R-squared	0.07	0.08	0.08	0.08	0.12	0.04	0.07

Standard errors in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

Household fixed effects controlled for

Regressions also include demographic variables (adult males, adult females, boys, girls, household size, age of household head and age age of household head squared) but coefficients are not reported

Table 10: Determinants of changes in Grain and Livestock Holdings

	(1)	(2)	(3)	(4)
	grain storage		livestock sales	
Permanent income	0.381		-0.032	
	[0.196]*		[0.006]***	
Transitory income	0.245		-0.004	
	[0.075]***		[0.002]**	
Unexplained income	0.047		-0.002	
	[0.057]		[0.002]	
Rich				
Permanent income		0.396		-0.033
		[0.199]**		[0.006]***
Transitory income		0.507		-0.003
		[0.105]***		[0.003]
Unexplained income		-0.116		-0.011
Poor				
		[0.093]		[0.003]***
Permanent income		0.312		-0.015
		[0.299]		[0.008]*
Transitory income		0.048		-0.001
		[0.102]		[0.003]
Unexplained income		0.066		0.007
		[0.078]		[0.002]***
Constant	-188.694	-205.779	2.279	1.875
	[37.238]***	[37.735]***	[0.508]***	[0.498]***
Observations	340	340	464	464
Number of hh	126	126	126	126
R-squared	0.38	0.42	0.23	0.3

Absolute value of t in brackets

* significant at 10%; ** significant at 5%, *** significant at 1%

Household fixed effects controlled for

Regressions also include demographic variables (adult males, adult females, boys, girls, household size, age of household head and age age of household head squared) but coefficients are not reported

Table 11: Livestock Indivisibilities and Consumption Smoothing

		(1)	(2)	(3)	(4)
		Sahel	Sudanian	Northern Guinean	total
	A. Consumption Growth with y_u as permanent income				
1	Total Number of Household - Year Observations	88	85	109	282
2	Number of Household -Years for which Consumption Growth is Lower than Predicted	35	24	56	115
3	Proportion of Line 2 for which household has positive assets	0.971	0.958	0.982	0.974
4	Proportion of Line 2 for which household has positive livestock	0.971	0.958	0.839	0.904
5	Proportion of Line 2 for which household has positive livestock, BUT for which indivisibility binds	0.057	0.208	0.304	0.209
	B. Consumption Growth with y_u as transitory income				
1	Total Number of Household - Year Observations	88	85	109	282
2	Number of Household -Years for which Consumption Growth is Lower than Predicted	35	29	59	123
3	Proportion of Line 2 for which household has positive assets	0.971	0.966	0.966	0.968
4	Proportion of Line 2 for which household has positive livestock	0.971	0.966	0.864	0.919
5	Proportion of Line 2 for which household has positive livestock, BUT for which indivisibility binds	0.086	0.138	0.322	0.211

note: Indivisibility is definded to bind when the village-year specific price of a household's least expensive animal (held at the end of the year) is greater than the gap between expected consumption growth of consumption (livestock sales) and actual consumption growth (livestock sales).

Table 12: Determinants of Consumption and Livestock Sales by Region

	(1)	(2)	(3)	(4)
	Consumption		Livestock sales	
	Other Regions	Northern-Guinean	Other Regions	Northern-Guinean
Permanent income	1.161	0.362	-0.033	-0.064
	[0.469]**	[0.307]	[0.010]***	[0.017]***
Transitory income	0.469	0.351	-0.009	0.009
	[0.155]***	[0.120]***	[0.004]**	[0.006]
Unexplained income	0.83	0.327	-0.019	0.003
	[0.179]***	[0.060]***	[0.004]***	[0.003]
Constant	192.519	-26.156	1.555	4.753
	[97.831]*	[63.945]	[2.275]	[3.545]
Observations	162	135	194	146
Number of hh	65	46	77	49
R-squared	0.47	0.59	0.34	0.56

Standard errors in brackets

* significant at 10%; ** significant at 5%, *** significant at 1%

Table 13: Determinants of Saving

	(1)	(2)	(3)	(4)
		for rich		for rich
Permanent income	0.494	0.686	0.726	0.868
	[0.043]***	[0.061]***	[0.046]***	[0.057]***
Transitory income	0.58	0.726	0.676	0.803
	[0.060]***	[0.088]***	[0.062]***	[0.092]***
Unexplained income	0.485	0.624	0.476	0.611
	[0.043]***	[0.063]***	[0.046]***	[0.066]***
Income variance	0.007	0.005		
	[0.001]***	[0.001]***		
Coeff of var income			3.664	4.079
			[0.463]***	[0.905]***
		for poor		for poor
Permanent income		0.236		0.393
		[0.067]***		[0.079]***
Transitory income		0.529		0.633
		[0.074]***		[0.076]***
Unexplained income		0.395		0.391
		[0.053]***		[0.056]***
Income variance		0.007		
		[0.001]***		
Coeff of var income				2.745
				[0.542]***
Rich		-8.36		-10.38
		[2.401]***		[3.067]***
age of hh head	0.288	0.35	0.096	0.354
	[0.264]	[0.262]	[0.277]	[0.277]
head age squared	-0.004	-0.004	-0.002	-0.004
	[0.003]	[0.003]	[0.003]	[0.003]
Constant	-23.983	-20.31	-24.533	-23.021
	[6.841]***	[6.680]***	[7.233]***	[7.024]***
Observations	392	392	392	392
R-squared	0.63	0.66	0.59	0.62

Standard errors in brackets

* significant at 10%; ** significant at 5%, *** significant at 1%

Table 14: Impact of Idiosyncratic Income Shocks on Consumption and Labor Supply

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
			Consumption			Household labor on the farm	
					Arellano-Bond	OLS	IVE
	OLS	OLS	IVE	IVE	IV-lagged instruments		
cropincome	0.449		0.400		0.428	-12.17	-18.63
	[10.32]***		[4.93]***		[6.74]**	[2.02]**	[1.75]*
Poor cropincome		0.508		0.437			
		[9.71]***		[4.61]***			
Rich cropincome		0.374		0.311			
		[6.51]***		[2.19]**			
	[2.10]**	[2.05]**	[2.21]**	[2.23]**		[0.21]	[0.14]
Constant	46.780	50.422	52.190	55.174		1762.92	1936.70
	[1.81]*	[1.95]*	[1.92]*	[1.98]**		[1.06]	[1.12]
Test of coefficient of poor=coefficient of rich							
F(2, 270)		4.01					
$\chi^2(2)$				0.57			
R-squared	0.62	0.62					

Absolute value of t in brackets

* significant at 10%; ** significant at 5%, *** significant at 1%

Village-year dummies and household fixed effects Regressions also include demographic variables (adult males, adult females, boys, girls, household size, age of household head and age age of household head squared) but coefficients are not reported

The first stage regressions are reported in table 5

Table 15: Restricted Version of Full Insurance Test, No Village-year Fixed Effects

	(1)	(2)
	IVE	IVE
cropincome	0.380	
	[4.16]***	
Poor cropincome		0.439
		[3.65]***
Rich cropincome		0.304
		[2.24]**
Constant	44.266	47.224
	[1.41]	[1.51]
coefficient(vyrfe)-coefficient(no vyrfe)		
Crop income	-0.020	
	0.122	
Poor		0.002
		0.452
Rich		-0.007
		0.138
Observations	395.0	395.0
Number of hh	112.0	112.0
R-squared		

Absolute value of t in brackets

* significant at 10%; ** significant at 5%, *** significant at 1%

Household fixed effects controlled for

Regressions also include demographic variables (adult males, adult females, boys, girls, household size, age of household head and age age of household head squared) but coefficients are not reported

The first stage is regression 4 but without the village-year dummy variables γ_{tv}

Table 16: Determinants of Net Transfers Received

	(1)	(2)	(3)	(4)
	OLS	IVE	OLS	IVE
cropincome	-0.005	-0.010		
	[0.97]	[0.90]		
Poor cropincome			-0.012	-0.009
			[1.79]	[0.71]
Rich cropincome			0.003	-0.011
			[0.42]	[0.59]
Constant	1.366	1.382	0.979	1.650
	[0.42]	[0.41]	[0.30]	[0.47]
Observations	399	399	399	399
Number of hh	114	114	114	114
R-squared	0.570		0.580	

Absolute value of t in brackets

* significant at 10%; ** significant at 5%, *** significant at 1%

Village-year fixed effects and household fixed effects Regressions also include demographic variables (adult males, adult females, boys, girls, household size, age of household head and age age of household head squared) but coefficients are not reported

The first stage regressions are reported in table 5.

Table 17: Estimates of Net Changes in Grain and Livestock

	(1)	(2)	(3)	(4)
	grain storage		livestock sales	
income	0.413		-0.02	
	[5.22]***		[5.20]***	
Poor income		0.264		-0.015
		[0.87]		[1.08]
Rich income		0.42		-0.02
		[5.36]***		[5.36]***
Constant	16.336	22.701	2.261	2.062
	[0.62]	[0.77]	[3.91]***	[3.03]***
Observations	340	340	464	464
Number of hh	112	112	126	126

Absolute value of t in brackets

* significant at 10%; ** significant at 5%, *** significant at 1%

Village-year fixed effects and household fixed effects Regressions also include demographic variables (adult males, adult females, boys, girls, household size, age of household head and age age of household head squared) but coefficients are not reported

The first stage regressions are reported in table 5.

Table 18: Indivisibilities, Livestock Sales and Idiosyncratic Risk by Region

		(1)	(2)
		vill1-4	vill5-6
1	Total Number of Household- Year Observations	119	64
2	Number of Household -Years for which Consumption Growth is Lower than Predicted	52	27
3	Proportion of Line 2 for which household has positive assets	1.00	1.00
4	Proportion of Line 2 for which household has positive livestock	0.962	0.815
5	Proportion of Line 2 for which household has positive livestock, BUT for which indivisibility binds	0.058	0.222

note: Indivisibility is definded to bind when the village-year specific price of a household's least expensive animal (held at the end of the year) is greater than the gap between expected consumption growth of consumption (livestock sales) and actual consumption growth (livestock sales).

Table 19: Idiosyncratic Risk and Consumption/Livestock Sales by Region

	(1)	(2)	(3)	(4)
	Consumption		Livestock sales	
	Other Regions	Northern-Guinean	Other Regions	Northern-Guinean
cropincome	1.286	0.328	-0.038	-0.015
	[0.358]***	[0.066]***	[0.014]***	[0.004]***
age of hh head	-4.122	1.195	-0.012	0.109
	[2.120]*	[2.004]	[0.022]	[0.126]
headage*headage	0.051	-0.023	0	-0.001
	[0.026]*	[0.023]	[0.000]	[0.001]
adfemale	0.281	5.536	-0.041	0.175
	[2.411]	[3.328]*	[0.078]	[0.208]
admale	-0.156	3.428	0.042	-0.077
	[2.124]	[3.010]	[0.070]	[0.186]
kidmale	0.775	4.029	-0.018	0.018
	[1.570]	[1.680]**	[0.047]	[0.105]
kidfemale	-1.141	4.382	0.003	0.174
	[1.735]	[2.230]**	[0.059]	[0.138]
hhsize	-0.758	-4.796	-0.053	-0.248
	[1.704]	[2.138]**	[0.054]	[0.132]*
Constant	85.059	18.794	1.328	-0.646
	[38.021]**	[71.594]	[0.629]**	[3.194]
Observations	240	155	295	169
Number of hh	66	46	77	49

Absolute value of t in brackets

* significant at 10%; ** significant at 5%, *** significant at 1%

Village-year fixed effects and household fixed effects Regressions also include demographic variables (adult males, adult females, boys, girls, household size, age of household head and age age of household head squared) but coefficients are not reported

The first stage regressions are reported in table 5.

Table 20: Determinants of Age of Livestock at Sale

	(1)	(2)	(3)	(4)
Crop income	0.008	0.003	0.009	0.009
	[0.53]	[0.24]	[0.25]	[0.27]
adult males	0.171	0.214	0.124	0.174
	[2.47]**	[3.02]***	[0.95]	[1.26]
adult females	-0.067	-0.149	-0.469	-0.634
	[1.40]	[2.39]**	[3.23]***	[3.70]***
age hh head	0.002	0.005		
	[0.28]	[0.76]		
girls		-0.03		-0.159
		[0.69]		[1.50]
boys		0.117		0.177
		[2.87]***		[1.74]*
Constant	-0.505	-0.666	1.215	1.616
	[1.58]	[2.04]**	[0.96]	[1.26]
Observations	1331	1331	1331	1331

Absolute value of t in brackets

* significant at 10%; ** significant at 5%, *** significant at 1%

Columns 1-2: Village-year-animal type-animal sex fixed effects fixed effects

Columns 3-4: Village-year-animal type-animal sex fixed effects and household fixed effects

Income is instrumented as explained in regression 4.

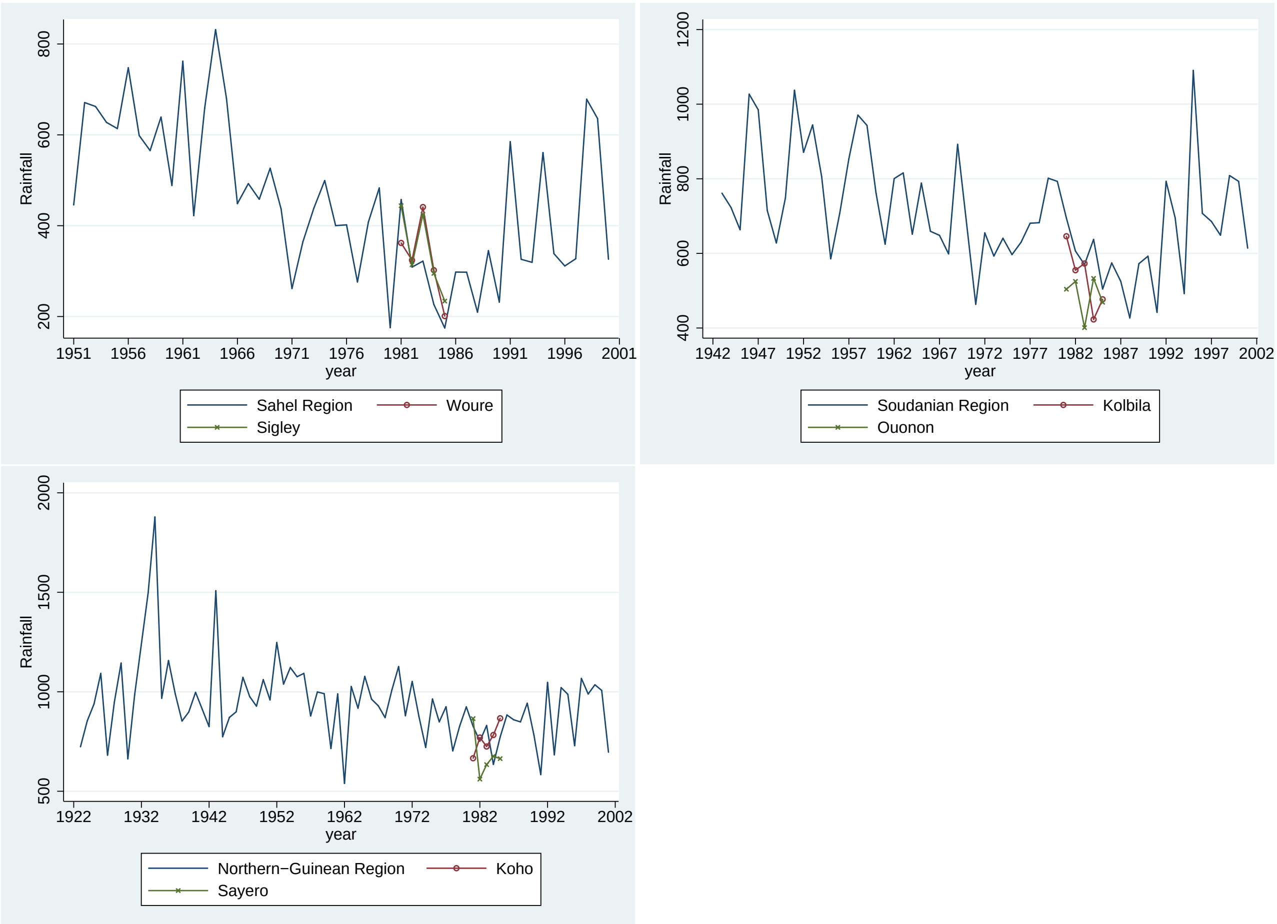

Figure 1: Long run rainfall

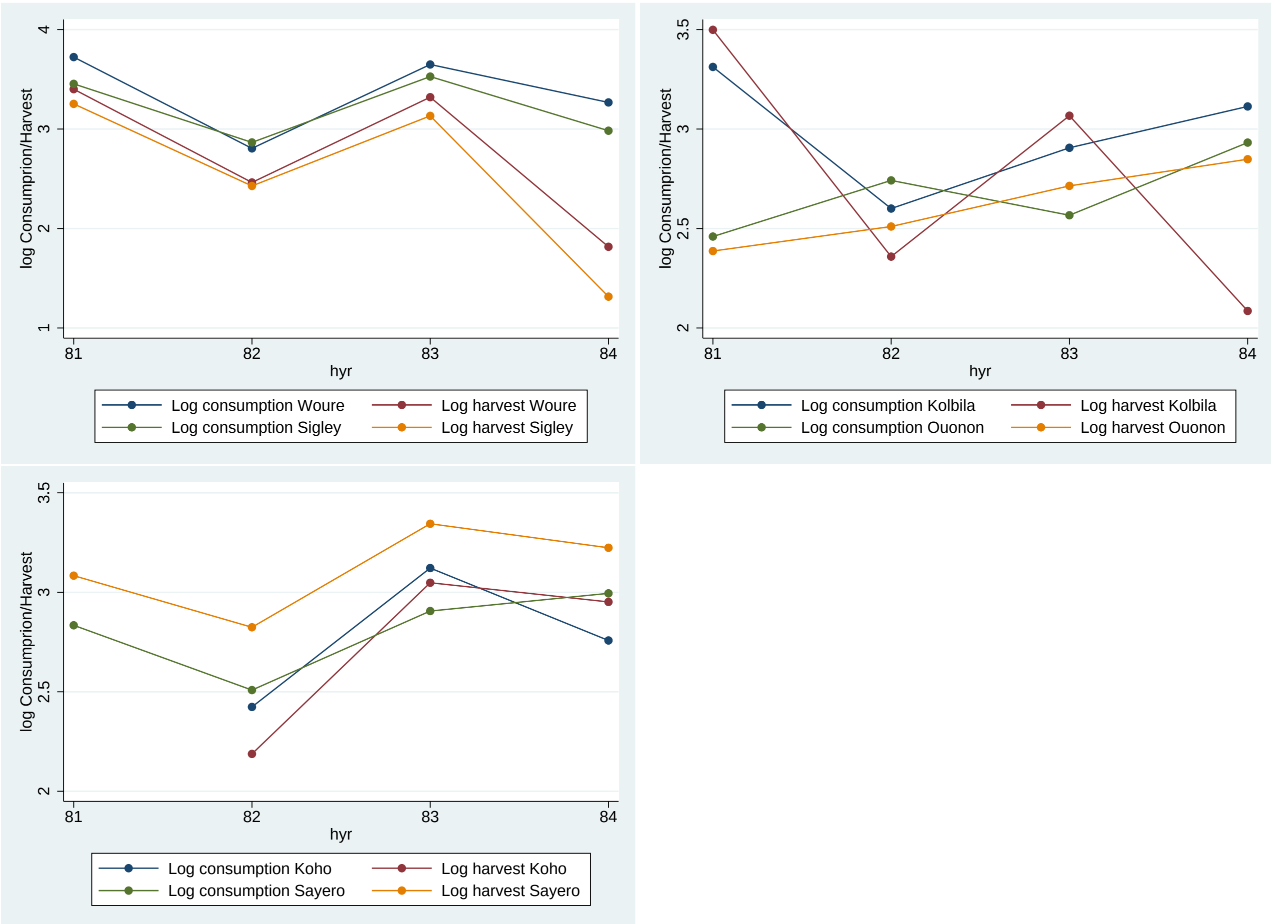

Figure 2: Village income and consumption growth