Consumption Smoothing and Livestock in Rural Burkina Faso[*]

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Abstract

This paper tests the extent of consumption smoothing between 1981 and 1985 in rural Burkina Faso. In particular, we examine the extent to which livestock, grain storage, transfers and reorganization of household units are used to smooth consumption against income risk. The survey coincided with a period of severe drought, so that 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 livestock sales to smooth out consumption. The outcome, however, is far from complete insurance. Hence the main risk-coping strategies which are hypothesized in the literature (risk sharing and buffer stock), 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 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 buffer stock during this period, nor was there significant use of financial markets to smooth these aggregate shocks. Nor were village-level risk pooling mechanisms 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 perfectly compensate for losses in income from other sources. In the specific context of the WASAT, Fafchamps, Udry, and Czukas (1998) show that during some of the worst drought years in

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

the recent history of the 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].

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 resulted in positive livestock holdings as long as consumption was at least above subsistence level. We cannot reject this hypothesis as 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 (Alderman and Paxson, 1994; Bardhan and Udry, 1999; Kinsey, Burger, and Gunning, 1998; Jalan and Ravallion, 1999; Attanasio and Szekely, 2004) {perhaps a few more recent papers here – Kinsey, Burger & Gunning, Jalan & Ravallion, Ersado, Alderman & Alwang, Attanasio & Szekely, Hoogeveen, Dercon (2002) is a review}. In recent years, a large body of empirical research has consistently found that households in poor

[2] For the West Africa's Sahel countries (Burkina, Mali, Niger), livestock is one of the main sources of export revenues. Thus, whether households raise livestock for buffer stock or not may have also macro implications.

developing areas are able to protect consumption against a substantial fraction of income risks, but that full insurance is not achieved (Alderman and Paxson, 1994; Townsend, 1994)[3].

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). Deaton shows that households subject to borrowing constraints are able to smooth consumption with relatively low asset holdings. He proposes an inter-temporal model that incorporates a stochastic labor income and a non-productive asset (cash or grain on hand). In this model, even in the complete absence of financial markets, prudent households may accumulate and draw down stocks of physical or financial assets to maintain consumption levels that vary little from year to year. Substantial changes in consumption arise only when stocks of assets are drawn down to near zero, which may happen infrequently. Moreover, it is not necessary that asset holdings be large relatively to income. For instance, simulation exercises show that for a household holding an average stock of asset value less than the standard deviation of income, consumption variation is half that of income (Deaton, 1992a, p.257).

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 source of 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 than as a source of power in agricultural production. Therefore we focus more on the price dynamics and the livestock production process which govern the offtake decisions and hence the ability to use livestock to smooth consumption. 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 livestock sales to smooth out consumption. The outcome, however, is far from complete insurance. Hence the main risk-coping strategies which are hypothesized in the literature (risk

[3] We do not provide a review of this literature, which is rather extensive. Instead we refer the interested reader to Besley (1995) for a recent and comprehensive review.

sharing and buffer stocks) were not effective during the survey period. Moreover, we show that under reasonable assumptions, it is optimal for a household which is above subsistence level to hold on to its livestock at the cost of more destabilization in consumption.

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. The fourth section explores how exogenous income shocks affect herd management in the context of the Sahel. The fifth section concludes.

2 Survey description and context

2.1 Survey and descriptive statistics

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 consistently below its long run average. 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 (Tapsoba, Hache, L. Perreault, and Bobee, 2004; Barbe, Lebel, and Tapsoba, 2002; Nicholson and Grist, 2001). For our analysis, it is important to note that 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.

The sample consists of very low-income households. Table 2, shows that annual annual income and consumption per adult equivalent is less than CFA 20,000 most of the time. If evaluated at the exchange rate of the time of the survey (CFA 250 for $1), the consumption level corresponds to $ .25 per adult equivalent per day. Even if we suppose that households were spending the same amount on non-food items (which is exaggerated) consumption would correspond to $ .50 dollar a day, far below the conventional $1 a day adopted for global poverty measures.

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 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 (FAO-WHO-UNU, 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[4]. To sum up, the actual food intake data portray households with extremely low food intake who choose to hold onto their livestock at the cost of further deterioration of their already inadequate nutrition[5].

[4]Moreover, in 54.68 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).

[5]An important issue is how these costs are redistributed within the household. Unfortunately, our data cannot be used to examine food reallocation within the household.

2.2 Shock measures

In this section we use the data on rainfall deviations and the allocation of cultivated land across soil types to recover 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. We exploit the strong dependence of farm outcomes on rainfall in the WASAT environment (Alderman and Paxson, 1994; Fafchamps, Udry, and Czukas, 1998). 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 income shock which is both exogenous and unanticipated (Fafchamps, Udry, and Czukas, 1998).

$$y_{itv} = z_{itv}\alpha_1 + \left(X'_{itv} \otimes F_{vt}\right)\alpha_2 + \gamma_{tv} + \gamma_i + \varepsilon_{itv} \tag{1}$$

Where y_{itv} is the income of household i at time t in village v, z_{itv} is a set of household demographic variables, X_{itv} represents the allocation of plot areas to specific soil types, F_{vt} is current rainfall deviation from its long run mean measured in each village, γ_{tv} is a village-year fixed effect, γ_i is a household fixed effect and ε_{itv} is an error term.

Estimates of regression (1) are reported in table 3. The table shows separate results for crop income and total income,and for poor and wealthier households. Beneath each table, we report the F statistic for the joint significance test of the instruments. The null hypothesis that all instruments are jointly non-significant is rejected at the one percent level across all specifications (the calculated F statistic range from 4.67 to 7.91). Rainfall affects income through its interactions with land topology and distance from the compound. Income of household with plots on lowland and near the compound is less sensitive to rainfall variations than those with plots in upland areas or distant from the compounds. Fafchamps, Udry, and Czukas (1998) and Matlon and Fafchamps

(1989) show similar results.

We use regression 1 to assess the variation of income during the survey period. We predict idiosyncratic shocks using the interaction terms $((X'_{itv} \otimes F_{vt})\,\hat{\alpha}_2)$ and aggregate shocks using the village-year fixed effects $(\hat{\gamma}_{tv})$. Table 4 shows the coefficient of variation for these shocks for each village. There is appreciable rainfall-induced ideosyncratic risk in these villages. However, it is apparent that aggregate income volatility is the main source of concern, with a standard deviation about twice of the mean income in most villages.

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 cost of more variation in consumption.

3 Consumption smoothing

Limited livestock sales in the face of severe adverse income shocks could simply reflect the availability of alternative mechanisms for smoothing consumption. We first examine self-insurance, and then risk sharing at the village level.

3.1 Self-insurance

In this section, 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 which we develop below. Consider a world with missing insurance markets but with well functioning credit markets. In particular households can borrow or save at the market interest rate. We first consider the simple PIH model, and then we test a buffer stock model more consistent with precautionary saving.

3.1.1 The PIH model

Each household i maximizes an intertemporal expected utility, with an instantaneous utility u defined over the consumption of a single aggregate good c_i. Households are supposed to be risk averse, with a planning horizon T. Each period, household i earns a risky income y_i, and has access to a risk-free asset A_i. With time discount rate β and interest rate r, household i economic program at period τ can be written as follows:

$$Max_{c_{i\tau}} u_i(c_{i\tau}) + \beta^{t-\tau} E_{t=\tau} \left[\sum_{t=\tau+1}^{T} u(c_{it}) \right] \tag{2}$$

subject to the budget constraint:

$$A_{it+1} = (1+r)A_{it} + y_{it} - c_{it} \tag{3}$$

With T large enough so that $A_{iT+1} = 0$, 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).

$$u'(c_{it}) = \beta(1+r)Eu'(c_{it+1}) \tag{4}$$

If we assume that preferences are quadratic, separable across periods, and time invariant, 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 consumption plan, and transitory shocks are smoothed(Deaton, 1992b)

$$\Delta c_{ivt} = \gamma_0 + \gamma_1 \Delta y^P_{ivt} + \gamma_2 \Delta y^T_{ivt} + \gamma z_{it} + d_v + \upsilon_{ivt} \tag{5}$$

Where y^P is permanent income, y^T is transitory income, d_v is a vector of village dummy variables, and all other variables are as defined before. Permanent and transitory income are defined following (Paxson, 1992). We estimate regression 1, but omitting γ_{tv} and including a constant in X_{itv}. Thus the village-level rainfall shock now enters 1 directly as well as through interactions with household land characteristics. Transitory shocks are defined as $\left(\tilde{X}'_{itv} \otimes F_{vt}\right)\hat{\alpha}_2$, where $\tilde{X}_{itv} = [1 \ X_{itv}]$, and permanent shocks are defined as $z_{itv}\hat{\alpha}_1$.

The PIH implies that γ_1 is unity and γ_2 is zero. Finally, to allow for systematic inter-household differences in the extent of consumption smoothing, we stratify our sample by average household wealth. We use the possession of animal traction at the beginning of the survey as a wealth index. The wealth indicator we use can also be seen as a crude proxy for credit constraint, since acquisition of animal equipment necessitates the disbursement of large amounts of cash or access to credit.

Estimates of this regression are shown in table 5. 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. The coefficients associated with income are all statistically significant at the one percent level. The results indicate 43 percent of the changes in permanent income are passed onto consumption, while 61 percent of changes in transitory income are passed onto consumption. 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 pattern is inconsistent with the standard permanent income model.

The results presented in table 5 may be subject to another source of bias. Income is measured as farm gross output minus hired input costs and therefore does not account for the value of family labor. As a consequence, our estimator may lead to over-rejection of the permanent income hypothesis (Rosenzweig and Wolpin, 2000). The source of the bias arising from the estimation of the effects of income shocks on on consumption using rainfall shocks as instruments can be characterized as follows. Suppose that labor markets operate smoothly, and for simplicity suppose that labor is the only variable input chosen by the farmer. Farm profits are

$$\pi^*(r) = \arg\max_l f(l,r) - wl.$$

While a standard envelope argument implies that the impact of rainfall shocks on farm profits is simple $\frac{d\pi^*}{dr} = \frac{\partial f(l^*,r)}{dr}$ we observe output, not profits. Hence we estimate

$$\frac{df(l^*,r)}{dr} = \frac{\partial f(l^*,r)}{\partial r} + \frac{\partial f(l^*,r)}{\partial l}\frac{dl^*}{dr} \tag{6}$$

Since the marginal product of labor in agriculture is not zero, it is evident that our IVE of the impact of rainfall variation on farm profits is consistent only if there is no labor response to rainfall variation. However, Fafchamps (1993) finds that labor allocation decisions evolve as the extent of rainfall shocks becomes known. For example, if rainfall is better than expected, farmers may devote additional time to weeding crops. But if rainfall shocks are negative, labor is reallocated out of agriculture.

To ascertain the direction of the bias we are confronted with, we use plot level labor data collected during the first three cropping seasons of the survey to estimate the labor response to rainfall. We regress total labor per hectare on household characteristics, and soil types and topo-sequence interacted with rainfall deviations, controlling for village-year fixed effects[6].

$$l_{ivt} = \beta_0 + \beta_1 Z_{ivt} + \beta_3 X_{itv} \otimes F_{vt} + \gamma_{vt} + \mu_{itv} \tag{7}$$

Table 6 shows the estimation results, including village and year dummy variables (column 1) and village-year fixed effects (column 2). The relevant results for assessing the bias of the PIH estimation results are those contained in column (1). The interaction effects are not individually significant, but the joint effects of the rainfall deviations are significant ($F = 2.32$, $P = 0$), indicating that aggregate family labor adjusts to rainfall.

Beneath each column, we report the implied labor response to rainfall, taken at the sample average. The parameters are imprecisely estimated, but the labor response to rainfall is negative. An increase of of 100 mm in rainfall is associated with a reduction of about 16 hours per hectare[7]. This means that we have underestimated the impact of rainfall shocks on transitory income. As a consequence, consumption may be *more* responsive to transitory income than implied by the IV estimates. Therefore, it is unlikely that we are wrongly rejecting the PIH.

[6]Total labor is obtained by adding up male,female and child labor measured in hours. Child labor is weighted by 1/5, and the weighting factor is implied by estimated production functions contained in Udry (1996).

[7]This average negative labor response to rainfall does not rule out the fact that labor applied to specific tasks responds positively to rainfall shocks. Likewise labor response is gender and age dependent. In separate regressions, we found that male labor decreases with rainfall, while female and child labor is increasing with rainfall. Yet, given rainfall uncertainty and inactive labor markets, households may allocate their crops across different types of land to minimize labor dependence on rainfall.

3.1.2 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 preceeding results, because the data are 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:

$$\Delta a_{it} = \beta_1 + \beta_2 y_{it}^P + \beta_3 y_{it}^T + \beta_4 z_{it} + d_v + \varepsilon_{it}, \tag{8}$$

where a_{it} is holdings of either grain or livestock by household i in year t.

Estimates from (8) are presented in table 7. Net savings in grain stocks appear to be a relatively important mechanism for smoothing consumption over time, as found by Udry in nothern 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 (.28) and permanent income (.33). There is also some suggestive evidence that saving does not only serve consumption smoothing purpose, but also may be used also to accumulate wealth, since households save from their permanent income. 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 7.

3.1.3 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

(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. Zeldes (1989) shows that even if a household has no inherent precautionary demand for savings (because preferences are quadratic), liqudity 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). In either case, we would observe current consumption being especially low (and thus consumption growth being particularly high) for those households that anticipate higher variance in consumption in the future.

We examine the possibility that there is important precautionary saving by these farming household by estimating an Euler equation that includes the variance of income innovations as regressor: a positive coefficient on the variance can be interpreted as evidence in favor of precautionary saving hypothesis, as economic agents postpone consumption to the future by reducing current consumption in response to anticipated higher future income variance (Banks, Blundell, and Brugiavini, 2001; Browning and Lusardi, 1996; Carroll, 1997). The regression can be motivated by assuming a constant relative risk aversion (CRRA) utility function (2) and by assuming that income shocks follow an auto regressive process. Blundell and Stoker (1999) show that consumption growth, with CRRA preferences structure and stochastic income, depends on conditional variance of income innovations scaled by the fraction of income to expected wealth which, as common in this literature, is proxied by consumption. We estimate the consumption growth as follows.

$$\Delta ln(C_{it+1}) = \alpha + \gamma Z_{it} + \phi\omega_{it+1} + \beta D_v + \mu_{t+1} \tag{9}$$

Where $\Delta ln(C_{it+1})$ is consumption growth in food consumption between period t and $t+1$, Z_{it} is household characteristics, and ω_{it+1} anticipated income variance scaled by the ratio of current income to current consumption, i.e. $\omega_{it+1} = \left(\frac{y_{it}}{c_{it}}\right)^2 \sigma^2_{it+1}$. A positive ϕ indicates that consumption is lower in period t when households expect future income shocks to have a larger potential impact on consumption variability, that is when households anticipate large income shocks in the future, they decrease current consumption and increase current saving.

Our empirical strategy exploits regression (1) and the assumption that households use previous rainfall information to update their expectations on future rainfall. There are two main reasons to believe that this assumption may provide a good approximation of the reality. First, from figure (1) it is reasonable to suppose that by the mid 1980's households may have reacted to the persistent drought by revising their expectations on future rainfall. Second, there is descriptive evidence suggesting that farmers in Burkina use past rainfall information and contemporary anomalies in their environment to guess future season rainfall (Roncoli, Ingram, and Kirshnen, 2002). Discuss with H: although we have σ^2_{it+1}, it's really identified off of cross sectional variation in σ... there can't be that much change in expected variance over time That's OK, we just need to make it explicit}

We proceed by re-estimating a version of regression (1) as follows:

$$\Delta y_{itv} = \alpha_1 \Delta z_{itv} + \alpha_2 \Delta X_{itv} \otimes F_{vt} + \alpha_3 \gamma_v \otimes F_{vt} + \gamma_v + \varepsilon_{itv} \tag{10}$$

We use the parameters α_2 and α_3 to predict the income shocks entirely due to rainfall. For each household, the land endowment in terms of soil quality and topo sequence can be used to estimate income shock attributable to rainfall. To proceed further, we assume that the average cultivated area over the five years approximates the total land endowment for each household. This information is then interacted with the historical rainfall data to recover historical income shocks for each household. Then for each household, we take the conditional variance for these shocks[8].

Table 8 summarizes our estimation results. The base specification is shown in column (1). In column (2), the effect of conditional income variance on consumption growth is allowed to vary with wealth level. There is a positive and statistically significant response of income growth to income variance, thus indicating the existence of precautionary saving in household behavior. In other words, when households expect future income shocks, they reduce current consumption. In terms of magnitude, the response of poor households is six times as large as that of rich households. This is consistent if richer households have access to more insurance mechanisms than poor households. As already suggested, the wealth measure that we use may also serve as a proxy for credit access, in that case our results imply that consumption growth of households with more access to credit is less sensitive to income variance.

A potential concern is that cross-sectional shocks are confounded with the conditional variance[9]. To detect such confounding effects, we re-estimate the regression with current income shocks included as a control variable. The results are contained in columns (3) and (4). It is apparent that the results contained in columns (1) and (2) are not due to omitted contemporary shocks[10].

A final 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, so that expected returns to holding livestock are temporarily high, thus causing the livestock sales to be lower than that would have resulted in the absence of price dynamics. 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 the subject of the next section.

3.2 Risk sharing

We turn now to an examination of the extent of risk pooling within these villages. Table 4 shows that in the context of the enormous aggregate income shocks associated with the drought

[8] The procedure and all intermediary resulted are contained in the appendix.

[9] A bigger concern is the presence of the scaling term which is likely to be correlated with error term. Consumption persistence will be sufficient for such correlation. We will address this issue later.

[10] Including determinants of current income did not affect the results.

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 shocks, 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 preferences are separable between consumption and leisure, and preferences are additively separable across time and states, then consumption growth depends on aggregate resources and not on changes in own resources. Empirically, changes in individual consumption over time should be uncorrelated with changes in individual income conditional on the resources of the reference group:[11]

$$\Delta c_{itv} = \beta_1 + \beta_2 \Delta y_{itv} + \beta_3 \Delta z_{itv} + \gamma_{tv} + \varepsilon_{itv} \tag{11}$$

Where c is consumption, y is income, γ_{tv} is a village year fixed effect, z is household demographics and Δ denotes changes, and complete risk pooling implies $\beta_2 = 0$. We experiment with variants of equations (11), namely by instrumenting for income, and by accounting for potential endogeneity of the household composition. The instruments for income are described in 2.2, where we also present the first stage results.

Table 9 sets out estimation results of regression 11. OLS estimates are presented in columns (1)to (4), and IV estimates in columns (5) to (8). All regressions include village-year fixed effects to control for covariate shocks. Separate estimation of consumption smoothing with respect to total income shocks and crop income shocks are presented in columns (1) and (2). In columns (4) and (8), 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.

[11]For theoretical motivations of the empirical model, see for example Bardhan and Udry (1999) or Deaton (1997).

The point estimates suggest that on average the effect of idiosyncratic income shocks on consumption ranges from 43 percent to 51 percent with OLS estimates, and from 39 percent to 44 percent when we instrument for income.

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

In column (5) and (7), the marginal propensity to consume out of idiosyncratic income is 0.39 for total income and .40 for crop income. In columns (6) and (8), statistical tests cannot significant differences in the marginal propensity to consume between wealth groups. Thus, based on the wealth indicator that we use, there is evidence that consumption of wealthier households is more protected against idiosyncratic income shocks than consumption of poorer households, a finding which is similar to that of Jalan and Ravallion (1999). Overall, it is clear that a large proportion of idiosyncratic variation in income is uninsured for households at all levels of wealth.

In regression (11), 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, we see that aggregate shocks are important[13]. Therefore, it may be informative to test households ability to cope with aggregate shocks.

One option to examine the exposure to aggregate risk is simply to exclude the village-time fixed

[12]This is critical in our context where consumption is derived from an accounting flow.

[13]More formally, regressions of changes in consumption onto village-year dummies indicate that aggregate shocks accounted for about 60 percent of consumption growth.

effects, which summarize the covariate shocks, from regression (11), and estimate the following regression:

$$\Delta c_{itv} = \beta_1 + \tilde{\beta}_2 \Delta y_{itv} + \beta_3 \Delta z_{itv} + \varepsilon_{itv} \quad (12)$$

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 10 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.

The criticism raised by Rosenzweig and Wolpin (2000) on the use of weather shocks as instruments applies to the results presented in tables 9 and 10 as well. However, as our previous estimates (tables) indicate, our IV estimate is conservative on average, that is there is less risk sharing than that implied by our estimates.

3.2.1 Transfers

One obvious way to implement informal risk sharing is through transfers. Members of the insurance pool who experience positive income shocks transfers resources to peers who experience negative shocks. Thus, if consumption is smoothed through risk sharing, then one would expect net transfers to move in opposite direction with income shocks. We estimate transfers response to income shocks using the following regression.

$$T_{ivt} = \beta_1 + \beta_2 y_{itv} + \beta_3 z_{itv} + \gamma_{tv} + \gamma_i + \varepsilon_{itv} \tag{13}$$

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 is met with an increase of CFA 1 in transfers, and vice-versa. Estimates of (13) are reported in table **??**. 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 10. Moreover, the descriptive statistics (table 2) indicated that transfers were too small to play any significant role in consumption smoothing. In table 12 we test the extent to which self-insurance mechanisms (grain storage and livestock sales) respond to idiosyncratic shocks, by estimating versions of regression 13 where the dependent variable is grain storage (columns 1 and 2) and livestock sales (columns 3 and 4), respectively. It is apparent that grain storage is the only asset that is used for insurance.

Overall, the response of transfers and grain storage to income shocks support our findings: there is little insurance and that consumption smoothing occurs essentially through self-insurance. Figure 3 plots the distribution of the estimated error terms of the PIH model, the risk sharing model and the buffer stock model from panel 1 to 3, respectively, along with a normal density with the same mean and variance as the residuals. In the first two panels, the substantial mass in the tail and the skewness of the distributions suggest that the residuals are far from normal. The distribution of the residuals from the buffer stock (third panel) is much closer to normal, although tails still contain more mass than a normal distribution with the same variance. These conclusions are supported by the parametric tests provided below the figure. Thus, as first approximation the buffer stock model seems to provide a better description of the data.

4 Income shocks and herd management

One of the prominent hypotheses advanced in the literature to explain low livestock offtake during periods of negative rainfall shocks is that livestock lagged price dynamics provide additional incentives to hold onto livestock. It is argued that livestock mortality during drought periods and reduced pressure on common grazing land afterwards, lead to higher price in subsequent periods because of supply shortage (Fafchamps, Udry, and Czukas, 1998)[14]. 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 have seen in Table 12 (columns 3 and 4) that even within villages (that is, conditional on the future path of prices), households subject to transitory idiosyncratic shocks are no more likely to sell livestock than other households.

Since price dynamics fail to account for livestock overstocking, we turn to livestock production technology. We start from the observation that, even in the absence of income shocks, optimal herd management still implies periodic sales. That is even if livestock rearing were totally unrelated to consumption smoothing objectives, livestock offtake would still occur. This type of offtake, however, obeys some optimality rules in the sense that offtake decisions are determined only by profit objectives[15]. Deviations from optimality rules provides some suggestive evidence that herd management constraints are binding.

To motivate our empirical model, consider the standard household model under complete markets, so that production and consumption decisions are separable. 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. For simplicity, suppose that households are only producing livestock of different types (e.g. cattle, goats, and sheep). Under complete market assumption, the household maximizes the profit derived from each type of livestock, the same way profit is maximized on each plot when households are producing from multiple plots and markets are complete (Udry, 1999). We describe the household decision as follows. In any point in time and state of the nature,

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

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

the household observes his stock of each type of livestock (which is given by the entire history of previous offtake decisions), the local production conditions, labor costs for rearing animals, the local price dynamics and then decides on offtake. The offtake decision consists in picking a specific animal to sell, i.e. choosing the type of livestock, the age, and the sex. We formalize the offtake decision as follows.

$$y_{ia} = f(l_{ia}, n_{ia}, \omega_i) \tag{14}$$

Where l_{ia} is labor applied on animal of type a by household i, n_{ia} is stock of animal a of household i, and ω is a shock that affects household i. We make explicit that shocks in other income sources affect offtake decisions[16]. Regardless of period and state, provided that markets are complete the profit function at the optimum can be expressed as follows (household index is dropped):

$$\pi_a(n_{a0}, x_a, \omega) = f(n_a^*(n_{a0}, x_a, \omega), l_a^*(n_{a0}, x_a, \omega), x_a) - wl^*(.) \tag{15}$$

Where n_0 is initial stock of animal of type a, w is labor cost, and x is other variables entering the production of the specific type of animal, such as access to grazing. Now, consider a household with two types of livestock, a and b. Since profit is maximized for each type of animal, we can write separate profit functions for a and b. To see the influence of the shock on the optimal herd management path, consider the following first order approximation of the difference between the profits derived from a and b:

$$\pi_a(.) - \pi_b(.) \simeq \frac{\partial \pi}{\partial x}(x_a - x_b) + \frac{\partial \pi}{\partial n}(n_{a0} - n_{b0}) + \frac{\partial \pi}{\partial \omega}(\omega - \omega) \tag{16}$$

That is income shock affecting the entire household should not affect the differences between the outputs y_a and y_b, conditional on n_0 and x. In other words, optimal herd management implies that for any pair of animals sold by a household in a given period, the difference between the age

[16]Later, we will consider the case where shocks may have animal specific effects. For example, we could have $\omega_i = \widetilde{\omega_i} + \rho_a$.

at which animals are sold depends only on herd composition, local market prices and production costs. In particular, crop income shock does not play any role in this regression.

Note that this result depends on the assumption that livestock production technology is constant across animals. If production function is animal specific, (i.e. $f_a \neq f_b$) then our result does not hold[17]. Nevertheless, we believe that the the conclusion can still be used to provide some indication of some distress sales.

For empirical estimation, we have data on the age, the type and the sex of each animal sold. To pool all animals (cattle, goat, and sheep) we use standardized age based on the average life expectancy of each type of animal.

$$s_{it} = \tau_1 \Delta y_{it} + \tau_2 \Delta z_{it} + \tau_3 m_{lstv} + \mu_{it} \tag{17}$$

Where s_{it} is standardized age at sale, y is income (excluding livestock sales), z is household composition capturing labor costs, and m_{lstv} is a livestock, sex, village, year dummy variable which capture the local market conditions. Note that the fixed effects will capture both current and future prices. Optimal herd management implies that households choose the age at which each animal is sold based only on the local market conditions (m_{lstv}) and the household labor supply (z_{it}), which together determined the net profit per animal. Δy is redundant in equation (17), and thus can serve for an exclusion restriction test. In particular a significant and 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. A positive τ also reflects failure of financial markets, since if household could borrow, income shocks should not matter to optimal herd management.

In table 13, we report estimates of equation (17). We also explore the sensitivity of the income variable to the inclusion of household labor supply. The estimated income coefficient ranges from .33 to .36 and is statistically significant. The estimated coefficient implies that on average, for each income drop of CFA 1000 per adult equivalent, household sell their animal eight months earlier. This supports the hypothesis of distress sales and indicates that households are approaching a

[17]This should be the case for instance if different species respond differently to shortage of grazing.

threshold where additional sales are undermining herd reproductive potential.

The estimation results in table 13 suggest that livestock biological constraints in livestock production are critical on offtake decisions. In particular the complex price dynamics and biological gestation lags can hinder the self-insurance role of livestock, so that households choose intentionally to destabilize consumption in order to retain livestock.

5 Conclusion

This paper has investigated whether rural households in the WASAT who experience annual income variation use livestock sales to smooth consumption. We found little consumption smoothing. Moreover, households relied on self-insurance to smooth consumption and risk sharing was not found to be central for household consumption smoothing.

The evidence uncovered suggests that households intentionally destabilized consumption in order to conserve more livestock, contradicting the simple optimal saving theories. Household behavior appears to be more consistent with a buffer stock model than risk sharing or PIH models. Livestock offtake appear to be constrained by herd management considerations.

Our reduced forms results, however, provide some insights in the saving behavior of poor households. In particular the findings that poor households, already close to subsistence levels subject to large income shocks show still hold onto their livestock. A possible extension, based on the data that we have, is to develop a structural model to account for livestock production and subsistence constraints to assess the degree to which herd management considerations account for the lack of use of livestock to smooth consumption. 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 food subsistence requirements may provide a 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
	0.75	0.68	0.92	0.63	0.42
Silgey	444	314	425	295	234
	0.93	0.65	0.89	0.62	0.49
Sudanian region					
Kolbila	646	555	573	423	477
	0.89	0.76	0.79	0.58	0.66
Ouonon	504	525	401	533	469
	0.7	0.73	0.55	0.74	0.65
Northern-Guinean region					
Koho	666	770	725	783	877
	0.7	0.81	0.76	0.82	0.92
Sayero	865	561	634	676	664
	0.9	0.59	0.67	0.71	0.7

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

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

Table 2: Summary statistics

	Vill 1	Vill 2	Vill 3	Vill 4	Vill 5	Vill 6
cons	32.98	27.57	22.82	15.78	17.92	19.42
	(17.23)	(12.44)	(13.31)	(6.36)	(8.83)	(11.61)
cropincome	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)
dcons	-6.23	-4.51	-1.08	2.38	2.85	0.65
	(25.67)	(18.38)	(16.81)	(7.54)	(13.61)	(13.53)
dcropincome	-9.50	-5.84	-9.23	1.95	5.50	2.35
	(21.52)	(16.25)	(16.70)	(8.58)	(15.54)	(27.70)
dincome	-10.53	-5.29	-8.25	1.94	3.98	3.00
	(21.51)	(22.04)	(16.66)	(9.01)	(17.22)	(28.55)
aidcfa	0.47	0.30	0.01	0.05	0.00	0.00
	(1.09)	(0.61)	(0.02)	(0.14)	0.00	0.00
transf. in	0.78	0.61	0.22	0.16	0.27	0.05
	(1.31)	(1.60)	(0.68)	(0.35)	(0.68)	(0.17)
transf. Out	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 trans	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 number	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 num	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 num	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)
hh size (ae)	7.43	7.60	9.75	8.54	12.71	8.21
	(4.62)	(4.04)	(5.45)	(5.23)	(7.96)	(5.37)
hh size	9.78	9.93	13.11	11.64	15.95	11.07
	(6.15)	(5.52)	(7.45)	(7.29)	(10.75)	(7.41)
ad male	2.46	2.76	2.80	2.32	3.77	2.28
	(1.41)	(1.31)	(1.75)	(1.74)	(2.39)	(1.28)
ad female	2.83	2.85	3.68	3.69	4.50	3.36
	(2.10)	(1.88)	(2.32)	(2.41)	(3.04)	(2.26)
boys	2.28	2.16	3.55	2.94	3.87	2.76
	(2.13)	(1.99)	(2.35)	(2.35)	(3.19)	(2.46)
girls	2.20	2.16	3.08	2.69	3.82	2.67
	(2.31)	(2.18)	(2.55)	(2.24)	(3.98)	(2.62)
Per rich	22.20	45.83	28.00	40.63	46.67	42.86
hh 82	20	22	21	17	29	23

Table 3: First stage regressions: idiosyncratic shocks

	(1)	(2)	(3)	(4)	(5)	(6)
	Income	Income-rich	Income-poor	Crop income	crop income-rich	Crop income-poor
Adult males	-0.790	-2.777	5.356	0.144	-1.390	4.297
	[0.38]	[0.98]	[1.26]	[0.08]	[0.58]	[1.05]
Adult females	-0.184	-0.370	4.213	0.755	1.058	3.993
	[0.10]	[0.15]	[1.12]	[0.45]	[0.49]	[1.10]
Boys	0.720	0.597	4.831	0.950	0.408	5.020
	[0.61]	[0.39]	[1.94]	[0.88]	[0.31]	[2.09]*
Girls	0.686	0.623	3.518	0.673	-0.099	4.236
	[0.46]	[0.31]	[1.11]	[0.50]	[0.06]	[1.38]
hh. Size	-2.237	-1.674	-6.599	-1.418	-0.617	-5.830
	[1.82]	[1.05]	[2.26]*	[1.27]	[0.46]	[2.07]*
age of hh head	-0.340	-0.818	1.127	-0.184	-0.474	1.029
	[0.58]	[1.18]	[0.71]	[0.35]	[0.81]	[0.67]
age of hh head squared	0.006	0.008	-0.005	0.006	0.006	-0.003
	[0.92]	[0.96]	[0.29]	[0.94]	[0.85]	[0.15]
Rainfall deviation interacted with						
Seno soil area	-0.040	-0.176	0.045	0.001	-0.109	0.059
	[1.29]	[3.34]**	[1.17]	[0.04]	[2.45]*	[1.59]
Zinka soil area	0.008	0.016	-0.032	0.014	0.031	-0.026
	[0.15]	[0.21]	[0.34]	[0.27]	[0.48]	[0.29]
Bissiga soil area	0.012	-0.111	0.033	-0.004	-0.129	0.037
	[0.27]	[1.50]	[0.62]	[0.10]	[2.05]*	[0.73]
Raspuiga soil area	0.037	-0.017	-0.007	0.039	-0.022	0.076
	[0.61]	[0.21]	[0.02]	[0.71]	[0.32]	[0.21]
Ziniare soil area	0.011	-0.105	0.135	0.016	-0.091	0.117
	[0.22]	[1.49]	[1.27]	[0.34]	[1.51]	[1.15]
Other soil area	0.033	-0.074	0.054	0.041	-0.061	0.072
	[1.95]	[2.34]*	[2.67]**	[2.70]**	[2.28]*	[3.72]**
Low land area	-0.100	-0.059	-0.051	-0.124	-0.111	-0.059
	[3.82]**	[1.43]	[1.28]	[5.25]**	[3.14]**	[1.52]
Near low land area	-0.039	0.069	-0.097	-0.050	0.031	-0.096
	[1.81]	[1.67]	[3.71]**	[2.57]*	[0.90]	[3.79]**
Midslope area	-0.021	0.064	-0.046	-0.036	0.052	-0.072
	[0.91]	[1.42]	[1.73]	[1.76]	[1.35]	[2.81]**
Near upland area	-0.005	0.240	-0.059	-0.038	0.157	-0.078
	[0.07]	[1.94]	[0.78]	[0.65]	[1.49]	[1.07]
Near home area	-0.151	-0.262	-0.087	-0.108	-0.158	-0.065
	[4.72]**	[3.18]**	[2.09]*	[3.74]**	[2.26]*	[1.63]
Distance to home	0.000	0.000	0.000	0.000	0.000	0.000
	[0.42]	[0.85]	[0.72]	[0.49]	[0.75]	[0.29]
Constant	28.568	63.057	-14.797	8.264	31.166	-15.350
	[1.91]	[3.07]**	[0.41]	[0.61]	[1.79]	[0.44]
Observations	464	203	261	464	203	261
Number of hh	126	55	71	126	55	71
R-squared	0.58	0.64	0.69	0.6	0.66	0.7
F test-rainfall interactions	7.44	4.17	6.52	7.91	4.67	6.41
F-test village-year dummies	16.93	6.52	11.14	20.13	7.5	12.47

Absolute value of t statistics in brackets

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

Table 4: Magnitude of income shocks

Villages	Shock nature	Crop income	Total income
Woure			
	Aggregate	1.787	2.384
	Idiosyncratic	0.585	0.579
Silgey			
	Aggregate	2.179	2.307
	Idiosyncratic	0.562	0.569
Kolbila			
	Aggregate	2.179	2.307
	Idiosyncratic	0.520	0.490
Ouonon			
	Aggregate	1.113	0.736
	Idiosyncratic	0.336	0.303
Koho			
	Aggregate	1.819	1.691
	Idiosyncratic	0.506	0.472
Sayero			
	Aggregate	0.66	0.56
	Idiosyncratic	0.42	0.37

Coefficients of variation of each type shocks.

Table 5: PIH tests

	(1)	(2)
	cons	cons
Permanent income	0.429	
	[2.90]***	
Transitory income	0.613	
	[9.87]***	
Unexplained income	0.440	
	[8.21]***	
Rich		
Permanent income		0.291
		[1.81]*
Transitory income		0.556
		[5.59]***
Unexplained income		0.477
		[5.40]***
Poor		
Permanent income		0.848
		[3.68]***
Transitory income		0.662
		[7.98]***
Unexplained income		0.456
		[6.43]***
age of hh head	-2.038	-1.776
	[1.38]	[1.20]
age of hh head sq.	0.028	0.025
	[1.65]	[1.43]
adult female	2.250	2.335
	[1.14]	[1.17]
adult male	-0.962	-1.047
	[0.58]	[0.64]
boys	0.369	0.533
	[0.32]	[0.46]
girls	0.531	0.365
	[0.39]	[0.27]
hh size	-1.092	-0.653
	[0.95]	[0.57]
Constant	47.276	35.146
	[1.44]	[1.06]
Observations	395	395
Number of hh	112	112
R-squared	0.43	0.44

Absolute value of t statistics in brackets

* significant at 5%; ** significant at 1

Table 6: Labor response to rainfall

	(1)	(2)
	Dummies	Village-Year FE
plot area	25.93	14.628
	[0.26]	[0.15]
plot area squared	1.108	1.158
	[2.55]**	[2.71]***
perct. of area fertilized last year	168.44	197.76
	[0.76]	[0.90]
perct. of area manured last year	259.661	200.93
	[1.74]*	[1.36]
wtd avg of years since last fal	-1.855	-3.405
	[0.55]	[0.95]
head age	-4.153	-1.975
	[1.10]	[0.52]
head age squared	-0.019	-0.027
	[0.59]	[0.83]
adult male	113.099	92.741
	[3.26]***	[2.65]***
adult female	62.511	67.798
	[1.89]*	[2.06]**
children male	32.68	37.213
	[1.58]	[1.83]*
children female	20.579	21.663
	[1.09]	[1.17]
hectares of topo1	-97.257	-95.137
	[0.91]	[0.90]

hectares of topo2	-132.7	-116.259
	[1.29]	[1.14]
hectares of topo3	-115.334	-114.482
	[1.16]	[1.15]
hectares of topo4	-91.357	-59.4
	[0.79]	[0.52]
hectares of soils2124	37.735	-2.817
	[1.20]	[0.08]
hectares of soil31	-136.921	47.63
	[1.35]	[0.43]
hectares of soil32	-102.948	-18.458
	[1.47]	[0.25]
hectares of soil35	-42.346	-46.464
	[0.63]	[0.69]
hectares of soil45	178.645	321.83
	[1.51]	[2.19]**
hectares of soil51	-12.921	-7.234
	[0.30]	[0.17]
wtd avg of distance to plots	0.037	0.024
	[0.72]	[0.45]
wtd avg of location of plots	50.592	42.199
	[0.50]	[0.41]
rainfall	-1.388	
	[0.86]	
rain. squared	0.001	
	[0.82]	
Rainfall deviation interacted with		
hectares of topo1	0.24	0.238

	[1.12]	[1.13]
hectares of topo2	0.299	0.267
	[1.41]	[1.27]
hectares of topo3	0.261	0.266
	[1.26]	[1.29]
hectares of topo4	0.238	0.175
	[0.99]	[0.73]
hectares of soils2124	-0.078	0.031
	[1.03]	[0.37]
hectares of soil31	0.241	-0.1
	[1.29]	[0.49]
hectares of soil32	0.229	0.054
	[1.75]*	[0.39]
hectares of soil35	0.094	0.093
	[0.82]	[0.81]
hectares of soil45	-0.34	-0.615
	[1.50]	[2.18]**
hectares of soil51	0.027	0.018
	[0.43]	[0.29]
plot area	-0.212	-0.194
	[1.04]	[0.97]
wtd avg of location of plots	-0.016	-0.019
	[0.08]	[0.09]
wtd avg of distance to plots	0	0
	[0.88]	[0.62]
perct. of area fertilized last year	-0.16	-0.18
	[0.43]	[0.48]
perct. of area manured last year	-0.416	-0.339

	[1.47]	[1.20]
wtd avg of years since last fal	0.004	0.006
	[0.53]	[0.84]
adult male	-0.142	-0.106
	[2.48]**	[1.83]*
adult female	-0.067	-0.071
	[1.16]	[1.24]
children male	-0.04	-0.053
	[1.12]	[1.49]
children female	-0.021	-0.025
	[0.66]	[0.78]
head age	0.015	0.012
	[2.71]***	[2.20]**
Constant	671.236	281.145
	[1.35]	[2.30]**
Observations	337	337
R-squared	0.65	0.33
F join test:	2.32	1.88
Implied labor response	-0.163	-0.075
	[-.61,.16]	[-1.19, 1.65]

Absolute value of t statistics in brackets

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

Column (1) includes village and year dummies

Column (2) includes village-year fixed effects

Table 7: Grain stock and livestock sales response to changes in income

	(1)	(2)	(3)	(4)
	grain stock		livestock sales	
Permanent income	0.327		-0.027	
	[2.15]**		[5.95]***	
Transitory income	0.275		-0.004	
	[3.56]***		[2.04]**	
Unexplained income	0.043		-0.002	
	[0.78]		[1.02]	
Rich				
Permanent income		0.353		-0.028
		[2.20]**		[5.96]***
Transitory income		0.502		-0.003
		[4.75]***		[1.04]
Unexplained income		-0.067		-0.01
		[0.78]		[3.70]***
Poor				
Permanent income		0.227		-0.013
		[0.94]		[1.95]*
Transitory income		0.067		-0.001
		[0.62]		[0.41]
Unexplained income		0.053		0.006
		[0.71]		[2.71]***
age of hh head	5.136	5.569	-0.013	-0.008
	[3.44]***	[3.74]***	[0.71]	[0.47]
age of hh head sq.	-0.05	-0.053	0	0
	[3.28]***	[3.51]***	[1.13]	[0.84]
adult females	3.84	3.578	-0.068	-0.058
	[1.30]	[1.23]	[1.07]	[0.93]
adult males	0.641	0.425	-0.008	-0.017
	[0.26]	[0.18]	[0.14]	[0.33]
boys	1.2	1.03	-0.059	-0.051
	[0.79]	[0.69]	[1.64]	[1.45]
girls	4.398	4.215	0.029	0.027
	[2.04]**	[1.98]**	[0.64]	[0.63]
hh size	1.009	1.186	-0.11	-0.103
	[0.52]	[0.62]	[2.88]***	[2.75]***
Constant	-181.903	-194.011	1.954	1.613
	[5.01]***	[5.31]***	[3.99]***	[3.36]***
Observations	340	340	464	464
Number of hh	126	126	126	126
R-squared	0.38	0.41	0.23	0.28

Absolute value of t statistics in brackets

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

Table 8: Test for precautionary saving

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	OLS	IVE	IVE	OLS-wealth	OLS-wealth	IVE-wealth	IVE-wealth
scaled cons var.	0.00095		0.00086	0.00096				
	[2.68]***		[2.12]**	[2.93]***				
scaled inc. var		0.00027						
		[2.05]**						
dincome				0.36126				
				[4.08]***				
scaled in. var. rich						0.00025		
						[1.92]*		
scaled in. var. poor						0.00268		
						[2.27]**		
scaled cons. var rich					0.00072		0.00078	0.00082
					[1.78]*		[1.84]*	[2.29]**
scaled cons. var poor					0.00169		0.00335	0.00365
					[2.30]**		[2.34]**	[3.06]***
dincome rich								0.44811
								[2.66]***
dincome poor								0.31611
								[3.09]***
adult males	-0.073	0.686	0.419	-0.111	-0.146	0.804	0.033	-0.637
	[0.04]	[0.39]	[0.24]	[0.08]	[0.08]	[0.45]	[0.02]	[0.42]
adult females	-0.092	-0.181	-0.339	-0.010	-0.145	-0.504	-0.820	-0.206
	[0.06]	[0.12]	[0.23]	[0.01]	[0.10]	[0.33]	[0.55]	[0.15]
boys	0.017	0.224	0.245	0.530	0.018	0.288	0.308	0.700
	[0.02]	[0.26]	[0.29]	[0.76]	[0.02]	[0.33]	[0.37]	[0.94]
girls	-1.278	-1.253	-1.200	-0.833	-1.203	-1.089	-1.092	-0.620
	[0.98]	[0.94]	[0.94]	[0.78]	[0.92]	[0.82]	[0.85]	[0.56]
hh size	0.434	0.187	0.284	0.203	0.418	0.136	0.445	0.306
	[0.42]	[0.18]	[0.28]	[0.24]	[0.41]	[0.13]	[0.44]	[0.35]
age of hh head	0.009	0.090	0.052	0.104	-0.021	-0.006	-0.037	0.027
	[0.03]	[0.22]	[0.13]	[0.31]	[0.06]	[0.01]	[0.09]	[0.08]
age of hh head squared	-0.001	-0.002	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
	[0.28]	[0.45]	[0.38]	[0.41]	[0.19]	[0.23]	[0.19]	[0.24]
wealthy					0.927	1.465	0.850	1.413
					[0.52]	[0.72]	[0.44]	[0.84]
Constant	-14.074	-15.376	-14.826	-11.429	-13.682	-13.446	-13.642	-11.112
	[1.61]	[1.50]	[1.50]	[1.39]	[1.56]	[1.31]	[1.38]	[1.30]
Observations	279	279	279	279	279	279	279	279
R-squared	0.35	0.35			0.36	0.36		

Village and year dummies also included in regressions

All variables in first differences except wealth and head age

Instruments for log income: rainfall interactions and village-year dummies

Absolute value of t statistics in brackets

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

Table 9: Test for full insurance

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	OLS	OLS	OLS	IVE	IVE	IVE	IVE
income	0.427				0.392			
	[10.16]***				[4.85]***			
Poor income		0.487				0.422		
		[9.76]***				[4.75]***		
Rich income		0.345				0.287		
		[6.12]***				[1.85]*		
cropincome			0.449				0.400	
			[10.32]***				[4.93]***	
Poor cropincome				0.508				0.437
				[9.71]***				[4.61]***
Rich cropincome				0.374				0.311
				[6.51]***				[2.19]**
age of hh head	-1.584	-1.802	-1.331	-1.568	-1.526	-1.700	-1.341	-1.571
	[1.23]	[1.41]	[1.04]	[1.23]	[1.13]	[1.24]	[1.00]	[1.14]
age of hh head squared	0.020	0.023	0.015	0.018	0.019	0.021	0.015	0.018
	[1.31]	[1.49]	[0.99]	[1.19]	[1.15]	[1.26]	[0.92]	[1.07]
adult females	2.153	2.259	2.571	2.635	2.656	2.853	2.939	3.020
	[1.24]	[1.31]	[1.50]	[1.54]	[1.47]	[1.57]	[1.65]*	[1.69]*
adult males	0.478	0.493	0.973	0.980	0.727	0.873	1.149	1.206
	[0.31]	[0.33]	[0.65]	[0.65]	[0.45]	[0.54]	[0.73]	[0.77]
boys	1.389	1.208	1.510	1.338	1.533	1.409	1.680	1.539
	[1.38]	[1.20]	[1.51]	[1.34]	[1.46]	[1.34]	[1.62]	[1.46]
girls	0.409	0.466	0.749	0.737	0.654	0.790	0.872	0.887
	[0.34]	[0.39]	[0.63]	[0.62]	[0.53]	[0.63]	[0.71]	[0.72]
hh size	-1.555	-1.583	-2.186	-2.128	-1.909	-2.096	-2.458	-2.467
	[1.47]	[1.51]	[2.10]**	[2.05]**	[1.65]*	[1.78]*	[2.21]**	[2.23]**
Constant	43.033	46.693	46.780	50.422	45.723	50.634	52.190	55.174
	[1.66]*	[1.80]*	[1.81]*	[1.95]*	[1.67]*	[1.80]*	[1.92]*	[1.98]**
Observations	395	395	395	395	395	395	395	395
Number of hh	112	112	112	112	112	112	112	112
R-squared	0.61	0.62	0.62	0.62				

Absolute value of t statistics in brackets
* significant at 10%,** significant at 5%; *** significant at 1%

Table 10: Test for full insurance, inclusive of idiosyncratic and aggregate risks

	(1)	(2)	(3)	(4)
	IVE	IVE	IVE	IVE
income	0.347			
	[3.78]***			
Poor income		0.386		
		[3.33]***		
Rich income		0.288		
		[2.01]**		
cropincome			0.380	
			[4.16]***	
Poor cropincome				0.439
				[3.65]***
Rich cropincome				0.304
				[2.24]**
age of hh head	-1.431	-1.570	-1.540	-1.773
	[0.96]	[1.04]	[1.04]	[1.18]
age of hh head squared	0.020	0.022	0.021	0.024
	[1.18]	[1.27]	[1.24]	[1.39]
adult females	2.819	2.927	2.819	2.921
	[1.38]	[1.44]	[1.40]	[1.46]
adult males	-0.283	-0.248	-0.205	-0.164
	[0.16]	[0.14]	[0.12]	[0.10]
biys	0.670	0.533	0.697	0.523
	[0.56]	[0.44]	[0.59]	[0.44]
girls	1.027	1.096	1.035	1.048
	[0.73]	[0.78]	[0.75]	[0.76]
hh size	-1.609	-1.625	-1.924	-1.866
	[1.34]	[1.36]	[1.65]*	[1.61]
Constant	37.520	39.576	44.266	47.224
	[1.18]	[1.24]	[1.41]	[1.51]
β-$\tilde{\beta}$				
Total income	-0.045			
Poor		-0.036		
Rich		0.001		
Crop income			-0.020	
Poor				0.002
Rich				-0.007
Observations	395.0	395.0	395.0	395.0
Number of hh	112.0	112.0	112.0	112.0
R-squared				

Absolute value of t statistics in brackets

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

Separate village and year dummies also included

Table 11: Transfer response to income shocks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	IVE	OLS	IVE	OLS	IVE	OLS	IVE
income	-0.009	-0.008						
	[2.20]*	[0.81]						
Poor income			-0.010	-0.007				
			[1.61]	[0.57]				
Rich income			0.003	-0.014				
			[0.40]	[0.70]				
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]
adult females	0.000	0.045	0.020	0.054	0.027	0.042	0.018	0.043
	[0.00]	[0.20]	[0.09]	[0.24]	[0.13]	[0.19]	[0.08]	[0.19]
adult males	0.002	0.078	0.071	0.083	0.070	0.073	0.068	0.073
	[0.02]	[0.38]	[0.37]	[0.41]	[0.37]	[0.36]	[0.36]	[0.36]
boys	-0.073	-0.064	-0.068	-0.070	-0.086	-0.066	-0.065	-0.068
	[0.99]	[0.49]	[0.54]	[0.53]	[0.69]	[0.51]	[0.52]	[0.51]
girls	-0.006	-0.073	-0.066	-0.067	-0.063	-0.076	-0.065	-0.075
	[0.06]	[0.47]	[0.44]	[0.42]	[0.42]	[0.49]	[0.43]	[0.48]
hh size	-0.012	-0.021	-0.013	-0.030	-0.009	-0.014	-0.016	-0.013
	[0.14]	[0.15]	[0.10]	[0.20]	[0.07]	[0.10]	[0.12]	[0.10]
age of hh head	-0.006	-0.108	-0.084	-0.117	-0.106	-0.110	-0.082	-0.113
	[0.22]	[0.65]	[0.52]	[0.68]	[0.66]	[0.66]	[0.52]	[0.66]
age of hh head squared	0.000	0.002	0.001	0.002	0.002	0.002	0.001	0.002
	[0.26]	[0.75]	[0.64]	[0.79]	[0.80]	[0.78]	[0.64]	[0.78]
Constant	0.762	1.705	0.645	1.955	1.366	1.382	0.979	1.650
	[1.02]	[0.50]	[0.20]	[0.55]	[0.42]	[0.41]	[0.30]	[0.47]
Observations	399	399	399	399	399	399	399	399
Number of hh	114	114	114	114	114	114	114	114
R-squared			0.580		0.570		0.580	

Absolute value of t statistics in brackets
* significant at 5%; ** significant at 1

Table 12: Grain stock and livestock sales idiosyncratic shocks

	(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]**
adult male	-1.201	-0.912	-0.039	-0.043
	[0.69]	[0.51]	[0.53]	[0.60]
adult female	-0.749	-0.551	-0.004	-0.01
	[0.48]	[0.35]	[0.06]	[0.16]
boys	0.722	0.779	-0.031	-0.032
	[0.71]	[0.79]	[0.72]	[0.77]
girls	0.123	0.317	0.032	0.03
	[0.10]	[0.26]	[0.61]	[0.58]
hh size	0.966	0.618	-0.132	-0.123
	[0.86]	[0.48]	[2.83]**	[2.48]*
age hh head	-1.709	-1.794	-0.018	-0.016
	[1.31]	[1.40]	[0.85]	[0.76]
age hh head sq.	0.022	0.022	0	0
	[1.35]	[1.40]	[0.87]	[0.78]
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 statistics in brackets
* significant at 10%,** significant at 5%; *** significant at 1%
household fixed effects and village-year dummies also included

Table 13: Income shocks and livestock age at sale shocks

	(1)	(2)	(3)	(4)
dcropincome	0.034	0.034	0.036	0.033
	[2.90]***	[2.90]***	[3.00]***	[2.77]***
admale	0.28	0.28	0.293	0.317
	[3.31]***	[3.31]***	[3.44]***	[3.71]***
adfemale	-0.099	-0.099	-0.068	-0.159
	[1.70]*	[1.70]*	[1.08]	[2.18]**
age of hh head	0.071	0.071	0.059	0.054
	[2.12]**	[2.12]**	[1.72]*	[1.56]
headage*headage	-0.001	-0.001	-0.001	0
	[2.11]**	[2.11]**	[1.65]*	[1.47]
kidfemale			-0.068	-0.059
			[1.31]	[1.13]
kidmale				0.117
				[2.38]**
Constant	-2.066	-2.066	-1.783	-1.782
	[2.32]**	[2.32]**	[1.95]*	[1.96]*
Observations	930	930	930	930

Absolute value of t statistics in brackets * significant at 5%; ** significant at 1%

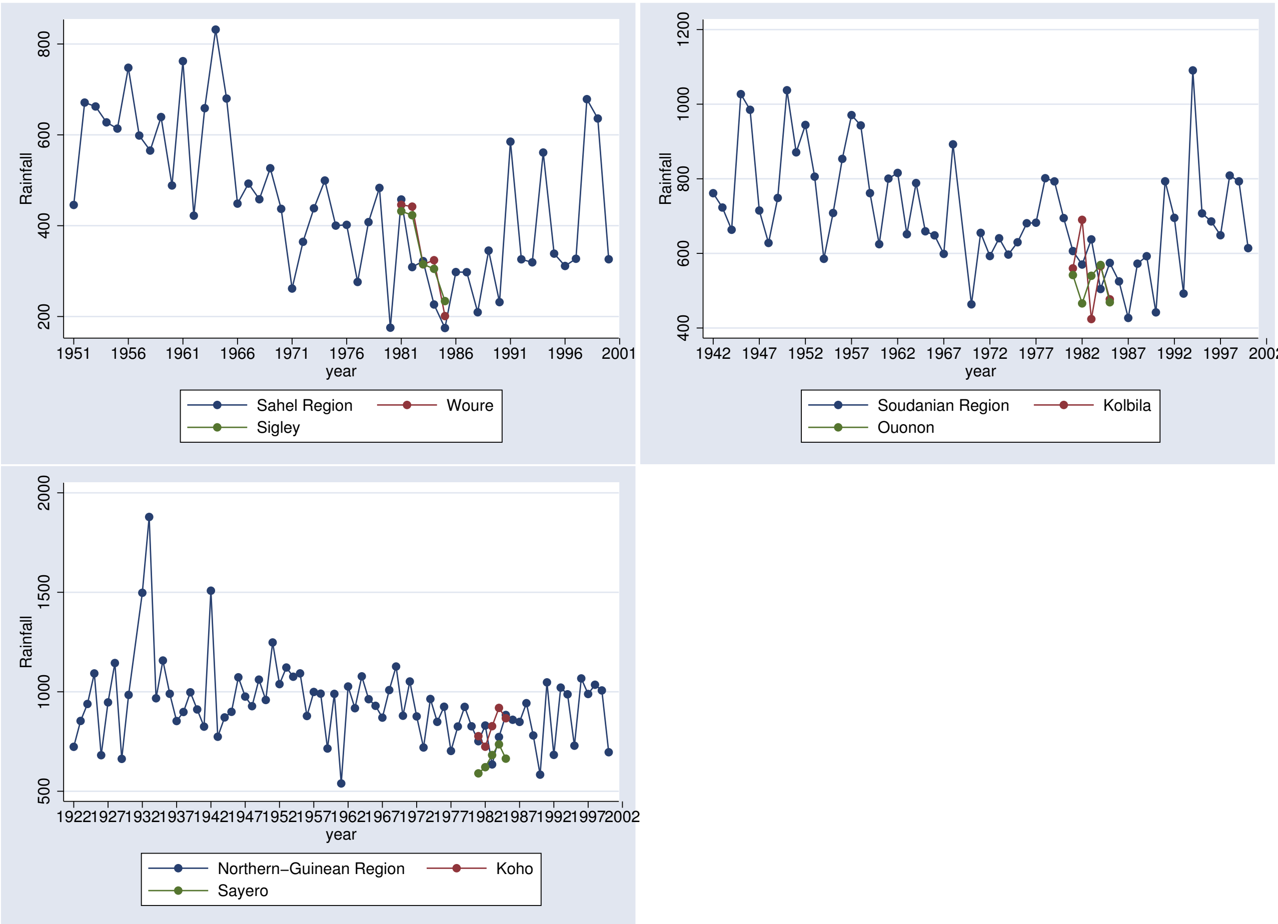

Figure 1: Long run rainfall

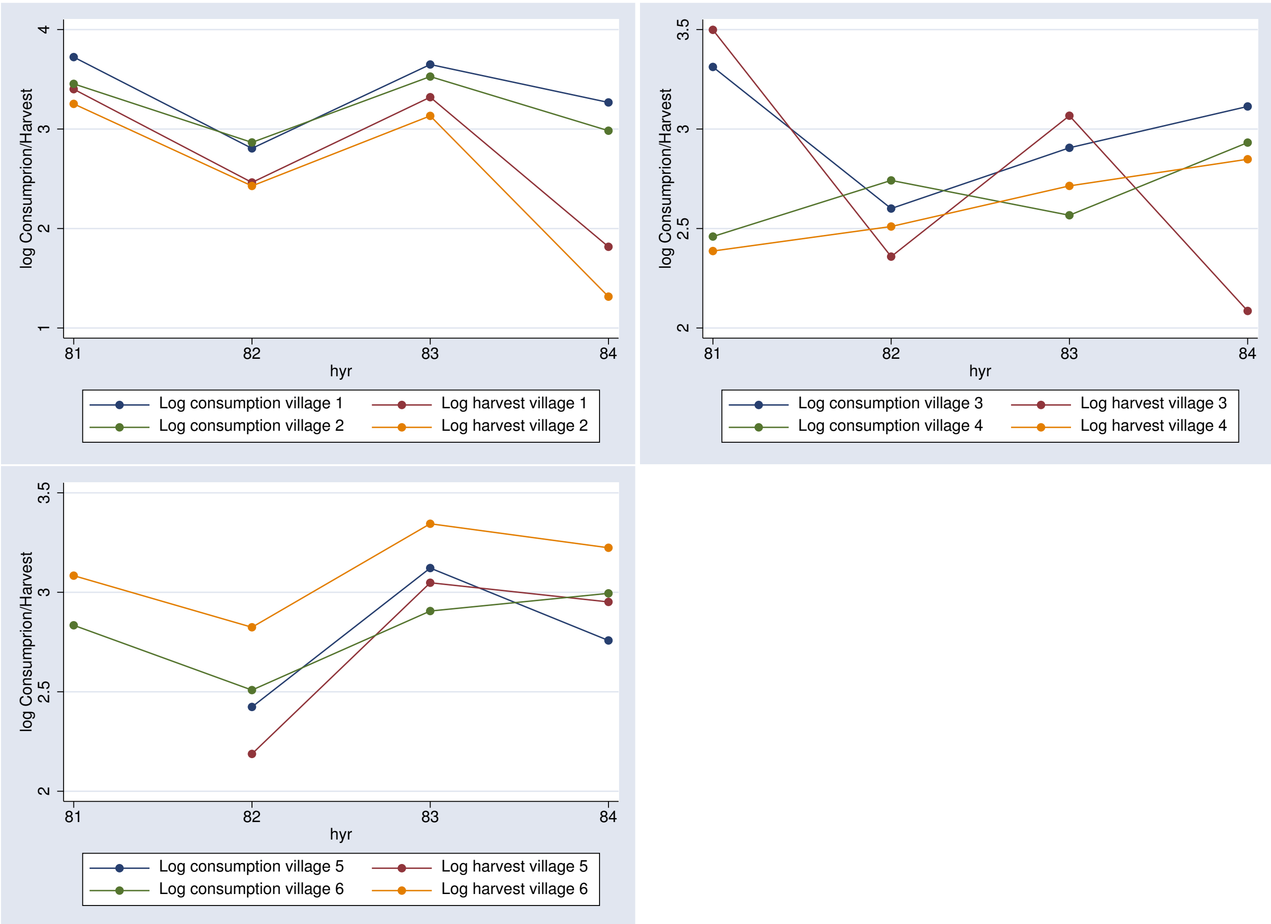

Figure 2: Village income and consumption growth

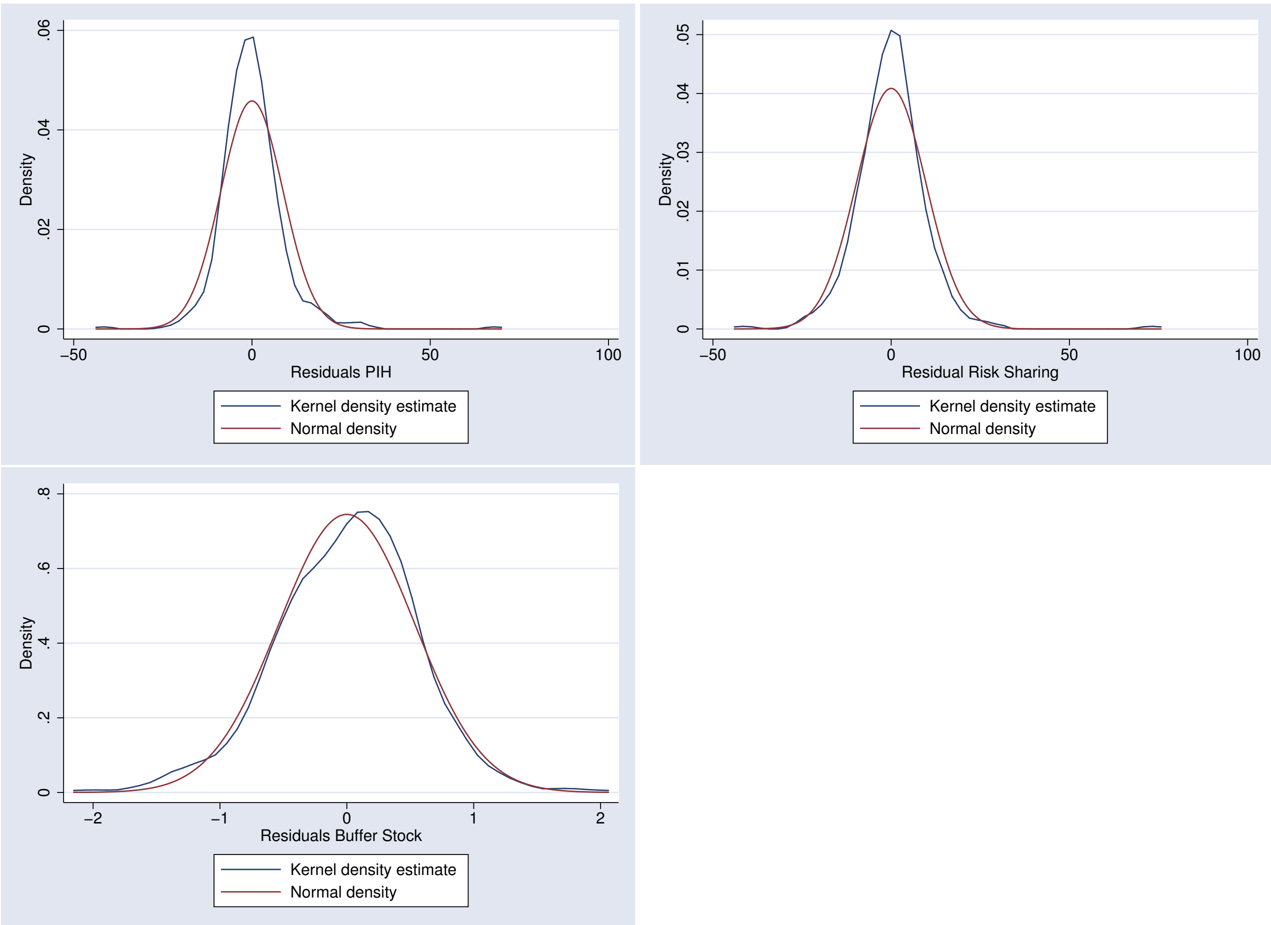

Figure 3: Distribution of the residuals from 3 benchmark models compared to the normal distribution