
WHO SMOOTHES WHAT?
ASSET SMOOTHING, CONSUMPTION SMOOTHING & UNMITIGATED RISK IN BURKINA FASO

PRELIMINARY DRAFT—COMMENTS WELCOME!

Travis Lybbert, University of California, Davis

Michael Carter, University of California, Davis

December 2009

Abstract

The permanent income hypothesis posits that rational agents smooth consumption as transitory income fluctuates. Empirical evidence of this behavior among the poor has been mixed, but often suggests very limited consumption smoothing tendencies. We contend that much of this evidence pools agents that pursue different smoothing strategies and consequently produce muddled tests of consumption smoothing. In this paper, we use dynamic asset smoothing as a theoretical structure to justify wealth-differentiated smoothing tendencies. We test this theory by allowing the smoothing target to shift from assets and consumption as livestock wealth increases. We find evidence for the existence of a threshold that divides asset and consumption smoothers and document behavioral differences between these groups that are consistent with asset smoothing as a response to the presence of a dynamic asset threshold. These results suggest that failing to carefully distinguish between asset and consumption smoothers may be responsible for the muddled consumption smoothing evidence common in previous analyses. Such muddled evidence may lead to missed opportunities to improve welfare outcomes with innovative policy interventions.

Who Smoothes What?

Asset Smoothing, Consumption Smoothing & Unmitigated Risk in Burkina Faso

The permanent income hypothesis posits that rational agents smooth consumption as transitory income fluctuates. Economists have looked for evidence of consumption smoothing behavior in a variety of development contexts. Since the poor typically have limited access to financial markets in which to save and invest or withdraw and borrow, consumption smoothing in these contexts would presumably involve building up asset stocks in good times and drawing them down in bad times. Empirical evidence of this behavior among the poor has been mixed, but often suggests very limited consumption smoothing tendencies. For example, Fafchamps *et al.* (1998) test whether livestock holdings are used to buffer transitory income shocks due to drought in Burkina Faso. They find (a) that most households that sell livestock indeed do so to offset consumption shortfalls due to negative income shocks. When they use data from all households to test whether transitory shocks induce livestock sales, however, they find (b) almost no evidence of the sort of systematic dis-saving that would be needed to smooth consumption. At best, only 15%-30% of consumption shocks are buffered by livestock sales. Our contention in this paper is that a richer theoretical framework that allows for an alternative to consumption smoothing motives is needed to reconcile findings (a) and (b). Without explicitly allowing for such an alternative, an empirical test that pools together agents pursuing distinct smoothing strategies produces a muddled test based on a data-weighted average of these different smoothing regimes.

Recent research on asset and poverty dynamics suggests a compelling alternative to consumption smoothing and thereby sheds light on empirical tests of agents' response to transitory income shocks. In the presence of a dynamic asset threshold the poor may rationally destabilize consumption in order to protect productive assets from irreversible withdrawals. For the poor who appreciate the dynamic forces shaping their future, smoothing assets may simply make more sense than smoothing consumption. In such a case, testing for consumption smoothing using a pooled sample that includes both asset and consumption smoothers may well yield confused or even misleading results. This pooled sample problem muddles the distinction between asset and consumption smoothers. Furthermore, this muddling problem has policy implications: it may well prevent the implementation of innovative safety net policies designed to protect the poor from falling below critical asset thresholds (e.g., Barrett *et al.*, 2008).

Kazianga and Udry (2006) use the same data as Fafchamps *et al.* (1998) and test for differences in consumption smoothing tendencies between the rich and poor. While they find evidence that the rich smooth consumption more than the poor, which is consistent with the dynamic asset smoothing hypothesis, their criterion for distinguishing the rich from the poor is ad hoc and their motivation for testing for differences between them is atheoretic. In this paper, we use dynamic asset smoothing as a theoretical structure to justify wealth-differentiated smoothing tendencies. We test this theory by allowing the smoothing target to shift from assets and consumption as wealth increases. In particular, we use threshold estimation techniques to estimate (i) whether a consumption smoothing threshold marking a shift from asset to consumption smoothing exists and (ii) the location of such a threshold conditional upon its existence. This approach allows us to test the presence and location of a dynamic asset threshold in asset wealth space as perceived by those in our sample.

We find evidence for the existence of a threshold that divides asset and consumption smoothers and document behavioral differences between these groups that are consistent with asset smoothing as a response to a dynamic asset threshold. These results suggest that failing to carefully distinguish between asset and consumption smoothers may be responsible for the muddled consumption smoothing evidence common in previous analyses. As a broader methodological contribution, these results highlight the potential value of threshold estimation techniques in empirical microeconomics of development, especially where promising policy options presuppose an ability to discern between different behavioral regimes among the poor.

1. Theoretical Insights: Consumption vs. Asset Smoothing

Risk has long been a central preoccupation of development economics – particularly in rural agricultural settings. The obvious absence of insurance and other financial markets in low income areas, coupled with the equally obvious riskiness of agricultural production underwrote the suspicion that risk could result in major welfare losses and stand as a major impediment to economic development as individuals might understandably shy away from mean income-increasing but riskier technological and market opportunities.¹

¹ Among other things, these observations have led agronomic researchers to search for ‘pro-poor’ seeds and technologies that reduce income fluctuation while still increasing the mean.

In addition to an outpouring of work on the effectiveness of informal risk-sharing mechanisms, these observations led to efforts to understand the capacity of financial market-constrained households to autarchically manage risk through savings, a form of intertemporal arbitrage with themselves. Deaton (1991) put forward a canonical model of this intertemporal choice problem that has the following form:

$$\begin{aligned} \max_{\{c_{it}, L_{it}\}} E_0 \left\{ \sum_{t=0}^{\infty} \left(\frac{1}{1+\delta} \right)^t u(c_{it}) \right\} \\ \text{subject to:} \\ c_{it} \leq F(\theta_{it}) + (L_{it} - L_{i,t+1}) + rL_{it} \quad \forall t \\ L_{it} \geq 0 \quad \forall t \end{aligned}$$

where c_{it} is the consumption of household i in time period t , F is the production or income generation function of the household that depends on a random variable θ_{it} , L_{it} is the households stock of assets, and the non-negativity restriction on assets captures the borrowing constraint implicit in missing financial markets. First order necessary conditions to this intertemporal maximization problem imply consumption smoothing and behavior that mimics that permanent income hypothesis first articulated by Milton Friedman (1957):

$$u'(c_t) = \max \{u'(x_t), \beta E_t[u'(c_{t+1})]\}$$

where $\beta \equiv \left(\frac{1+r}{1+\delta} \right)$ and $x_t \equiv F(\theta_{it}) + L_{it} + rL_{it}$. Thus, provided it is not optimal to consume all income and savings in period t (and ‘exit’ the system), individuals will save or dis-save a substantial portion of transitory income shocks in order to equate the marginal utility of consumption over time and thereby smooth consumption. Using numerical simulation, Deaton shows that an asset stock valued at 7% of expected income is sufficient to optimally and autarchically manage income risk characterized by a 10% coefficient of variation.² The force of this analysis would seem to be that uninsured risk may be less of a problem than economists may have suspected.

While often undertaken without any particular alternative theoretical model in mind, a number of studies have tried to test for consumption smoothing behavior. Two questions drive the structure of these tests: (1) How much of a positive income shock is consumed rather than

² In a literary fusion of Angus Deaton and Conan Doyle (Sherlock Holmes), this represents the 7% solution to the 10% problem.

saved? and (2) How much of a negative income shock is offset by liquidation of savings or assets? To address these questions, Paxson (1992) decomposes household income in Thailand into permanent, transitory and unexplained components using weather variability and then uses these to estimate the responsiveness of savings and consumption to these income components. Tests of consumption smoothing generally begin with a similar income decomposition and many use Paxson's original consumption function specification in these tests. In developing contexts, the results of these tests suggest little or no consumption smoothing. The poor seem to smooth income, but neither to the full temporal extent – as implied by the permanent income hypothesis – nor to the full spatial extent – as implied by a Pareto efficient allocation of risk. Two consumption smoothing analyses in this literature use the same Burkina Faso data as we do and reach conclusions that are consistent with this general consensus (Fafchamps et al., 1998; Kazianga and Udry, 2006).

Since the structure of most previous empirical consumption smoothing tests is very similar, not surprisingly they share a theoretical limitation: they lack a well-specified theoretical alternative to the canonical consumption smoothing model. In other words, if a particular test finds limited evidence of consumption smoothing, what does this imply about households' intertemporal decision making? Such a result indicates what households are not doing, but can we learn anything about what they *are* doing? While no analysis has yet formulated a clear and compelling alternative to consumption smoothing, some have acknowledged that rich and poor households may rely to varying degrees on selling buffer stocks to smooth consumption – an acknowledgment that sets the stage for formulating theoretical alternatives. Kazianga and Udry (2006), for example, recognize that rich and poor households may differ in their smoothing strategies, but resort to an ad hoc and atheoretic approach to testing for and interpreting these differences.

Recent work on poverty traps and asset dynamics articulates a natural and well-specified theoretical alternative to consumption smoothing. Asset smoothing becomes a compelling intertemporal strategy when asset wealth dynamics are characterized by non-convexities (e.g., Lybbert et al., 2004). In such cases, agents may rationally destabilize consumption in order to protect their asset stocks from irreversible losses or liquidation (Zimmerman and Carter, 2003), which entail dynamic opportunity costs. A key feature that emerges in these models is what Zimmerman and Carter and others have labeled the Micawber Threshold, an asset level that

represent an unstable equilibrium at which dynamic behavior bifurcates. Individuals in the vicinity of the Micawber Threshold will tend to find it dynamically optimal to asset smooth (and destabilize consumption). The costs of falling below such a threshold are substantial, but the costs of avoiding that fall are also potentially quite substantial. Individuals in the neighborhood of this threshold might be expected to pursue severe income smoothing to avoid shocks. In addition, when those shocks do occur and families smooth assets by cutting consumption severely, the costs may also be quite high in terms of irreversible human capital losses for young children (Hoddinott, 2006). A recent theoretical paper by Carter, Barrett and Ikegami (2008) indicates that returns to insurance may be especially high for those in the vicinity of the Micawber Threshold.

Empirical evidence of asset smoothing is starting to trickle in. Barrett et al. (2006) find descriptive evidence that is consistent with asset smoothing: among the very poor in northern Kenya the coefficient of variation of income is less than the coefficient of variation of expenditure, but for the rest of their sample income is more variable than expenditure. Taking a different approach, Lybbert and McPeak (2007) estimate relative risk aversion and the elasticity of intertemporal substitution directly using an Epstein and Zin (1991) recursive utility function and find that the poor (also in northern Kenya) are simultaneously more risk averse and more willing to destabilize consumption than the relatively rich. Adato, Carter and May (2006) also find some direct evidence of non-linear asset dynamics in South Africa.

In this paper, we merge the theoretical insights of dynamic asset smoothing with empirical consumption smoothing literature of the sort pioneered by Paxson (1991). The econometric crux of our analysis is the threshold estimation technique developed by Hansen (2000), which enables us to empirically discern distinct smoothing strategies among Burkina herders. Carter has successfully used this estimation approach with data from Ethiopia and Honduras to infer the location of asset thresholds (Carter et al., 2007). In this paper, we demonstrate the potential of this technique to discern different smoothing regimes and thereby improve our understanding of asset and consumption smoothing behavior.

2. The ICRISAT VLS Data from Burkina Faso

To estimate the consumption and livestock sales equations specified above and the associated smoothing threshold, we use data from rural Burkina Faso collected from 1981 to 1985 by the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT). This panel dataset was constructed using household surveys across three distinct agro-climatic zones (Sahelian, Sudanian, Guinean), which vary in rainfall patterns, soil types and population densities. In each of these zones, two villages were included in the sampling frame, each with roughly 25 households selected into the survey. This panel dataset spans the drought of 1984, which makes it an excellent dataset for studying risk.

Carter (1997) extensively studies the extent of production risk in this system, but does not explore the degree to which individuals are able to buffer such shocks with asset management strategies. Subsequent studies explicitly study the extent which households use assets to smooth consumption in response to stochastic shocks (e.g., Fafchamps et al., 1998; Kazianga and Udry, 2006). For a detailed description of the survey, sample, and data, we refer interested readers to Malton (1988) and Malton and Fafchamps (1989).

3. Decomposing Income into Permanent and Transitory Components

We begin our analysis by decomposing observed household income into permanent, transitory and unexplained income components. Building on Paxson (1992) and following the approach of Kazianga and Udry (2006), we decompose income using farm profit model specified as follows:

$$(1) \quad \pi_{ivt} = \mathbf{a}_1' \mathbf{z}_{ivt} + \mathbf{a}_2' \mathbf{F}_{vt} \mathbf{X}_{ivt} + \alpha_v F_{vt} + \gamma_i + \varepsilon_{ivt}$$

where π_{ivt} is farm profit for household i in village v in year t , \mathbf{z}_{ivt} is a vector of household demographic variables, \mathbf{X}_{ivt} is a vector of variables indicating the amount of land cultivated by household i by slope and soil type, F_{vt} is a rainfall variable measured as the deviation of rainfall from its long-run village average, γ_i is a household fixed effect, and ε_{ivt} is the error term. After estimating the coefficients in this farm profit model, we can decompose income as follows:

$$(2) \quad \begin{aligned} \text{Permanent Income}_{ivt} &= y_{ivt}^P = \mathbf{a}_1' \mathbf{z}_{ivt} + \gamma_i \\ \text{Transitory Income}_{ivt} &= y_{ivt}^T = \mathbf{a}_2' \mathbf{F}_{vt} \mathbf{X}_{ivt} + \alpha_v F_{vt} \\ \text{Unexplained Income}_{ivt} &= y_{ivt}^U = \varepsilon_{ivt} \end{aligned}$$

Table 1 displays the results of the farm profit estimation in (1). On the basis of these estimates, we decompose farm profit for each household and each year using the equations in (2) and display these components graphically in Figure 1. This figure clearly depicts both the poverty and vulnerability of the households included in this sample. The absolute poverty level of the households is evident in the position of the permanent income distribution relative to the dollar-a-day poverty line. Specifically, the mass of permanent income (across households and years) clearly lies below this poverty line. The vulnerability of these households is evident in the substantial variance of the transitory income distribution. Households in our sample are exposed to significant livelihood risks, which makes their intertemporal coping strategies particularly important.

4. Discerning Asset vs. Consumption Smoothing

Following the work by Paxson (1992), income components as constructed in the previous section are often used to test for consumption smoothing. Kazianga and Udry (2006) use these components to estimate a consumption function and conclude that roughly half of transitory income shocks are passed on to consumption changes. We take this standard incomplete consumption smoothing result as our point of departure and test for patterns of smoothing that are consistent with asset smoothing as outlined above.

We are interested in testing for smoothing patterns that treat drawing down a productive asset such as livestock differently than consuming a non-productive asset such as grain stocks (a la Zimmerman and Carter). We estimate a parallel specification for both net livestock sales and changes in grain stocks as follows:

$$(3) \quad \begin{aligned} \text{Net Livestock Sales}_{i,t} &= \beta_1 y_{i,t}^P + \beta_2 y_{i,t}^T + \beta_3 y_{i,t}^U + \beta_z' \mathbf{z}_{i,t} + \gamma_i + \varepsilon_{i,t} \\ \Delta \text{Grain Stocks}_{i,t} &= \beta_1^g y_{i,t}^P + \beta_2^g y_{i,t}^T + \beta_3^g y_{i,t}^U + \beta_z^{g'} \mathbf{z}_{i,t} + \gamma_i + \varepsilon_{i,t} \end{aligned}$$

Tests of consumption smoothing hinge on the estimated coefficients on transitory income. For example, a negative and significant β_2 is evidence that households use livestock as a buffer stock to smooth consumption during transitorily bad production years. While the focus in the literature is squarely on transitory income in specifications such as these, unexplained income may also merit some attention. An exclusive focus on transitory income is well justified if unexplained income, which is simply the residual from the income decomposition, can be largely attributed to measurement or other data errors. If, however, unexplained income includes

realized household income that we do not capture because of omitted transitory variables in the income decomposition, this income component may represent an income shock to the household just like the transitory income component does. We use these two opposing interpretations of unexplained income to place bounds on households' responsiveness to income shocks. In addition to the equations above, we estimate the equations with transitory and unexplained income components combined to provide a second bound on their responsiveness.

The theory of asset smoothing predicts that productive assets drive smoothing tendencies, so we aim to discern different smoothing regimes in net livestock sales. We use Hansen's (2000) threshold estimation technique to test for the presence of a threshold that splits our sample into two meaningfully different livestock sales regimes and to estimate the location of such a threshold. We search for the presence and location of such a threshold using the value of households' average (1981-85) livestock wealth. Conditional on finding a threshold and estimating its location in livestock wealth space as L^* , we are then able to estimate a more flexible version of (3):

$$(4) \quad Net\ Livestock\ Sales_{ivt} = \begin{cases} \beta_1^h y_{ivt}^P + \beta_2^h y_{ivt}^T + \beta_3^h y_{ivt}^U + \beta_z^h \mathbf{z}_{ivt} + \gamma_i + \varepsilon_{ivt} & \text{if } L_i \geq L^* \\ \beta_1^\ell y_{ivt}^P + \beta_2^\ell y_{ivt}^T + \beta_3^\ell y_{ivt}^U + \beta_z^\ell \mathbf{z}_{ivt} + \gamma_i + \varepsilon_{ivt} & \text{if } L_i < L^* \end{cases}$$

where h and ℓ superscripts denote coefficients for the subset of households above and below the estimated threshold, respectively. In this specification, the estimated coefficients on transitory income would be consistent with dynamic asset smoothing if below the threshold $\beta_2^\ell = 0$ and above the threshold $\beta_2^h < 0$. Such a result may further suggest that L^* represents a dynamic asset threshold as perceived by households. Building on these threshold results, we then estimate the grain stocks equation on either side of this same L^* threshold.

We display the graphical results of Hansen's threshold estimator when applied to the net livestock sales function in Figure 2. At the 95% level, we find evidence of a threshold at a herd value of 596,000 CFA. This threshold, which is very precisely estimated (as indicated by the narrow confidence interval), divides herder households in our sample into two groups according to their responsiveness to transitory income shocks. Specifically, households with an average herd value below 596,000 CFA share a livestock sales regime that is statistically distinct from those with herds above this value. Figure 2 also includes the density of livestock wealth, which indicates that most households are below this threshold. To test whether the presence of this

significant threshold is consistent with our theoretical framework, we must now check for evidence of asset smoothing below this threshold and consumption smoothing above it.

Table 2 contains the estimation results from the net livestock sales equation. Note that the standard errors reported in this table are robust to heteroskedasticity and have been bootstrapped since the equation includes generated variables as explanatory variables. Consider the coefficient on transitory income in the net livestock sales equation. If livestock are used as a buffer to consumption shocks, this coefficient should be negative and significant. When we pool all households in our sample, this coefficient tells the same story as in Fafchamps et al. (1998) and Kazianga and Udry (2006): livestock appear to be used in only a very limited manner as a buffer stock. To interpret this coefficient, note that net livestock sales are measured in TLU, while income is measured in 1,000 CFA francs. The median price of livestock during this period was roughly 24,000 CFA/TLU (Fafchamps et al. 1998). Thus, the pooled coefficient of -0.01 is equivalent to approximately 26% of transitory income shocks being offset by livestock sales – a limited consumption smoothing response. Specification 1b combines transitory and unexplained income components into a single income shock variable and yields similar results.

Table 2 also includes results from the two livestock sales regimes as defined by the threshold L^* shown in Figure 2. Net livestock sales among households below the threshold are much less responsive to transitory income shocks. Only 8-12% of a negative transitory income shock among these households is offset by livestock sales. In contrast, among households above the threshold livestock sales appear to be an important buffer to consumption volatility from such shocks. Households with herd wealth above the threshold offset 60-95% of their income shock via livestock sales – i.e., their livestock sales are six or more times as responsive as households in the lower regime. As a graphical depiction of the regression results in Table 2, Figure 3 illustrates the responsiveness of expected livestock sales to transitory income shocks, holding other variables at their mean values. The relative responsiveness of herders above L^* is clear. We also use the figure to depict a robustness test of these results. Until now, we have included both positive and negative transitory income shocks, but our focus is plainly on responses to negative shocks. To insure that our results are indeed capturing negative shocks (i.e., are not driven by livestock *purchases* in response to positive income shocks), we estimate the net livestock sales equation for negative shocks alone. As shown, the distinction between the lower and upper smoothing regime is at least as sharp, if not sharper, for negative shocks alone.

The bottom of Table 2 includes final evidence that is consistent with dynamic asset smoothing below the threshold. Following an observation of Zimmerman and Carter (2003), we undertake a simple test of the asset smoothing hypothesis by comparing coefficients of variation for consumption and income for the low and high asset groups. Households below the herd wealth threshold have smoother income, with a coefficient of variation of crop income half that of households above the threshold. In addition, the lower asset households pass more of that income volatility onto consumption. Specifically, the coefficient of variation of consumption relative to the coefficient of variation of income is 81% for the low asset group versus 60% for the high asset group.

Table 3 displays results in the same format for the change in grain stocks equation. Since both the income components and change in grain stocks are measured in value units (CFA), the estimated coefficients on income shocks reflect the share of the shock that is offset by changes in grain stocks. ADD more here...

5. Conclusions

In this paper, we use Hansen's threshold estimation technique (Hansen, 2000) to test whether both asset smoothers and consumption smoothers are present in VLS data from Burkina Faso that have been used in well-known consumption smoothing analyses (Fafchamps et al., 1998; Kazianga and Udry, 2006). This threshold estimation approach suggests that two different smoothing regimes indeed exist in this data. Furthermore, our results are consistent with asset smoothing in the face of dynamic asset thresholds. Households below our estimated threshold choose to endure greater relative consumption volatility in order to preserve their livestock holdings, while those above the threshold actively buffer consumption shocks with livestock sales.

Threshold estimation as an empirical technique appears to be a promising way of discerning between behavioral regimes. For economists and policy makers alike, this ability to discern regimes is especially important in contexts that are subject to important non-convex wealth or asset dynamics. In such contexts, thresholds can drive substantial disparities in behaviors and in welfare outcomes. Being able to characterize these thresholds – as well as attendant behavioral and outcome differences – is a valuable input into the pro-poor policy process.

In this context, it is worth reiterating an observation from Hoddinott (2006). We have sought in this paper to distinguish between asset and consumption smoothing as distinct behavioral regimes. In reality, smoothing decisions often involve more than these two dimensions.

...asset smoothing implies an attempt to preserve assets, but consumption is an input into the formation and maintenance of human capital. [Thus] the distinction between consumption and asset smoothing, while useful as a descriptive tool, may be somewhat misleading. Rather, household responses to adverse shocks are effectively changes in their asset portfolio, with a critical issue being the extent to which the draw down of a given asset has permanent consequences. (Hoddinott, 2006)

Future research into asset and poverty dynamics and intertemporal smoothing tendencies should take this multidimensional view of smoothing into account. In the context of threshold estimation techniques, this suggests the potential for multiple thresholds or, possibly, thresholds that cut across multiple asset dimensions (*e.g.*, productive assets and innate ability (Lybbert and Barrett, forthcoming)).

Finally, from a policy perspective, evidence that risk is especially costly for asset smoothers suggests that additional efforts be given to the creation of viable insurance mechanisms. While the theoretical returns to insurance have been explored by Barrett, Carter and Ikegami (2008), there are multiple challenges to the implementation of insurance. In this regard, it is important to note that the transitory income component graphed in Figure 1 is in principal insurable as it is based on verifiable weather information. Weather or other index insurance contracts at least hold out the promise that either the public or the private sector can insure against these largely covariant risks.

References

- Adato, M., Carter, M. and J. May (2006). "Exploring Poverty Traps and Social Exclusion in South Africa using Quantitative and Qualitative Data," *Journal of Development Studies*,42(2):226-247.
- Barrett CB, Carter MR, Ikegami M. *Poverty Traps and Social Protection*. Cornell University Working Paper. 2008.
- Barrett CB, Marenya PP, McPeak JG, Minten B, Murithi FM, Kosura WO, Place F, Randrianarisoa JC, Rasambainarivo J, Wangila J. Welfare Dynamics in Rural Kenya and Madagascar. *Journal of Development Studies* 2006;42; 248-277.
- Carter MR, Little PD, Mogues T, Negatu W. Poverty Traps and the Long-term Consequences of Natural Disasters in Ethiopia and Honduras. *World Development* 2007;35; 835-856.
- Epstein L-G, Zin S-E. Substitution, Risk Aversion, and the Temporal Behavior of Consumption and Asset Returns: An Empirical Analysis. *Journal of Political Economy* 1991;99; 263-286.
- Fafchamps M, Udry C, Czukas K. Drought and Saving in West Africa: Are Livestock a Buffer Stock? *Journal of Development Economics* 1998;55; 273-305.
- Friedman M. *A theory of the consumption function*. Princeton University Press: Princeton,; 1957.
- Hansen BE. Sample Splitting and Threshold Estimation. *Econometrica* 2000;68; 575-603.
- Hoddinott J. Shocks and Their Consequences across and within Households in Rural Zimbabwe. *Journal of Development Studies* 2006;42; 301-321.
- Kazianga H, Udry C. Consumption Smoothing? Livestock, Insurance and Drought in Rural Burkina Faso. *Journal of Development Economics* 2006;79; 413-446.
- Lybbert TJ, Barrett CB. Risk taking behavior in the presence of nonconvex asset dynamics. *Economic Inquiry* forthcoming.
- Lybbert TJ, Barrett CB, Desta S, Coppock DL. Stochastic Wealth Dynamics and Risk Management Among a Poor Population. *Economic Journal* 2004;114; 750-777.
- Lybbert TJ, McPeak J. *Risk, Intertemporal Substitution & Early Resolution of Uncertainty: Livestock Portfolios & Off-Take Among Kenyan Pastoralists*. UC Davis Working Paper. 2007.
- Malton P. *Burkina Faso Farm Level Studies: Survey Methods and Data Files*. ICRISAT VLS and Miscellaneous Paper Series. ICRISAT Hyderabad, India; 1988.

Malton P, Fafchamps M. *Crop budgets in three agro-climatic zones of Burkina Faso*. ICRISAT Progress Report. Hyderabad, India; 1989.

Paxson C. Using Weather Variability to Estimate the Response of Savings to Transitory Income in Thailand. *American Economic Review* 1992;82; 15-33.

Zimmerman FJ, Carter MR. Asset Smoothing, Consumption Smoothing and the Reproduction of Inequality Under Risk and Subsistence Constraints. *Journal of Development Economics* 2003;71; 233-260.

Decomposition of Crop Income

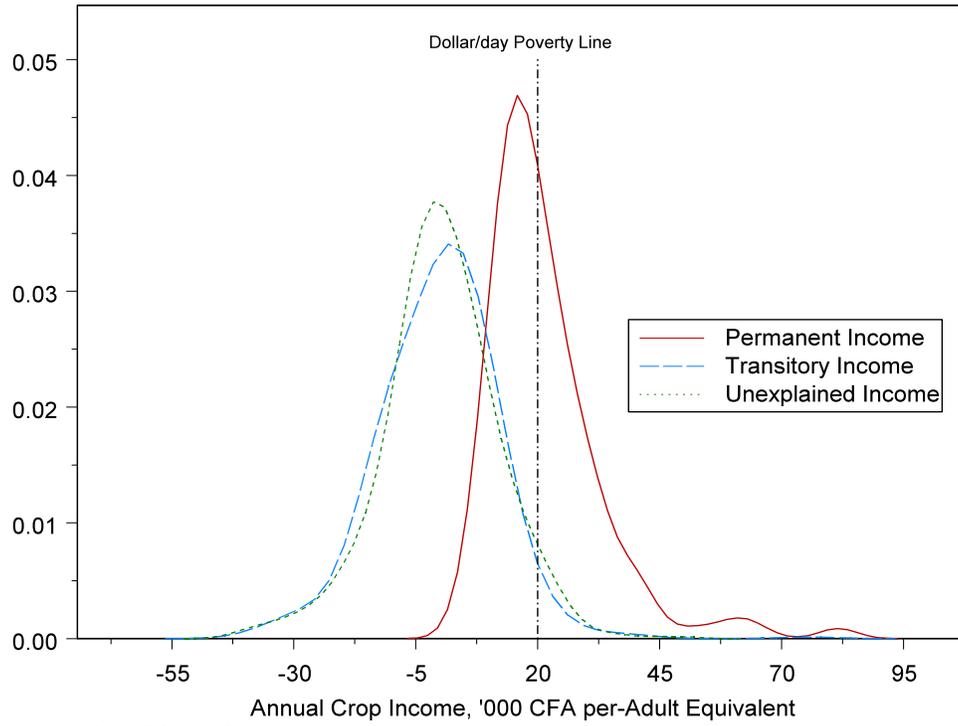


Figure 1 Kernel densities of crop income components

Significance Test for Asset Threshold \tilde{L}

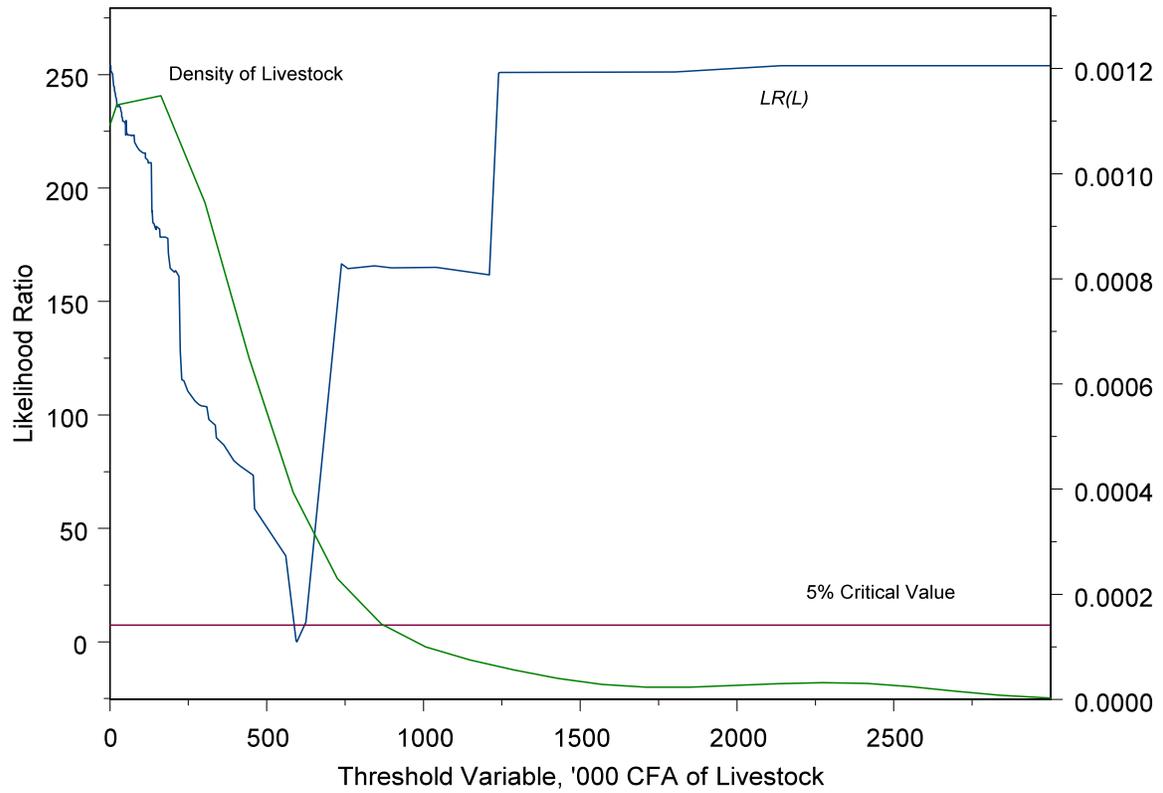


Figure 2 Likelihood ratio test of threshold in average household herd value space with density of livestock value (right axis)

Net Livestock Sales Conditioned on Transitory Income Shock

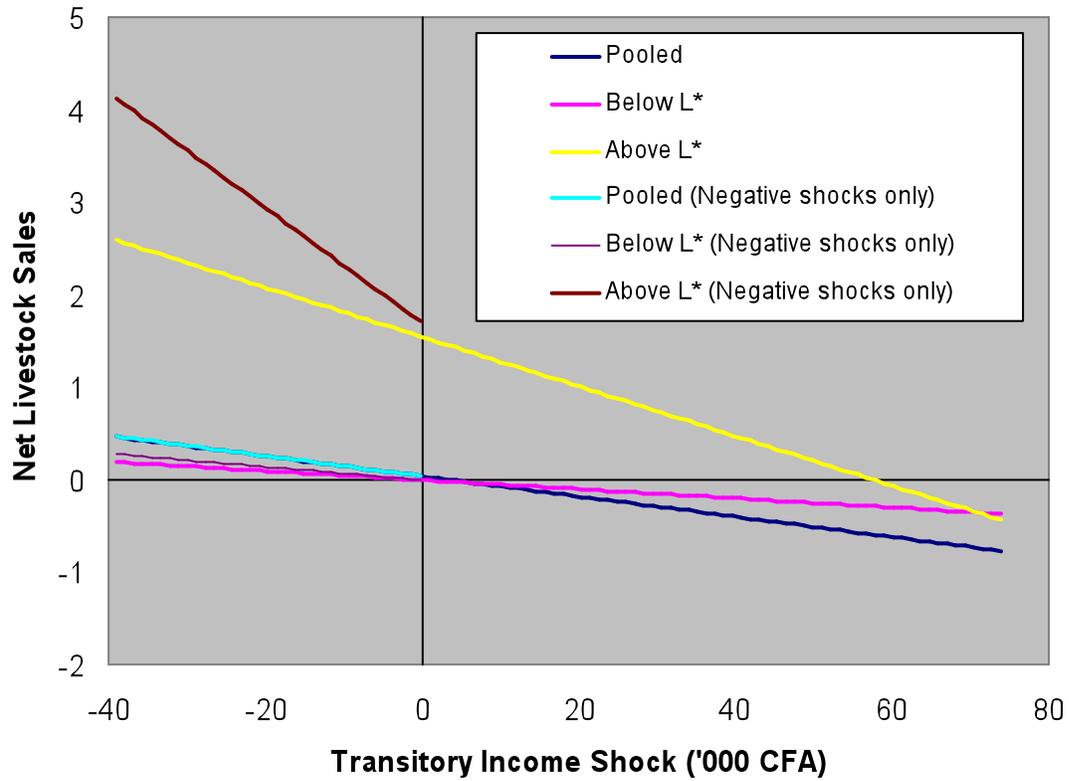


Figure 3 Conditional effect of transitory income shocks on net livestock sales (all other independent variables at mean values)

Table 1 Crop income regression used to extract household income components

	Coefficient	Std.Error
Age HH head	0.40	(0.58)
Age ²	-0.00	(0.01)
HH size	0.56	(0.61)
Adult males	-2.15	(1.52)
Adult females	-1.06	(1.91)
Boys (age 7-14)	-1.42	(1.54)
Girls (age 7-14)	-1.92	(1.72)
Rainfall deviation from long run average	0.11***	(0.02)
Rainfall deviation x ...		
<i>Seno</i> soil area	0.18***	(0.02)
<i>Zinka</i> soil area	0.16***	(0.06)
<i>Bissiga</i> soil area	0.02	(0.04)
<i>Raspuga</i> soil area	0.27***	(0.09)
<i>Ziniare</i> soil area	-0.00	(0.05)
Other soil area	0.03**	(0.02)
Low land area	-0.21***	(0.02)
Near low land area	-0.12***	(0.02)
Midslope area	-0.11***	(0.02)
Near upland area	-0.01	(0.07)
Near home area	-0.01	(0.03)
Distance to home	-0.00	(0.00)
Constant	13.10	(14.02)
HH fixed effects included (not shown)		
Observations	464	
R-squared	0.453	
Number of hh	126	

*** p<0.05, ** p<0.1, * p<0.15

Table 2 Livestock sales response to income components (with bootstrapped, heteroskedastic standard errors) and relative consumption volatility on either side of the estimated herd value threshold L^*

	Net Livestock Sales (TLU)					
	Pooled		Below L^*		Above L^*	
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
Permanent income	0.0232 (0.0297)	0.0252 (0.0316)	-0.00728 (0.0060)	-0.00566 (0.0059)	0.0469 (0.1220)	0.0495 (0.1160)
Transitory income	-0.0109 (0.0029)		-0.0049 (0.0014)		-0.0252 (0.0135)	
Unexplained income	-0.00655 (0.0029)		-0.0019 (0.0011)		-0.0586 (0.0292)	
Transitory + Unexplained		-0.00862 (0.0026)		-0.00328 (0.0013)		-0.0395 (0.0145)
Adult equivalents	-0.00893 (0.0176)	-0.00816 (0.0178)	0.0112 (0.0079)	0.0118 (0.0085)	-0.154 (0.1240)	-0.148 (0.1210)
HH size	-0.0666 (0.0316)	-0.0656 (0.0307)	-0.0154 (0.0094)	-0.0141 (0.0094)	0.0196 (0.1420)	0.0119 (0.1340)
Age of HH head	-0.00273 (0.0087)	-0.00262 (0.0097)	0.00323 (0.0023)	0.00357 (0.0025)	-0.0163 (0.0475)	-0.0136 (0.0562)
Constant	-4.74E-10 (0.0127)	-4.53E-10 (0.0168)	1.26E-10 (0.0055)	1.36E-10 (0.0069)	-5.75E-09 (0.0867)	-3.67E-09 (0.0836)
Observations	361	361	316	316	45	45
R-squared	0.223	0.218	0.134	0.11	0.627	0.607
<i>Share of income shock offset by livestock sales†</i>	26%	21%	12%	8%	60%	95%
<i>Coefficients of Variation</i>						
Food Consumption	25%		25%		37%	
Crop Income	34%		31%		62%	
CV Cons/CV Inc	73%		81%		60%	

† Based on median livestock price of 24,000 CFA per TLU during this period (Fafchamps et al. 1998) and assuming the income shock is transitory income in 'a' models and transitory plus unexplained income in 'b' models.

Table 3 Grain storage response to income components (with bootstrapped, heteroskedastic standard errors)

	Change in Grain Stocks (CFA)					
	Pooled		Below L*		Above L*	
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
Permanent income	0.829 (0.39)	0.849 (0.34)	0.765 (0.51)	0.774 (0.44)	0.179 (0.87)	0.191 (0.70)
Transitory income	0.153 (0.09)		0.194 (0.09)		0.13 (0.15)	
Unexplained income	0.196 (0.06)		0.211 (0.07)		-0.0179 (0.19)	
Transitory + Unexplained		0.175 (0.06)		0.203 (0.08)		0.0668 (0.08)
Adult equivalents	1.893 (0.62)	1.9 (0.56)	1.918 (0.48)	1.922 (0.67)	1.476 (1.48)	1.503 (1.53)
HH size	-0.0909 (0.64)	-0.0812 (0.61)	0.516 (0.57)	0.523 (0.75)	-0.637 (1.62)	-0.671 (1.76)
Age of HH head	0.0634 (0.23)	0.0645 (0.26)	0.24 (0.36)	0.241 (0.37)	-0.143 (0.89)	-0.131 (1.00)
Constant	-4.37E-09 (0.41)	-2.85E-09 (0.32)	-3.83E-09 (0.40)	-9.70E-10 (0.32)	-8.75E-09 (1.14)	-1.12E-08 (1.08)
Observations	361	361	316	316	45	45
R-squared	0.30	0.30	0.35	0.35	0.29	0.28