Drought and Saving in West Africa: Are Livestock a Buffer Stock?[1]

Marcel Fafchamps, [†]
Christopher Udry, [††]
and Katherine Czukas, [††]

First draft: December 1994
Last revision: April 1996

Abstract

Households in the west African semi-arid tropics, as in much of the developing world, face substantial risk -- an inevitable consequence of engaging in rainfed agriculture in a drought-prone environment. It has long been hypothesized that these households keep livestock as a buffer stock to insulate their consumption from fluctuations in income. This paper has the simple goal of testing that hypothesis. Our results indicate that livestock transactions play less of a consumption smoothing role than is often assumed. Livestock sales compensate for at most thirty percent, and probably closer to twenty percent of income shortfalls due to village-level shocks alone. We discuss possible explanations for these results and suggest directions for future work.

[1] We thank Andrew Foster, John Strauss, Elizabeth Sadoulet, Ethan Ligon, two anonymous referees, and participants at various seminars and conferences for their comments. Financial support from the National Science Foundation is gratefully acknowledged. We thank ICRISAT for making the data available.

† Food Research Institute, Stanford University, Stanford, CA 94305-6084. Email: fafchamp@leland.stanford.edu. †† Department of Economics, Northwestern University, Evanston, IL 60208. Email: udry@nwu.edu and k-czukas@nwu.edu.

Households in the west African semi-arid tropics, as in much of the developing world, face substantial risk -- an inevitable consequence of engaging in rainfed agriculture in a drought-prone environment. It has long been hypothesized that these households keep livestock as a buffer stock to insulate their consumption from fluctuations in income (e.g., Binswanger and McIntire (1987); Bromley and Chavas (1989)). The goal of this paper is to test that hypothesis. To do so, we use panel data collected from a sample of farmers in Burkina Faso. The data was collected between 1981 and 1985, a period that spans some of the most severe drought years for which rainfall records exist in the region. In particular, 1984 was a year of widespread famine during which large amounts of food aid were distributed in the Sahel and in the survey area (Reardon, Delgado, and Matlon (1992)). The data are therefore particularly appropriate to test whether livestock are used as buffer stock against large income shocks. As is well known, African livestock producers rarely kill their animals to consume meat; they prefer to sell livestock and purchase grain (e.g., Sandford (1983), Bernus (1980), Swift (1986); Loutan (1985)). Surveyed households are no exception (Reardon (forthcoming)). Sales and purchases of livestock are thus a principal means through which consumption smoothing may take place. We focus our attention on the relationship between livestock transactions and income fluctuations. The question we ask is a simple one: do net sales of livestock increase when a household is subjected to adverse rainfall shocks?

We begin by reviewing briefly the literature and discussing various conceptual issues surrounding the use of asset accumulation as a form of self-insurance. We then formalize the idea that livestock may serve as buffer stock against aggregate income fluctuations. Next, we next discuss the setting in which the data was collected and the evidence already available. A descriptive analysis of the data follows. It suggests that sales and purchases of cattle and small stock (i.e., goats and sheep) are different: there seems to be little relation between cattle transactions and rainfall shocks, but a weak negative correlation exists between small stock net purchases and rainfall. Using a more rigorous approach, the third part of the paper largely confirms these impressions: livestock sales offset at most 30%, and probably closer to 20% of the income losses resulting from village-level rainfall shocks. In the conclusion, we discuss possible explanations for these results and suggest directions for future work.

Section 1. Livestock as a Buffer Stock

There is an important literature on the role of livestock in the economies of semi-arid Africa. The early literature, based on the pioneering work of Herskovits (1926), focuses on the cosmological aspects of cattle and other livestock in many African societies, on their role in the generation of prestige, and on the aesthetics of keeping large herds. The continuing importance of livestock in the value systems of many different societies in Africa is evident. For example, in much of Burkina Faso, cattle, not the cash equivalent, remain an important component of bride price payments. Nevertheless, it is the economic aspects of keeping livestock, and in particular the role of livestock inventories as an insurance substitute that dominate the modern economic literature on Africa (e.g., Binswanger and McIntire (1987)).

For India, Jodha (1978) and particularly Rosenzweig and Wolpin (1993) provide convincing evidence that livestock sales and purchases are used as part of farm households' consumption-smoothing strategies. In the African context, the importance of cattle, goats and sheep as a store of wealth has been emphasized in a number of case studies by anthropologists and economists (see McCown et al. (1979); Dahl and Hjort (1976); and Eicher and Baker (1982) for reviews). Two studies which are particularly relevant to the present investigation argue that sales of livestock are a means of dealing with risk, particularly drought. Swinton (1988) examined the budgets of farmers in Niger (which borders Burkina Faso) during the same 1984 drought that afflicted the Burkina Faso households analyzed in this study. He concludes (p. 135) that "livestock liquidation was the principal means by which ... farm households financed their cereal needs following the 1984 drought." Watts (1983) provides an exceptionally rich and detailed account of Hausa farmers' responses to the early 1970s drought in northern Nigeria, an event that also affected sample households in Burkina Faso prior to the survey. Watts argues that sales of livestock played a central role in the response to drought.[2] We, however, know of no formal tests which show that livestock inventories are used to smooth income fluctuations in Africa.

---

[2] The literature on coping with drought in Africa is large. Much of it focuses on the Sahelian droughts of the 1970s. See van Appeldoorn (1981); Campbell (1984); Shepherd (1984); Silberfein (1984); Sen (1981); and Dasgupta (1993).

A Model of Livestock as Buffer Stock

To understand better the possible role of livestock as an insurance substitute, we construct a model of a typical farming household subject to rainfall shocks. This model captures, in a stylized fashion, the salient features of village communities in the West African semi-arid tropics (WASAT) as they have been described in Binswanger and McIntire (1987), Bromley and Chavas (1989), and Binswanger, McIntire and Udry (1989).

Each household maximizes its expected utility $E_0 \sum_{t=0}^{T} \delta^t U(c_t)$. We assume that households are risk averse, i.e., $U'' < 0$, and that they have decreasing absolute risk aversion. Each household is endowed with a stream of crop income $y(s_t)$ that varies with s_t, the realized state of nature at time t. Both consumption and crop income are measured in terms of grain, the staple food. The probability distribution of rainfall is nearly stationary and the rate of technological change in WASAT agriculture is very slow (Eicher and Baker (1982)). It is thus reasonable to treat crop income as stationary.[3] As a consequence, we assume that the probability of each state is constant over time and known by all.

We focus on asset accumulation as the main insurance substitute against income shocks which, like rainfall variations, are largely shared within a single village. Formal crop insurance does not exist in the WASAT, probably because of the high spatial covariance of rainfall shocks and of the moral hazard problems associated with crop insurance in general (Binswanger and Rosenzweig (1986); Binswanger and McIntire (1987)). Due to enforcement problems and information asymmetries, informal insurance arrangements tend to be focused geographically and to revert around single rural communities. They are largely ineffective against shocks that are highly correlated over space, such as droughts (Cashdan (1985); Platteau (1991); Binswanger and Rosenzweig (1986); Fafchamps (1992, 1994); Udry (1994)). Consumption credit too is geographically and socially concentrated and provides little or no protection against aggregate shocks (see Bell (1988), Besley (1993) and Alderman and Paxson (1993) for reviews of the large literature on rural credit). To capture these features in a stylized fashion, we assume that

---

[3] See, however, Carter (1994).

the village cannot borrow or secure insurance, formal or informal, from the rest of the world and we focus on income shocks due to rainfall variation. The possible role of credit and insurance to smooth idiosyncratic risk within the village is discussed later.

We denote the total liquid wealth of the household at the beginning of period t as W_t. The process that governs returns to wealth will be specified later. For now, we simply allow returns to wealth $r(W_{t+1}, s_{t+1}, s_t)$ to depend on liquid wealth and on present and past shocks. The Belman equation corresponding to the household's intertemporal decision problem can be written:

$$V(X_t) = \underset{W_{t+1} \geq 0}{Max} \quad U(X_t - W_{t+1}) + \delta EV(y(s_{t+1}) + (1+r(W_{t+1}, s_{t+1}, s_t))W_{t+1}) \qquad (1)$$

Variable X_t represents current income plus liquid wealth (i.e., 'cash-in-hand') measured in terms of grain. Given decreasing absolute risk aversion, precautionary saving is one motive for holding wealth (Deaton (1990), Kimball (1991)); if the household's discount rate is high enough, it is the only one (Zeldes (1989), Carroll (1992), Deaton (1992)). For large enough wealth, consumption is proportional to permanent income, in which case consumption in each period changes only by the annuity value of expected future wealth (Hall (1978), Zeldes (1989)). Sales and purchases of assets then play the role of a buffer stock: they absorb most of the transitory income shocks. When assets fall below a critical level, however, they can no longer serve as buffer stock and consumption begins to respond to unanticipated variations in income. When all asset holdings have been exhausted and no other source of insurance is available, consumption can but follow current income (Zeldes (1989), Deaton (1990, 1991)). Testing whether sales and purchases of assets respond to income shocks is thus a way of verifying whether small farmers use assets to smooth consumption (e.g., Rosenzweig and Wolpin (1993)).

To understand the relationship between income shocks and the sale and purchase of a single asset, we must also account for portfolio effects. WASAT households have at their disposal a variety of assets: grain stocks, livestock, cash holdings, gold, and jewelry. Bank accounts are *de facto* not available to WASAT small farmers. Other forms of wealth are not liquid enough to serve as insurance substitute. Land sales are extremely rare in the WASAT, a consequence of the relative abundance of land and of legal restrictions on land tenure (Binswanger and McIntire (1987); Atwood (1990); Platteau (1992)). In practice, grain storage and livestock are the most attractive assets in the WASAT: the former provides excellent protection against food price risk, the second has a high expected return. Together they account for most of liquid wealth in the hands of WASAT small farmers (Udry (1993); Binswanger, McIntire, and Udry (1989); Swinton (1988)).[4]

The most important portfolio effects are thus those that oppose grain storage to livestock. We now expand the model to allow for two assets, grain stocks and livestock L_t. Due to dessication and pest attacks, the return to grain storage is assumed negative and denoted $-\lambda$. Livestock is seldom consumed directly and WASAT farmers prefer to sell animals to purchase food (e.g., Sandford (1983), Bernus (1980), Swift (1986); Loutan (1985), Reardon (forthcoming)). Grain stocks thus constitute a more effective insurance against food price risk than livestock. To capture this fact in a stylized fashion, we assume that λ is constant.

Returns to livestock depend not only on the physical return to herding but also on the price of livestock relative to that of grain $P(s_t \mid s_{t-1})$. Relative prices vary with factors that affect the demand and supply of grain and livestock. Because of lagged demand and supply effects, prices are typically correlated over time (Rosen, Murphy and Scheinkman (1994)). The severe deterioration of the terms of trade between livestock and grain during periods of drought has been documented in a number of African countries (Sen (1981), Shapiro (1979)). We discuss these issues further below. Physical returns to herding, denoted $\eta(s_t \mid s_{t-1})$, comes from offspring and weight gain (Shapiro (1979)). They depend on external shocks (e.g., disease, death) and on the available stock of pasture, which in turn vary with current and past rainfall. Unlike in India, cattle is seldom used as draft power in the WASAT (Barrett et al. (1982)).[5] For simplicity, we include milk consumption in the physical returns to herding. Raising a single head of livestock requires a fixed minimum of household labor for herding, watering, and gathering fodder that we denote F. Additional labor is assumed proportional to the number of livestock heads νL_t.[6] The cost of labor is expressed in grain-equivalent. We abstract

[4] It should be noted, however, that little is known about cash holdings of WASAT farmers. Lim and Townsend (1994) reconstruct the cash holdings of ICRISAT Indian farmers and come to the conclusion that cash holdings constitute a large proportion of liquid wealth and play a crucial role in consumption smoothing not only within years but also between years. More research is needed on this issue.

[5] Things are slowly changing, but at the time the survey data were collected, animal traction was practiced by only a few households. Donkeys, not bullocks, were the draft animals of choice (Matlon and Fafchamps (1989)).

[6] To capture the idea that raising more than a few dozen cattle is beyond the manpower of a typical WASAT farmer, one could alternatively assume that returns to livestock decline beyond a certain herd size (McIntire, Bourzat and Pingali (1992)). It is easy to show that, in this case, livestock assets increase more slowly with liquid wealth.

from wage fluctuation issues which are largely irrelevant given the way livestock is taken care of.[7] Taken together, these assumptions imply that returns to herding increase with herd size. The combined return on grain stocks and livestock is:

$$(1 + r_{t+1})W_{t+1} = (1-\lambda)(W_{t+1} - L_{t+1}\, P(s_t \mid s_{t-1})) +$$

$$(1 + \eta(s_{t+1} \mid s_t))L_{t+1}\, P(s_{t+1} \mid s_t) - F\, I(L_{t+1} > 0) - \nu\, L_{t+1} \qquad (2)$$

W_{t+1} denotes total liquid wealth in grain equivalent. L_{t+1} is the number of livestock heads, purchased at the end of period t at price $P(s_t \mid s_{t-1})$. $I(L_{t+1} > 0)$ is an indicator function that takes the value 1 when $L_{t+1} > 0$, and is 0 otherwise.

We are interested in the relationship between total liquid wealth, which we suspect serves the role of buffer stock, and one of its components, livestock. We proceed as follows. We begin by replacing return to liquid wealth in equation (1) by its value given by equation (2). We get:

$$V(X_t) = \underset{W_{t+1} \geq 0}{Max} [U(X_t - W_{t+1}) + \delta \underset{L_{t+1}\ s.t.\ W_{t+1} \geq L_{t+1} \geq 0}{Max} EV[y(s_{t+1}) - F\, I(L_{t+1} > 0) - \nu\, L_{t+1}$$

$$(1-\lambda)(W_{t+1} - L_{t+1}\, P(s_t \mid s_{t-1})) + (1 + \eta(s_{t+1} \mid s_t))L_{t+1}\, P(s_{t+1} \mid s_t)]] \qquad (3)$$

As model (3) indicates, the decision problem facing the household can formally be separated into two distinct steps: choosing how much liquid wealth W_{t+1} to hold; and choosing how much of that wealth to keep in the form of livestock L_{t+1}.

To characterize the relationship between total wealth and livestock, we focus on the second decision and momentarily treat W_{t+1} as given. We take a mean-variance approximation of the expected value function, i.e. $E[V(X)] \approx E[X] - \frac{1}{2} A\, \Sigma[X]$ where $\Sigma[X]$ is the variance of X and A is the coefficient of relative risk aversion $-\dfrac{V''(E[X])}{V'(E[X])}$. To simplify the notation, set $E[(1 + \eta(s_{t+1} \mid s_t))P(s_{t+1} \mid s_t)] \equiv 1 + \bar{\eta}(s_t)$ and set $\Sigma[(1 + \eta(s_{t+1} \mid s_t))P(s_{t+1} \mid s_t)] \equiv \sigma_L^2(s_t)$. We denote the mean and variance of crop income as $\bar{y}$ and σ_y^2, respectively. The correlation coefficient between crop income and returns to livestock is written $\rho_{yL}(s_t)$; it is probably positive since livestock pasture and crops are subject to the same weather shocks. Having observed s_t, households choose the

[7] Livestock labor is typically supplied by household members themselves -- in large part, chidren and young adults. The opportunity cost of herding is essentially in terms of reduced crop output or wage income.

level of their livestock by solving approximatively the following decision problem:

$$\underset{L_{t+1} \ s.t. \ W_{t+1} \geq L_{t+1} \geq 0}{Max} \ \bar{y} + (1-\lambda)W_{t+1} + L_{t+1}(1 + \bar{\eta}(s_t) - (1-\lambda)P(s_t \mid s_{t-1}) - \nu) -$$

$$F\, I(L_{t+1} > 0) - \frac{1}{2}A\,(\sigma_y^2 + \sigma_L^2(s_t)L_{t+1}^2 + 2\,\rho_{yL}(s_t)\,\sigma_y\,\sigma_L(s_t)L_{t+1}) \qquad (4)$$

We begin by ignoring the fixed cost of herding F. An interior solution to the above optimization problem requires that:

$$L_{t+1}^* = \frac{1 + \bar{\eta}(s_t) - (1-\lambda)P(s_t) - \nu - \rho_{yL}(s_t)\sigma_y\,\sigma_L(s_t)}{A\sigma_L^2(s_t)} \qquad (5)$$

Equation (5) makes intuitive sense: it indicates that livestock holdings are an increasing function of expected returns $\bar{\eta}(s_t)$ and storage losses λ; they are a decreasing function of the livestock purchase price $P(s_t$, labor requirements ν, correlation between crop and livestock returns $\rho_{yL}(s_t)$, aversion to risk A, and variance of livestock returns $\sigma_L^2(s_t)$. The presence of fixed costs of production in herding complicates the situation somewhat.[8] In this case, it is easy to show that there exists a level of liquid wealth $\underline{W}_{t+1}$ below which the household chooses to hold no livestock at all. As liquid wealth rises marginally above $\underline{W}_{t+1}$, livestock holdings jump in a discrete fashion.

We now examine the relationship between total liquid wealth and livestock holdings. Since we have assumed that $U(C)$ exhibits decreasing absolute risk aversion, A is a declining function of wealth.[9] Equation (5) then shows that, other things being equal, L_{t+1} increases with W_{t+1} provided that $W_{t+1} > \underline{W}_{t+1}$. Whether livestock represents an increasing or decreasing share of liquid wealth depends on whether relative risk aversion is decreasing or increasing. To see why, suppose that $A(W) = \frac{\bar{A}}{W^\gamma}$. Equation (5) then becomes:

$$L_{t+1}^* = \frac{1 + \bar{\eta}(s_t) - (1-\lambda)P(s_t) - \nu}{\bar{A}\sigma_L^2(s_t)}\, W_{t+1}^\gamma - \rho_{yL}(s_t)\frac{\sigma_y}{\sigma_L(s_t)} \qquad (5')$$

Ignore for the moment the second term in equation (5’), i.e., assume for a moment that

8 The invisible character of individual animals essential leads to the same conclusion.

9 As shown in Deaton (1991), the value function $V(X)$ in general inherits the risk aversion properties of the underlying utility function $U(X)$.

crop and livestock income are uncorrelated. Then, if relative risk aversion is constant, that is, if $\gamma = 1$, livestock holdings constitute a constant proportion of liquid wealth. If, in contrast, relative risk aversion is decreasing, i.e., $\gamma > 1$, the share of livestock in liquid wealth increases with wealth -- and vice versa.[10] It is generally believed that relative risk aversion is either constant or decreasing (e.g., Newbery and Stiglitz (1981)). We can therefore reasonably assume that livestock holdings constitute a constant or increasing proportion of liquid wealth, minus a constant -- the second term in equation (5') -- that does not depend on household wealth.

Now suppose that WASAT households liquidate wealth W_{t+1} to absorb income shocks s_t. If these housedholds have constant relative risk aversion, equation (5') predicts that, everything else being equal, they respond to an income shock by selling livestock roughly in proportion to its share in liquid wealth. If they have decreasing risk aversion, equation (5') then predicts that they will *overreact* to income shocks by liquidating livestock more than other assets. Only when $W_{t+1} < \underline{W}_{t+1}$ and households have sold all their animals are livestock holdings expected not to react to income shocks. These simple predictions make it possible to construct a test of whether livestock is used as buffer stock by regressing livestock transactions on income shocks. Results from such a test using data on WASAT farmers are presented in the next section.

Before we discuss these results, however, we first examine other factors that may influence livestock transactions. We are interested in net livestock sales $S_t \equiv (1 + \eta_t)L_t - L_{t+1}$. Define β_{t+1} as the share of livestock in liquid wealth, corrected for the effect of risk in equation (5'):

$$\beta_{t+1} = \frac{L_{t+1} + \rho_{yL}\sigma_y/\sigma_L}{W_{t+1}}$$

From equation (5'), we know that if relative risk aversion is constant, β_{t+1} is not a function of wealth. Consider the pattern of net livestock sales when liquid wealth is constant, i.e., when $W_{t+1} = W_t$. Provided that livestock prices and expected returns are also constant, then $\beta_{t+1} = \beta_t$: households keep a constant herd. It follows that $S_t = \eta_t L_t$: net sales of livestock equal net physical returns. Since average returns to livestock are positive on average, a household that wishes to maintain liquid wealth constant must, on

---

[10] Diamond and Stiglitz (1974), corollary 2, derive a similar result without resorting to approximations.

average, sell livestock. We thus expect livestock sales to be positive on average. Furthermore, physical returns to herdings are influenced by rainfall s_t. Consequently, livestock sales are expected to respond to rainfall shocks independently from the effect of rainfall on non-livestock income. We must therefore control for the direct effect of rainfall on livestock transactions if we are to avoid spurious results when evaluating the relationship between exogenous income shocks and livestock sales.

Next, consider how variations in livestock returns affect portfolio adjustments. Suppose that the household decides to subtract Δ_t from its liquid wealth in order to smooth consumption, i.e., $W_{t+1} = W_t - \Delta_t$. Continue to assume that livestock prices and expected physical returns to livestock are constant. It then follows that $S_t = \beta_{t+1}\, \Delta_t + \eta_t\, L_t$: livestock sales serve to buffer a negative income shock. If, however, the household has lost livestock to drought, disease or theft, i.e., if $\eta_t \ll 0$, an income shock may actually result in the purchase of livestock. To see why, suppose that a household starts period t with 100,000 Francs, half of which is in the form of livestock. The household then loses an animal worth 10,000 Francs. Liquid wealth is now 90,000 Francs. To maintain the same portfolio composition, the household has to purchase livestock worth 5,000 Francs: a low return to livestock has triggered a livestock purchase. In practice, this situation is unlikely to arise: droughts in Africa typically lead to crop failure and to a depletion of food stocks well before they begin affecting livestock survival (Sandford (1983), Swift (1986), Binswanger and McIntire (1987)). When hit by a drought, villagers are therefore expected to sell livestock to replenish their granaries.

Livestock transactions also respond to the evolution of livestock prices. Consider what happens when the distribution of livestock prices and physical returns is stationary. In this case, expected returns $\bar{\eta}(s_t)$ to herding are constant over time. It is easy to see from equation (5) that financial returns to livestock are an inverse function of the current livestock price P_t: the cheaper livestock is, the higher livestock holdings should be. A current drop in livestock prices then induces households to liquidate some of their grain stock to purchase animals. In practice, however, returns to livestock may not be stationary. Insufficient rainfall -- i.e., a low s_t -- does not only lower crop income today, it also reduces pasture quality and thus expected physical returns to herding in the future. As seen in equations (5) and (5'), the implied drop in livestock productivity $\bar{\eta}(s_t)$ has a negative effect on livestock holdings that is independent from the effect of rainfall on current incomes and prices. These possible effects can be controlled for by including current and lagged rainfall as separate determinants of livestock sales.

Finally, we must consider general equilibrium effects on livestock prices and assets. Indeed, income shocks affects the relative prices of livestock and grain in ways that depend critically on the integration of village grain and livestock markets with the rest of the world. If grain and livestock markets are perfectly integrated so that relative prices are not influenced by local events, livestock has no difficulty serving as buffer stock. In case of crop failure, farmers can sell animals to purchase grain from the rest of the world. This may not be true if markets are poorly integrated, however. To see why, suppose for a moment that WASAT farmers are totally isolated and continue to assume that they do not consume livestock directly. Net sales of livestock aggregated over the entire village, i.e., $\sum_{i \in V} S_{it}$ must then equal zero:

$$\sum_{i \in V} \left[\frac{1 + \bar{\eta}_i(s_t) - (1-\lambda)P_t - \nu_i - A_i \rho_{yL}(s_t)\sigma_y \sigma_L(s_t)}{A_i \, \sigma_L^2(s_t)} \right] = \sum_{i \in V} (1 + \eta_t^i) L_t^i \qquad (6)$$

In case of widespread crop failure, many households attempt to convert livestock assets into grain: formally, their coefficient of absolute risk aversion goes up, and the aggregate net demand for livestock -- the left hand side of equation (6) -- goes down. The supply of livestock -- the right hand side of equation (6) -- is predetermined. To reestablish equilibrium between the two, the local terms of trade between livestock and grain P_t must fall. As P_t drops, the expected return from livestock $1 + \bar{\eta}_i(s_t) - (1-\lambda)P_t - \nu_i$ rises. This induces some farmers to hold onto their animals so that, in equilibrium, there are no aggregate net sales of livestock. In this case, any grain shortfall results in a drop of the current livestock price P_t. Livestock cannot serve as buffer stock against collective rainfall shocks.

Fafchamps and Gavian (1995a) show that in Niger, a Sahelian country bordering Burkina Faso, livestock markets are only poorly integrated in spite of strong evidence that local livestock prices respond to shifts in urban meat demand (Fafchamps and Gavian (1995b)). It is therefore possible that rainfall shocks affect P_t in such a way as to dampen the buffer role of livestock. Even if this is the case, sales and purchases of livestock within the community could serve to smooth idiosyncratic shocks (e.g., Lucas (1992)): households with poor harvest could exchange animals against grain with those who have a plentiful harvest. A simple way to test whether the lack of market integration helps explain the pattern of livestock transactions is thus to check whether livestock transactions respond more to idiosyncratic than to collective shocks. If, in contrast, we find that livestock transactions respond *more* to collective than idiosyncratic shocks, this can be interpreted as evidence that WASAT farmers rely on other mechanisms than livestock sales to share risk among themselves. Candidates include transfers and consumption credit (Udry (1990, 1994), Fafchamps (1992, 1994)). Modeling formally the interactions between livestock assets and risk pooling mechanisms is beyond the scope of this paper. The reader is referred to Townsend (1994), Udry (1994) and Fafchamps (1994) for details.

Other dynamic processes may also affect livestock holdings. Jarvis (1974) and, more recently, Rosen, Murphy and Sheinkman (1994) demonstrate that gestation lags in livestock production can generate cycles in livestock prices and assets. Fafchamps (1996) shows that, in the presence of common access to pasture, sales and losses of livestock during droughts raise the expected returns to surviving animals $\overline{\eta}(s_t)$. This effect dampens the response of livestock transactions to rainfall shocks and can also generate livestock cycles. These complicated dynamic effects may also contribute to the observed patterns of livestock sales and purchases. Since they all ultimately depend on aggregate rainfall shocks, we can hope to partly control for these effects by adding current and lagged rainfall as variables independently explaining livestock transactions. In the absence of data on the number of animals in the hands of each household, it is indeed impossible to control for these non-linear processes in a more precise fashion.

Having conceptually clarified the role of livestock as a buffer stock, we are now ready to test whether actual sales and purchases of livestock respond to aggregate and idiosyncratic shocks. The data we use is particularly well-suited for this purpose, having been collected during a time of drought. But the data are imperfect and information is missing on important dimensions of the model. Nonetheless, we are able to verify that livestock is used as buffer stock, alas to an extent much smaller than what we had originally anticipated.

Section 2. An Application to Burkina Faso

We examine the livestock transactions of a sample of farmers in Burkina Faso between 1981 and 1985. During this period, the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) collected data on crop production and asset transactions from 25 households in each of six villages in three distinct agro-climatic zones in Burkina Faso. These zones vary in soil quality, annual rainfall patterns, and population densities. The Sahel in the north of Burkina Faso 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) (Matlon (1988); Matlon and Fafchamps (1989); Fafchamps (1993)).

The farming system is characteristic of rainfed agriculture in the WASAT. There is one cropping season per year. Each household simultaneously cultivates multiple plots -- the median number of plots is 10 -- and many different crops -- the median number of primary crops is 6, more if secondary intercrops are taken into account. Irrigation is not widely practiced; agriculture is primarily rainfed. The predominant crops in all the regions are sorghum and millet. Millet is predominant in the drier north (Sahel), sorghum in the more humid south (Sudanian and North Guinean zones). Cotton is also grown in the North Guinean savannah. There are active markets for agricultural output in all six villages. As land has become scarce over the past few decades, particularly in the Mossi highlands, large variations in cultivated land per adult household member have begun to appear (Reardon et al. (1988); Matlon (1988)). Neither labor nor land rental markets have yet emerged to accommodate these variations, however, presumably because of the relative historical abundance of land in the region (Binswanger and McIntire (1987))

All of the surveyed farmers are poor and face high income risk. Mean income per capita is less than 100 US dollars (Fafchamps (1993)). The inter-year coefficients of variation in crop income, averaged across households, are 67%, 52% and 45% in the Sahelian, Sudanian and Guinean zones, respectively (Reardon et al. (1992)). The corresponding figures for total income are 41%, 40% and 31% *(ibidem)*. The primary source of income risk is rainfall variation. Much (but not all) of rainfall risk is aggregate because all households in a village are subject to similar rainfall variation. Carter (1994) estimates that aggregate rainfall shocks are responsible for approximately 50 percent of crop income variation for households in two of the three agroclimatic zones covered in the ICRISAT sample.

The cropping season runs typically from April through September. Rains peak in July and August. The rainy season is 2.5-3 months long in the Sahel; 5-6 months long in the North Guinean zone (Matlon (1988); Matlon and Fafchamps (1989)). Rainfall data in the surveyed villages was collected daily between 1981 and 1985. The survey area encompasses wide variability in rainfall. In each village and each of the survey years, rainfall was below its long term average in the nearest meteorological station (Table 1). Between 1981 and 1985, the Sahelian villages experienced three of the five lowest rainfall years since meteorological data collection began in 1952. The Sudanian zone experienced 4 of the 6 lowest rainfall totals since 1942. One of the North Guinean villages had 4 of its lowest 6 rainfall years, the other, 4 of its worst 10 rainfall years since the collection of rainfall data began in 1922. In each case, rainfall was comparable to or lower than during the famine of the 1970s. These large aggregate shocks are partly responsible for the high coefficients of variation of crop income reported in the previous paragraph, and also for the high correlation between household income and average village income. As a result of several years of drought, a famine erupted in the survey area in 1984, leading to significant inflows of food aid. So much rainfall variability creates an interesting opportunity to examine the relationship between aggregate income shocks and asset transactions.

Table 2 provides information concerning livestock transactions and inventories among the sample households. Information concerning livestock inventories was collected only at the end of the survey period. It is not possible to construct stock series because no information was collected on livestock consumption (which is likely to be small, especially for cattle) and, more importantly, on animal births and deaths. Mean sales and purchases of cattle are large, but most households neither sold nor purchased cattle over the entire course of the survey period. This is unexpected if cattle sales are used to smooth consumption. Transactions are more frequent for small stock than for cattle. Yet at the end of the survey period, even after a number of years of severe drought, 90 percent of the households retained goats and sheep and about 70 percent still had cattle. Most households, therefore, would have been in a position to use the sale and purchase of animals to smooth consumption. Holdings of cattle were particularly high in the Sahel and North Guinean zones; goats and sheep were most important in the central, Sudanian zone. In contrast, Reardon (1988) reports that by 1985, grain stocks were largely exhausted. The sample thus constitutes an ideal test case to verify whether or not livestock transactions respond to transitory income shocks: households were subjected to large aggregate shocks; their most important, alternative stock of liquid wealth was depleted; and most households were still in a position to sell animals to compensate for income shortfalls even by the end of the survey period.

Data Preparation and Sample Limitations

We have crop income and livestock transaction data from May 1981 to December 1985, thus covering five cropping seasons. Information on livestock transactions was collected by the ICRISAT survey team about every 10 days. Animal sales and purchases are large, discrete transactions that surveyed households should find easier to recall than many components of either consumption or income. In most of the analysis that follows, livestock transactions for each household are aggregated by season. S_{it} denotes the number of net sales of livestock by household i in year t. Throughout, we treat cattle and small stock (goats and sheep) separately.

As discussed in the first section, it is not possible to equate livestock transactions with net saving: other forms of saving exist. Christensen (1989), for instance, estimates that livestock accounted for 54 percent of the value of these households portfolios in 1984 (where total wealth is the sum of wealth in livestock, cereal stocks, transport equipment, agricultural equipment and household goods). But we do not have data on consumption nor do we have time series information on asset stocks. We lack individual data on credit, grain stocks, cash holdings and jewelry. It is impossible, therefore, to estimate a model of optimal saving (as in Fafchamps and Pender (1996)) or to test the hypothesis that transitory income has no effect on consumption (e.g., Mace (1991); Cochrane (1991); Townsend (1994); Morduch (1991); Paxson (1992)). This paper focuses on a single but important issue that can be addressed with the available data: the use of livestock as buffer stock.

Section 3. Are Livestock Used as Buffer Stock?

Our goal is to estimate the extent to which households use livestock sales and purchases to smooth the effect of income shocks. We first examine the evidence graphically. Then we construct various measures of income shocks. Finally we regress livestock transactions on these shocks, controlling for other possible external effects.

In the absence of irrigation, crop income is strongly dependent on rainfall. For reasons we discussed in the first section, aggregate rainfall shocks are likely to require the liquidation of village's assets in order to import grain from elsewhere. On theoretical grounds, variations in rainfall are thus the exogenous source of risk most likely to be correlated with net sales of livestock. In contrast with theoretical expectations, however, the raw data on village rainfall and livestock sales provide no strong evidence that livestock transactions are used to smooth consumption. Figures 1 and 2 display the relationship between annual rainfall (deviated from its long-run average) and annual aggregate livestock sales in each village (deviated from their 5 year annual average). The Figures show no relationship between cattle sales and rainfall. There is, however, some suggestion that sales of small stock are higher when rainfall is lower.

To explore the impression conveyed by Figures 1 and 2, the relationship between livestock transactions and income risk must be examined in a more rigorous fashion. We do so in two steps. We first derive estimates of income shocks. Then we regress livestock transactions on these estimates and other explanatory variables.

Estimates of Crop Income Shocks

We derive three sets of crop income shock estimates. The first measures the effect of transitory rainfall variation on total crop income, thereby identifying a component of income that is both exogenous and transitory (see Paxson (1992) and Alderman (1994) for a similar approach). If precautionary savings serves primarily to ensure the survival of the household and its members, however, livestock sales may respond more strongly to variation in food availability than to shocks in non-food crop income. To test for this, we construct a second set of income shock estimates as the effect of rainfall variation on combined sorghum and millet output. These two sets of estimates constitute lower bounds since they ignore other possible factors that influence agricultural income (e.g., pests, theft). The third estimates, more in line with Bhalla (1980) and Wolpin (1982), use the converse strategy of identifying a permanent component of income and interpreting deviations from it as transitory shocks. They can be considered an upper bound on income shocks since they include both aggregate and idiosyncratic shocks -- the latter being partly corrected through risk pooling within the village. Because errors in the measurement of both current and permanent income tend to bias the third estimates away from zero, we rely on the first two measures in most of our analysis.

To derive the first two sets of estimates of income shocks, we run a regression of the form:

$$y_{it} = \alpha_1 X_i + \alpha_2 F_{it} + \alpha_3 X_i \otimes F_{it} + \lambda_i + \varepsilon_{it} \qquad (7)$$

where y_{it} is either crop income in CFA Francs (first set) or cereal output in quintals (second set) accruing to household i in year t. The vector X_i represents household characteristics that are determinants of income, such as the demographic structure of the household and detailed information on its landholdings and their quality. F_{it} is a village level measure of rainfall, comprised of the deviation of village rainfall in year t from its long-term average and this deviation squared. Carter (1993) finds that total rainfall and rainfall squared are good summaries of the overall affect of rainfall variation on output in these villages. We experimented with various measures of intra-season dry spells, the number of rainfalls within a season, and the starting and stopping dates of the rains but, in contrast to the results of Rosenzweig and Binswanger (1993), these other measures contribute nothing to the explanation of crop income once one accounts for total rainfall and rainfall squared. The final cross-product term in equation (7) is included in recognition of the fact that production on different types of land responds differently to similar levels of rainfall. λ_i is a household fixed effect reflecting the effect on income of unobserved characteristics of the household, and ε_{it} is a random error term. The third set of estimates consists of the residuals from an income equation not containing rainfall. These residuals are simply the deviation of household income in year t from their 1981-1985 average.

The parameters α_1 and λ_i in equation (7) cannot be separately estimated, but α_2 and α_3 can. If we can obtain consistent estimates of α_2 and α_3, then $\hat{y}_{it} \equiv \hat{\alpha}_2 F_{it} + \hat{\alpha}_3 X_i \otimes F_{it}$ provides a consistent estimate of a component of income for household i in period t that is transitory and could not be anticipated. Estimates of equation (7) are presented in Table 3. The null hypothesis that there are no individual fixed effects is strongly rejected: the $\chi^2(13)$ test statistic is 425. The individual rainfall coefficients are not significantly different from zero, but they are jointly statistically significant ($F(2,486)=10.94$, p=0.00). Rainfall also affects income through its interaction with soil quality: the income of households with land higher on the toposequence is more sensitive to rainfall variation than that of households cultivating valley bottoms (in agreement with Matlon and Fafchamps (1989)). There is also substantial variability across soil types in the responsiveness of crop income to rainfall. The joint *F*-statistic for the $X_i \otimes F_{it}$ regressors is $F(12,485)=9.36$ (p=0.00).

The second part of Table 3 presents estimates of equation (7) using combined millet and sorghum output in quintals as the dependant variable. The effects of rainfall on cereal output are similar to those on the total value of crop production, with the exception that the direct effect of rainfall is convex rather than concave. This result may be a consequence of the remarkably low levels of rainfall which occured over the sample period. The joint *F*-statistic for the $X_i \otimes F_{it}$ regressors is 17.09 (p=0.00).

Crop Income Shocks and Motivations for Selling Livestock

During the survey, sample households were asked to report their motivations for selling or buying livestock. Using the first set of crop income shock estimates, we tabulated their answers according to the severity of the shock the household faced (Table 4). The results provide some evidence in support of the buffer stock hypothesis. Indeed they show that, for those who faced large negative income shocks, the purchase of grain for consumption was the main motivation for selling cattle. For those who faced less severe shocks (i.e., in the 3rd and 4th quartile), other motivations such as the purchase of other livestock dominate. While households report selling cattle for a variety of reasons, they are more likely to cite consumption purposes when they sell goats and sheep. This is true across all crop income shock quartiles, but consumption purposes are more often cited in case of large negative shocks. Indeed, 80% of the goats and sheep sold by those in the first quartile were sold for consumption purposes. Those who face strong negative income shocks, therefore, seem to act in the way the precautionary saving mode predicts: in the face of income shocks, they liquidate assets.

Crop Income Shocks and Livestock: A Non-Parametric Analysis

When we turn to actual livestock transaction data, however, the pattern becomes less clear. Figures 3 and 4 present graphically the relationship between livestock sales and our first set of income shock estimates: along the horizontal axes is $\hat{y}_{it}$, the estimated shock to crop income caused by rainfall in CFA Francs. The vertical axes measures the net number of animals (cattle in figure 3, goats and sheep in figure 4) sold by the household following that shock. The curve represents the non-parametric regressions of net livestock sales on income shock, calculated using a Gaussian kernel with bandwidth of 20. Pointwise 90 percent confidence intervals are reported for every 10th observation.[11]

The figures reveal at most a weak relationship between net livestock sales and transitory income. Net cattle sales (Figure 3) show little noticeable relationship to adverse income shocks. There is no evidence that positive rainfall shocks lead to significant cattle purchases. Large negative income shocks caused by inadequate rainfall are associated with additional sales of only a fraction of a cow, which fail to compensate fully for the magnitude of the income shortfall. Take, for instance, the 90th lowest percentile of the distribution of estimated income shocks, which is about -80,000 FCFA, and consider the upper bound of the non-parametric regression's 90 percent confidence interval for resulting livestock sales. Even in this extreme case, households are predicted to sell no more than one-half to three-quarters of a cow. Given that the median cattle price during the survey period was less than 24,000 FCFA, this means that cattle sales offset at most twenty percent of the income loss resulting from a severe rainfall shock. If crop income and livestock prices co-move, for instance, because livestock markets are not perfectly integrated and shocks are spatially correlated (see section 1), then the proportion of the income shock offset by livestock sales is even lower.

---

[11] We use the Nadaraya-Watson estimator to determine a smoother for each income shock data point. Let X_i and Y_i be the income shock and livestock sale of observation i, respectively. Then the regression estimate for income shock x is:

$$\hat{m}_h(x) = \frac{\frac{1}{n}\sum_{i=1}^{n} K_h(x - X_i)Y_i}{\frac{1}{n}\sum_{i=1}^{n} K_h(x - X_i)}$$

K_h refers to the Gaussian kernel which shapes the weights placed upon each data point to determine the smoother, h refers to the bandwidth which scales the weights place upon the data points. For the Gaussian kernel,

$$K_h(u) = \frac{1}{h} K\left(\frac{u}{h}\right)$$

where

$$K(\nu) = (2\pi)^{-1/2} e^{-\nu^2/2}$$

For these regressions we select a bandwidth of 20, relatively small compared to the income shock value, to obtain a smooth for each type of livestock sales revealing a close replication of the original values. This bandwidth is sufficient to show the variation in the response of type of livestock sales to income shocks. Confidence intervals are determined by estimates of the variance for each data point x. See Hardle (1990), pp.99-100.

The pattern of net sales of goats and sheep, depicted in Figure 4, corresponds more closely to our expectations. The regression curve indicates that income shocks are inversely correlated with net sales of animals. Once again, however, sales fail to compensate for the magnitude of the shock. Take a -80,000 FCFA crop income shortfall and consider the upper bound of the 90 percent confidence interval for livestock sales. Figure 4 shows that, even in this case, sales of goats and sheep are unlikely to exceed 2 or 3 animals. Given that the average price of these animals is about 2500 FCFA, our upper bound estimate is that sales of goats and sheep offset at most 10 percent of the income loss due to a severe rainfall shock. Together, livestock sales offset at most 30% of aggregate income loss -- well below their 54% share in households liquid wealth (Christensen (1989)). Results conform even less with theoretical expectations when we use our two other measures of crop income shocks, variations in cereal output due to rainfall, and deviations from average household crop income. In either case, predicted animal sales in response to shocks drop to roughly half the size of the response shown in Figures 3 and 4.

Crop Income Shocks and Livestock: A Multivariate Analysis

The nonparametric regressions presented in Figures 3 and 4 do not control for other factors possibly influencing animal sales and purchases. To take them into account and get a more precise measure of the effect of crop income shocks on livestock transactions, we estimate the following equation:

$$S_{it} = \beta_1 Z_i + \beta_2 F_{it} + \beta_3 \hat{y}_{it} + \nu_{it} \qquad (8)$$

where S_{it} is the net number of livestock (either cattle or small stock) sold by household i in year t, and Z_i is a vector of household characteristics, such as demographic structure and initial asset holdings, which might affect expected income, precautionary savings, and thus livestock transactions. $\hat{y}_{it}$ is one of the three measures of the transitory income shock derived above. ν_{it} is a random error term. F_{it} stands for rainfall shocks. Current rainfall is added because of its possible direct effect on the productivity of livestock production through fodder growth, the availability water, and the disease environment. In an effort to capture the influence of past productivity shocks and general equilibrium effects on livestock prices (see section 1), lagged rainfall is included as well.

Estimates of equation (8) are presented for cattle in Table 5 and for goats and sheep in Table 6. All standard errors are corrected for the use of the estimated income shock variable.[12] Consider cattle first. The first two columns of Table 5 present the determinants of net cattle sales using the effect of rainfall on crop income as measure of income shocks. In order to capture some of the nonlinearity apparent in Figures 3 and 4, the effects of positive and negative income shocks are permitted to differ. No statistically significant relationship is found between income shocks and cattle sales. The point estimate indicates that households adversely affected by drought sell more cattle than other households, but the effect is very small. The point estimate implies that a household subjected to an 80,000 FCFA adverse shock sells about one-third of a cow. If we again evaluate the effect of an income shock at the lowermost boundary of the 90 percent confidence interval, a -80,000 FCFA income shortfall is associated with the sale of about 90 percent of a cow -- the equivalent of 22,000 FCFA.

Estimates of equation (8) using our second set of income shock estimates -- the effect of rainfall on cereal production -- are presented in the middle two columns of Table 5. Results indicated a very weak relationship between shocks and livestock sales. The lowest nintieth percentile of cereal production shock is equivalent to a drop in grain output of 1,800 Kg -- enough to feed a family of 8 people. At the height of the 1984-85 drought, buying that much grain would have required the sale of approximately 7.5 cows. At the regression point estimate, however, a 1,800 Kg grain shortfall translates into the sale of only a third of a cow. Even evaluated at the most negative edge of the 90 percent confidence interval, such a large adverse shock is associated with the sale of just one cow. The estimated responsiveness of cattle sales thus fails far short of what would be required to offset output loss. Results using our third set of income shock estimates -- deviations from household income averages -- are shown in the final two columns of Table 5. They confirm the very weak relationship between crop income shortfalls and cattle sales. The relationship is not statistically significant, and for negative income shocks the point estimate even has the wrong sign. At the most negative boundary of the 90 percent confidence interval, a -80,000 FCFA income shortfall is associated with the

[12] A simple modification of the argument presented in Pagan (1984) shows that the covariance matrix of $\beta \equiv [\beta_1, \beta_2, \beta_3]$ is

$$\Sigma = \sigma_v^2(A'A)^{-1} + \sigma_\varepsilon^2(A'A)^{-1}A'B(C'C)^{-1}B'A(A'A)^{-1}$$

where $A_{it} \equiv [Z_i, W_{it}, \hat{y}_{it}]$, $B_{it} \equiv [W_{it}, X_i \otimes W_{it}]$ and $C_{it} \equiv [X_{it}, W_{it}, X_i \otimes W_{it}]$. B and C are in deviated form, with the household mean over the 5 years subtracted from each observation. In practice, this adjustment increases the estimated standard errors by less than 1 percent.

sale of less than one twentieth of a cow.

Let us now turn to goats and sheep. The relationship between our first measure of income shocks and the sale of small stock is on the border of conventional levels of statistical significance, at least for adverse shocks (the first two columns of Table 6). However, as in the case of cattle, the relationship is very weak. Evaluating as before the effect of a severe income shock at the uppermost boundary of the 90 percent confidence interval, a -80,000 FCFA crop income shortfall would result in the sale of about one and a half goats or sheep, yielding about 3,750 FCFA. When we use income shock estimates based on physical grain output (the middle two columns of Table 6), the relationship between shocks and net sales remains very weak. Neither point estimate is statistically significantly different from zero. Once again, evaluating at the most negative edge of the ninety percent confidence interval, a drop of 1,800 Kg in grain output is associated with increased sales of just 1.5 goats or sheep. Finally, using our third set of measures of income shocks (the deviation of current income from average income - the final two columns of Table 6), the point estimates are not statistically significantly different from zero, and they are very small. Again evaluating at the most negative edge of the ninety percent confidence interval, we find that an 80,000 FCFA adverse shock is associated with additional sales of only about one tenth of a goat or sheep.

Crop Income Shocks and Discrete Livestock Transactions

Livestock transactions, in particular for cattle, are discrete events. As indicated in Table 2, mean cattle sales per household are over 5 animals, but the median is zero. Estimating equation (8) using OLS thus result in model misspecification. Could it be that the regression results reported in Tables 5 and 6 are due to this misspecification? To test this possibility, we reestimate equation (8) using ordered probit. Results using the first set of crop income shock estimates are presented in Table 7.[13] The regression on cattle sales (column 1 of Table 7) provides no evidence of a statistically significant relationship between income shocks and animal sales. Once again, the effect is small. To evaluate the strength of the relationship, consider a household with median characteristics. If this household is subjected to an extremely adverse income shock of -80,000 FCFA, and if

[13] Standard errors are not corrected for the presence of the estimated shock variables. Footnote 12 suggests that the bias introduced is small.

we evaluate its response at the uppermost boundary of the 90 percent confidence interval, we see that the expected value of cattle sales increases by about 3/4 of a cow. A smaller adverse shock of 24,000 FCFA, which is about the value of a single cow, is associated with an increase in the probability of the sale of one cow of about 10 percentage points. There is also no statistically significant relationship between adverse income shocks and net sales of goats and sheep (column 3 of Table 7). If we consider a household with median characteristics and estimate its upper bound response to, say, a -40,000 FCFA income shock, we find that expected sales increase by less than two goats or sheep, offsetting about ten percent of the income shortfall.

Idiosyncratic versus Collective Shocks

Our estimates so far have looked at the correlation between livestock transactions and the sum of village-level and idiosyncratic transitory income shocks. One possible explanation for the the weak relationship between we have uncovered so far is that livestock and grain markets are not spatially integrated. As discussed in section 1, lack of integration means that livestock cannot be used to bring grain from the rest of the world, in which case livestock sales should not respond to aggregate income shocks. Even so, livestock transactions between village members may serve to insulate households against idiosyncratic shocks. If, in contrast, livestock sales and purchases are shown to respond more to aggregate than idiosyncratic shocks, this may be interpreted as evidence that risk sharing within the village is organized through means (e.g., gifts, consumption credit) other than asset transactions.

To check the validity of these predictions, we decompose our first two measures of transitory shocks into two components: a village-level component $\hat{y}_t^v = \alpha_2 F_{it} + \alpha_3 F_{it} \otimes \bar{X}_v$, and an idiosyncratic component $\hat{y}_{it}^{id} = \alpha_3 F_{it} \otimes (X_i - \bar{X}_v)$. The village mean of X_i is denoted $\bar{X}_v$. The variable $\hat{y}_{it}^{id}$ should have no effect on livestock transactions if risk is shared efficiently. The variable $\hat{y}_t^v$ should not influence animal sales if livestock markets are not spatially integrated.

The results of this exercise are reported in Table 7 using crop income shocks.[14] They provide at most marginal support for the idea that risk is shared within the village.

---

[14] Similar qualitative results obtain if OLS is used instead of ordered Probit.

There is no statistically significant relationship between any kind of income shock and net cattle sales, and all point estimates are very small. Estimated coefficients for the effect of village-level shocks on net cattle sales are larger than those for ideosyncratic shocks, but the differences are not statistically significant. Turning to goats and sheep, we find that both adverse income shocks have a statistically significant effect on small stock sales, but animal sales are more responsive to village-level than idiosyncratic shocks. A household with median characteristics subjected to an adverse village level shock of -40,000 CFA increases expected sales of goats and sheep by about 3 animals. At the upper bound of the 90 percent confidence interval, expected sales increase by six animals, thereby offsetting 1/6 of the income loss. The responsiveness of small stock sales to idiosyncratic shocks is essentially zero. These results can be interpreted as limited evidence that risk sharing is present but imperfect -- perhaps due to information asymmetries and commitment problems (Fafchamps (1992, 1994)).

Conclusion and Prospects for Future Research

The theory of optimal saving predicts that households which face substantial risk but cannot smooth consumption through insurance or credit will use liquid assets for self-insurance. We examined this hypothesis for farming households in the West African semi-arid tropics. We found only very limited evidence that livestock inventories serve as buffer stock against large variations in crop income induced by severe rainfall shocks. Contrary to model predictions, livestock sales fell far short of compensating for the crop income shortfalls induced by the 1980s drought. The finding that the magnitude of livestock sales is small in response to large climatic shocks is consistent across a variety of statistical methods. We estimate that livestock sales of cattle and small stock combined offset at most thirty percent, and probably closer to only fifteen percent of the crop income shortfalls endured during severe drought, even though most surveyed households still held livestock at the end of the drought. Livestock transactions compensate for at most thirty percent, and probably closer to twenty percent of crop income shortfalls due to village-level shocks alone. The weight of the evidence, therefore, is that livestock plays a less important role in consumption smoothing than is commonly believed (e.g., Rosenzweig and Wolpin (1993)). This conclusion should be compared to a recent finding by Lim and Townsend (1994) that bullock sales in semi-arid India actually increase the variance of cash-on-hand instead of reducing it.

These results raise an unresolved issue: why is it that sample households, who were subjected to one of the worst droughts of their history, did not resort to selling livestock as much as we expected? One possibility is that they had access to alternative, less costly strategies to deal with the consequences of drought. What could these strategies have been? Households may have used off-farm activities to smooth crop income fluctuations. Reardon, Delgado and Matlon (1992) indeed show that non-farm activities by sample households are an important means of ex ante income diversification. They provide thirty to forty percent of total income and the income they generate is not perfectly correlated over time with crop income, thereby permitting some diversification of risk. To test whether non-farm activities insure sample households against crop income shortfalls, we regressed non-farm income on our estimates of rainfall-induced income shocks. Non-farm income includes all labor and business income from both migratory and local non-farm activities. The regression, in which we controlled for household fixed effects, yields a coefficient of 0.08 with a t-statistic of 5.15. Non-farm income is thus positively correlated with shocks affecting crop income: droughts adversely affect not only crop income but also non-farm income. These results are consistent with Sen's (1981) remark that droughts lead to a collapse of the demand for local services and crafts. There is no evidence, therefore, that the crop income losses due to rainfall shocks can be offset by gains in off-farm income.

Another possibility is that transfers serve to smooth consumption. We have already argued that local insurance mechanisms are likely to be ineffective against large-scale shocks such as severe droughts. Is it possible that large scale redistributive efforts, like international food aid, may have successfully smoothed consumption? Reardon, Matlon and Delgado (1988) show that food aid comprised a substantial portion (almost 60 percent) of all transfers received by the poorest of the Sahalien households during the 1984 drought. Transfers, however, constituted only a tiny proportion of total income: less than 3 percent. To verify if transfers compensate for drought, we regressed transfer income on our estimate of rainfall-induced income shock. Results show that transfers are not correlated, over time and within households, with the aggregate, rainfall-induced income shortfalls: the regression, with household fixed effects, yields a coefficient of transfer income on income shocks of 0.05 with a t-statistic of 0.173. Transfers thus do not serve to offset the decline in crop income associated with a drought. Food aid, however, exerts a pressure on local food prices and may have served to moderate grain price fluctuations.

There are three other mechanisms about which we have no direct data which can potentially serve to insulate consumption from income fluctuations. The first is the use of credit markets. Udry (1990) shows that, in a neighboring region of northern Nigeria, credit markets are actively used to deal with income shocks, but the circulation of credit remains largely limited to the village itself. Christensen (1989) reports the results of a survey of credit use amongst households included in the ICRISAT sample. He finds that participation in credit markets is widespread: more than 80 percent of all households borrow from either formal or informal sources. But the average amount borrowed is small: less than five percent of income. Unfortunately, household level data has not been made available to other researchers, and the credit data only covers a single point in time. It is impossible, therefore, to determine whether credit play a substantial role in coping with droughts and the extent to which it reaches beyond the confines of the village. More research is needed in this area.

The second possibility is the reorganization of household units. Available evidence on famines indicates that family units often split in extremely bad times (Alamgir (1980); Greenough (1982); Vaughan (1985)). Moreover, Watts (1983) and Guyer (1981) have argued that the boundaries of households in semi-arid Africa can be quite fluid, particularly during times of stress. It may then be that households shed members (e.g., repudiate wives, send children to live with relatives) to cope with large income losses. Further research is required to evaluate these hypotheses.

The third and most serious possibility is the use of buffer stocks other than livestock inventories. Likely candidates include grain stocks, cash holdings, valuables (gold, jewelry and cloth), and stocks of human and farm capital. In India, Jacoby and Skoufias (1995) show that investment in children's education decreases in response to income shocks. Given the low levels of schooling prevailing in the WASAT, however, lower investment in child education is unlikely to be an important source of consumption smoothing. With regard to grain stocks, the only available factual information is the mention by Reardon, Matlon and Delgado (1988) that grain stocks held by sample households were largely depleted by 1985. We have no direct information regarding the time path of inventories of grain, cash, or valuables, so it is not possible to determine precisely the role played by these stocks in buffering consumption from the effects of drought. Reconstructing flows of cash and grain from the available production and transaction data could nevertheless be undertaken, as in Lim and Townsend (1994), but in the absence of complete consumption expenditure data, such an excercise is unlikely to provide a definitive answer. These issues are left for future research.

Another unresolved issue is, if consumption smoothing is imperfect, why do households hold onto livestock instead of selling it? Livestock inventory data collected at the end of the survey period indicates that the great majority of surveyed households still owned livestock even after a major drought. Why is that? The model presented in section 1 offers one possible explanation, namely that returns to livestock production dramatically increase after a drought. Livestock mortality during the drought and reduced pressure on common grazing land afterwards indeed implies that those who are lucky or patient enough to hold onto their animals until after the drought can hope access to plentiful pasture (Livingstone (1984, 1986)). Moreover, gestation lags and herd composition effects complicate the dynamics of the household's decision process. Rosen, Murphy and Scheinkman (1994) and Fafchamps (1996) model some of these dynamic effects. Fafchamps and Gavian (1995a) document the rapid recovery of livestock prices in Niger in the aftermath of the 1984 drought. Whether hopes of high returns to livestock after the drought or other lagged dynamic effects are the driving force behind what we observed remains to be shown empirically.

References

Alamgir, M. 1980. Famine in South Asia: Political Economy of Mass Starvation. Cambridge, Mass: Oelgeschlager, Gunn and Hain Publ.

Alderman, Harold and Christina Paxson. 1992. "Do the Poor Insure?: A Synthesis of the Literature on Risk Sharing Institutions in Developing Countries." Manuscript, World Bank.

Atwood, D. A. 1990. "Land Registration in Africa: The Impact on Agricultural Production." World Development. 18(5), 659-671

Barrett, Vincent, Gregory Lassiter, David Wilcock, Doyle Baker and Eric Crawford. 1982. Animal Traction in Eastern Upper Volta: A Technical, Economic and Institutional Analysis. MSU International Development Paper No. 4. East Lansing.

Bell, C. 1988. "Credit Markets, Contracts, and Interlinked Transactions," in Chenery, H. and T.N. Srinivasan, eds. Handbook of Development Economics. New York: North Holland.

Bernus, E. 1980. "Famines et Secheresses chez les Touaregs Saheliens: Les Nourritures de Substitution". Africa. 50 (1), 1-7

Besley, T. 1993. "Savings, Credit and Insurance." Draft Chapter for the Handbook of Development Economics, Volume III.

Binswanger, H., J. McIntire and C. Udry. 1989. "Production Relations in Semi-Arid African Agriculture," in Bardhan, P., ed. The Economic Theory of Agrarian Institutions. Oxford: Clarendon.

Binswanger, H. and M. Rosenzweig. 1986. "Behavioral and Material Determinants of Production Relations in Agriculture." Journal of Development Studies, 22/3.

Bromley, D. W. and Jean-Paul Chavas, 1989. "On Risk, Transactions, and Economic Development in the Semiarid Tropics". Econ. Devel. Cultural Change. 37(4), 719-736

Campbell, D. 1984. "Response to Drought among Farmers and Herders in Southern Kajado District, Kenya." Human Ecology.

Carroll, Christopher D., 1992. "The Buffer-Stock Theory of Saving: Some Macroeconomic Evidence". Brookings Papers on Econ. Activity. 2, 61-156

Carter, Michael. 1994. "Environment, Technology and the Social Articulation of Risk in West African Agriculture." Manuscript: Wisconsin.

Cashdan, E. 1985. "Coping with Risk: Reciprocity Among the Basarwa of Northern Botswanna."

Man, 20/3.

Cashdan, E., ed. 1989. Risk and Uncertainty in Tribal and Peasant Economies. Boulder: Westview.

Christensen, Garry. 1989. "Determinants of Private Investment in Rural Burkina Faso." Ph.D. dissertation, Cornell.

Cochrane, John H. 1991. "A Simple Test of Consumption Insurance". J. Polit. Econ. 99(5), 957-976

Dahl, G. and A. Hjort. 1976. Having Herds. Stockholm: Dept. of Social Anthropology, University of Stockholm.

Dasgupta, Partha. 1993. An Inquiry into Well-Being and Destitution. New York: Oxford.

Deaton, Angus. 1990. "Saving in Developing Countries: Theory and Review". World Bank Econ. Rev., Proceedings of the World Bank Annual Conference on Development Economics, 61-96.

Deaton, Angus. 1991. "Saving and Liquidity Constraints." Econometrica. 59/5.

Deaton, Angus. 1992. "Saving and Income Smoothing in Cote d'Ivoire". Journal of African Economies. 1/1:1-24.

Diamond, Peter A. and Joseph E. Stiglitz, 1974. "Increases in Risk and in Risk Aversion". Journal of Economic Theory. 8/3: 337-360.

Eicher, Carl and Doyle Baker, 1982. "Research on Agricultural Development in sub-Saharan Africa: A Critical Survey". MSU International Development Paper No. 1, Michigan State University

Fafchamps, M. 1992. "Solidarity Networks in Rural Africa: Rational Peasants with a Moral Economy." Economic Development and Cultural Change.

Fafchamps, Marcel. September 1994. "Risk Sharing, Quasi-Credit and the Enforcement of Informal Contracts". Stanford University, Stanford. (mimeograph)

Fafchamps, Marcel and Sarah Gavian, August 1995a. "The Spatial Integration of Livestock Markets in Niger", Stanford University, Stanford. (mimeograph)

Fafchamps, Marcel and Sarah Gavian, June 1995b. "The Determinants of Livestock Prices in Niger", Stanford University, Stanford. (mimeograph)

Fafchamps, Marcel and John L. Pender. 1996. "Precautionary Saving, Credit Constraints, and

Irreversible Investment: Theory and Evidence from Semi-Arid India". Stanford University, Stanford. (mimeograph)

Fafchamps, Marcel. November 1996. "The Tragedy of the Commons, Cycles and Sustainability". Stanford University, Stanford. (mimeograph)

Greenough, Paul R. 1982. Prosperity and Misery in Modern Bengal: The Famine of 1943-1944. New York: Oxford University Press

Guyer, J. 1981. "Household and Community in African Studies." African Studies Review, 24.

Hall, Robert E. 1978. "Stochastic Implications of the Life Cycle-Permanent Income Hypothesis: Theory and Evidence". J. Polit. Econ. 86(6), 461-81

Herskovits, Melville. 1926. "The Cattle Complex in East Africa." American Anthropologist. 28.

Jacoby, Hanan and Emmanuel Skoufias. 1995. "Risk, Financial Markets, and Human Capital in a Developing Country". University of Rochester, Rochester (mimeograph).

Jarvis, L.S., "Cattle as Capital Goods and Ranchers as Portfolio Managers: An Application to the Argentive Cattle Sector", *J. Polit. Econ.*, 82(3): 489-520, 1974.

Jodha, N. 1978. "Effectiveness of Farmers' Adjustment to Risk." Economic and Political Weekly. 18.

Lim, Youngjae and Robert M. Townsend. December 1994. "Currency, Transaction Patterns, and Consumption Smooting: Theory and Measurement in ICRISAT Villages", Manuscript: University of Chicago.

Livingstone, Ian. 1984. Pastoralism: Practice, Process and Policy, Rome: FAO.

Livingstone, Ian. 1986. "The Common Property Problem and Pastoralist Economic Behavior". J. Devel. Studies. 23 (1), 5-19

Loutan, Louis. 1985. "Nutrition Amongst a Group of Wodaabe (Bororo) Pastoralists in Niger", in Population, Health, and Nutrition in the Sahel. Allan G. Hill (ed.). London: KDI

Lucas, R.E. March 1992. "On Efficiency and Distribution", *Econ. J.*, 102(411): 233-247.

Mace, Barbara J. 1991. "Full Insurance in the Presence of Aggregate Uncertainty", J. Polit. Econ. 99(5), 928-956

Matlon, P. 1988. "The ICRISAT Burkina Faso Farm Level Studies: Survey Methods and Data Files." Economics Group, VLS and Miscellaneous Papers Series, ICRISAT, Hyderabad, India.

Matlon, Peter J. and Marcel Fafchamps. 1989. "Crop Budgets in Three Agro-Climatic Zones of Burkina Faso". ICRISAT Progress Report. Hyderabad, India.

McCown, R., G. Haaland, and C, deHaan. 1979. "The Interaction Between Cultivation and Livestock Production in Semi-Arid Africa," in Hall, A., et. al., eds. Agriculture in Semi-Arid Environments. New York: Springer-Verlag.

McIntire, John, Daniel Bourzat and Prabhu Pingali. 1992. Crop-Livestock Interaction in Sub-Saharan Africa. Washington D.C.: World Bank.

Morduch, Jonathan. 1991. "Consumption Smoothing Across Space: Tests for Village-Level Responses to Risk". Harvard University. (mimeograph)

Negishi, Takashi. 1959. "Welfare Economics and Existence of an Equilibrium for a Competitive Economy". Metroeconomica. XI

Pagan, Adrian. 1984. "Econometric Issues in the Analysis of Regressions with Generated Regressors." International Economic Review.

Paxson, Christina H. 1992. "Using Weather Variability to Estimate the Response of Savings to Transitory Income in Thailand". Amer. Econ. Rev. 82(1), 15-33

Platteau, Jean-Philippe. 1991. "Traditional Systems of Social Security and Hunger Insurance: Past Achievements and Modern Challenges". in Social Security in Developing Countries. E. Ahmad, J. Dreze, J. Hills, and A. Sen (eds.), Oxford: Clarendon Press

Platteau, Jean-Philippe. 1992. "Formalization and Privatization of Land Rights in Sub-Saharan Africa: A Critique of Current Orthodoxies and Structural Adjustment Programmes". The Development Economics Research Programme, 34. London School of Economics, London.

Reardon, Thomas. forthcoming. "Cereals Demand in the Sahel and Potential Impacts of Regional Cereals Protection." World Development.

Reardon, Thomas, Peter Matlon and Christopher Delgado. 1988. "Coping with Household-Level Food Insecurity in Drought-affected Areas of Burkina Faso." World Development 16/9:1065-1074.

Reardon, Thomas, Christopher Delgado and Peter Matlon. 1992. "Determinants and Effects of Income Diversification Amongst Farm Households in Burkina Faso." Journal of Development Studies. 28/2.

Reardon, Thomas and Peter Matlon. 1989. "Seasonal Food Insecurity and Vulnerability in Drought-Affected Regions of Burkina Faso," in David Sahn, ed. Seasonal Variability in Third World Agriculture: The Consequences for Food Security. Baltimore: Johns Hopkins.

Rosen, Sherwin, Kevin Murphy and José Scheinkman. 1994. "Cattle Cycles." Journal of Political Economy. 102/3.

Rosenzweig, M. and K. Wolpin. 1993. "Credit Market Constraints, Consumption Smoothing and the Accumulation of Durable Production Assets in Low-Income Countries: Investments in Bullocks in India." Journal of Political Economy.

Sandford, Stephen. 1983. Management of Pastoral Development in the Third World. New York: John Wiley and Sons

Sen, Amartya. 1981. Poverty and Famines. Oxford: Clarendon Press

Shepherd, A. 1984. "Nomads, Farmers and Merchants: Old Strategies in Changing Sudan," in Scott, E. ed.

Silberfein, M. 1984. "Differential Development in Machakos District, Kenya," in Scott, ed.

Swift, Jeremy. 1986. "The Economics of Production and Exchange in West African Pastoral Societies". in Nomads and Pastoralists. Mahdi Adamu and Kirk Greene (eds.)

Swinton, Scott. 1988. "Drought Survival Tactics of Subsistence Farmers in Niger." Human Ecology, 16,2: 123-144.

Townsend, Robert M. 1994a. "Risk and Insurance in Village India". Econometrica. 62(3), 539-591

Townsend, Robert M. 1994b. "Financial Systems in Northern Thai Villages". Department of Economics, University of Chicago (mimeograph).

Udry, C. 1990. "Rural Credit in Northern Nigeria: Credit as Insurance in a Rural Economy", World Bank Econ. Rev.

Udry, C. 1993. "Risk and Saving in Northern Nigeria." Institute for Policy Reform Working Paper no. 62, Washington, D.C.

Udry, C. 1994. "Risk and Insurance in a Rural Credit Market: An Empirical Investigation in Northern Nigeria," Review of Economic Studies. 61(3), no. 208, pp. 495-526.

Van Apeldoorn, G.J. 1977. The Aftermath of the 1972-1974 drought in Nigeria. Zaria: Center for Social and Economic Research.

Vaughan, M. 1985. "Famine Analysis and Famine Relations: 1949 in Nyasaland". Past and Present. 108, 177-205

Watts, M. 1983. Silent Violence: Food, Famine and Peasantry in Northern Nigeria. Berkeley: University of California Press.

Wolpin, Kenneth. 1982. "A New Test of the Permanent Income Hypothesis: The Impact of Weather on the Income and Consumption of Farm Households in India." International Economic Review.

Zeldes, Stephen P. 1989. "Optimal Consumption With Stochastic Income: Deviations from Certainty Equivalence". Quarterly J. Econ. 104(2), 275-298

Table 1. Village Rainfall Data

Village	**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
	0.70	*0.73*	*0.55*	*0.74*	*0.65*
Northern-Guinean Region:					
Koho	666	770	725	783	877
	0.70	*0.81*	*0.76*	*0.82*	*0.92*
Sayero	865	561	634	676	664
	0.90	*0.59*	*0.67*	*0.71*	*0.70*

Source: ICRISAT data. 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.

Table 2. Livestock Characteristics by Household

	Cattle		Goats and Sheep	
	Mean	Median	Mean	Median
Inventories:				
Sahelian zone	6.5	2	16.0	8
Sudanian zone	4.6	0	26.6	20
Gunean zone	14.4	2	10.2	5
Transactions:				
Sales	5.1	0	9.7	5
Purchases	3.0	0	5.5	3
Number of observations	168		168	

Source: ICRISAT data.

Table 3. Fixed Effect Estimates of the Determinants of Crop Income and Cereal Output

Variable	Crop Income		Cereal Output	
	Parameter estimates	t-ratio	Parameter estimates	t-ratio
Rainfall	0.4680	*1.46*	0.1440	*5.10*
Rainfall squared	-0.0010	*-1.39*	0.0002	*3.96*
Rainfall *				
lowland area	-0.0910	*-3.97*	-0.0130	*-7.26*
near lowland area	-0.1480	*-6.28*	-0.0050	*-2.99*
midslope area	-0.0370	*-1.52*	-0.0001	*-0.05*
near upland area	0.3230	*1.39*	0.0190	*3.97*
Rainfall *				
seno soil area	0.0850	*3.72*	0.0080	*3.60*
zinka soil area	0.1890	*3.10*	0.0060	*1.26*
bissiga soil area	-0.0150	*-0.32*	-0.0100	*-3.08*
raspouiga soil area	0.2000	*2.46*	0.0220	*3.95*
ziniare soil area	-0.0440	*-0.82*	-0.0150	*-4.88*
other soil area	0.0150	*0.63*	-0.0001	*-0.06*
Rainfall *				
area in plots near home	-0.2450	*-2.99*	-0.0140	*-1.37*
Number of observations	631		631	

Table 4. Reported Motives for Livestock Sales

	Cattle				Goats and Sheep			
Income shock quartile:	bad shock	med. bad	med. good	good shock	bad shock	med. bad	med. good	good shock
Reported motive for sale:								
Consumption	78%	51%	39%	19%	80%	70%	65%	57%
Loan or tax payment	2%	12%	2%	2%	4%	9%	5%	4%
Production	4%	5%	10%	15%	2%	4%	15%	11%
Livestock care	7%	13%	13%	3%	3%	6%	1%	5%
Gifts	2%	5%	0%	0%	2%	2%	3%	2%
Purchase livestock	5%	14%	37%	55%	3%	4%	2%	11%
Other	2%	0%	0%	5%	6%	6%	9%	10%
Total:	100%	100%	100%	100%	100%	100%	100%	100%
Number of observations				709				1090

Source: ICRISAT data.

Table 5. Second Stage OLS Estimates of the Determinants of Net Cattle Sales

	Parameter estimates	*t-ratio*	Parameter estimates	*t-ratio*	Parameter estimates	*t-ratio*
Income shock due to rainfall (x 10,000 CFAF)						
positive	-0.0014	*-0.29*				
negative	-0.0040	*-0.80*				
Cereal output shock due to rainfall (x 100 Kg.)						
positive			-0.0158	*-0.44*		
negative			-0.0173	*-0.76*		
Income deviation from hh mean (x 10,000 CFAF)						
positive					-0.0022	*-1.34*
negative					0.0030	*1.12*
Rainfall deviation from mean	-0.0022	*-0.62*	-0.0022	*-0.64*	-0.0035	*-1.07*
Lagged rainfall deviation	-0.0013	*-0.67*	-0.0016	*-0.83*	-0.0028	*-1.76*
Household characteristics						
Share of lowland area	-0.1234	*-0.25*	-0.1452	*-0.29*	-0.0657	*-0.14*
Share of near lowland area	0.0297	*0.06*	0.0161	*0.03*	0.0799	*0.17*
Share of midslope area	-0.0955	*-0.20*	-0.1063	*-0.22*	-0.0294	*-0.07*
Share of upland area	-0.3328	*-0.60*	-0.3451	*-0.62*	-0.2139	*-0.42*
Total cultivated area	-0.0650	*-0.13*	-0.0507	*-0.10*	-0.0810	*-0.18*
Number of adult males	0.1035	*1.05*	0.1008	*1.02*	0.1265	*1.37*
Number of adult females	0.1830	*2.41*	0.1846	*2.43*	0.1426	*2.09*
Dummy for village 2	0.3560	*0.46*	0.3648	*0.47*	0.3509	*0.47*
Dummy for village 3	-1.7671	*-2.07*	-1.7392	*-2.05*	-1.5493	*-1.89*
Dummy for village 4	-0.8619	*-0.95*	-0.8352	*-0.92*	-1.0252	*-1.19*
Dummy for village 5	0.3195	*0.35*	0.3510	*0.39*	0.0135	*0.02*
Dummy for village 6	-1.2141	*-1.16*	-1.1280	*-1.09*	-1.3737	*-1.38*
Age of head of household	-0.0246	*-0.34*	-0.0245	*-0.34*	-0.0204	*-0.29*
Age of head squared	0.0006	*0.83*	0.0006	*0.84*	0.0005	*0.74*
F-test statistic	F(18,385)	*2.37*	F(18,385)	*2.37*	F(18,412)	*2.25*
level of significance		*0.00*		*0.00*		*0.00*
Number of observations	421		421		448	

Table 6. Second Stage OLS Estimates of the Determinants of Net Small Stock Sales

	Parameter estimates	*t-ratio*	Parameter estimates	*t-ratio*	Parameter estimates	*t-ratio*
Income shock due to rainfall (x 10,000 CFAF)						
positive	-0.0019	*-0.30*				
negative	-0.0112	*-1.74*				
Cereal output shock due to rainfall (x 100 Kg.)						
positive			-0.0265	*-0.58*		
negative			-0.0395	*-1.36*		
Income deviation from hh mean (x 10,000 CFAF)						
positive					-0.0023	*-1.08*
negative					0.0040	*1.18*
Rainfall deviation from mean	0.0015	*0.34*	0.0015	*0.34*	0.0017	*0.41*
Lagged rainfall deviation	0.0008	*0.31*	0.0000	*0.01*	0.0002	*0.09*
Household characteristics						
Share of lowland area	0.3692	*0.59*	0.3192	*0.51*	0.4051	*0.69*
Share of near lowland area	0.6745	*1.07*	0.6419	*1.02*	0.7475	*1.27*
Share of midslope area	0.9048	*1.47*	0.8840	*1.44*	1.0026	*1.76*
Share of upland area	1.1424	*1.61*	1.1117	*1.57*	1.2175	*1.87*
Total cultivated area	-0.8386	*-1.35*	-0.8033	*-1.30*	-0.8713	*-1.52*
Number of adult males	0.0536	*0.43*	0.0507	*0.40*	0.0943	*0.80*
Number of adult females	0.2900	*3.01*	0.2916	*3.02*	0.2404	*2.77*
Dummy for village 2	-2.2592	*-2.30*	-2.2740	*-2.31*	-2.3796	*-2.53*
Dummy for village 3	-3.2634	*-3.01*	-3.1581	*-2.92*	-2.8360	*-2.72*
Dummy for village 4	-3.0320	*-2.62*	-2.9785	*-2.58*	-3.1221	*-2.84*
Dummy for village 5	-3.0816	*-2.65*	-3.0117	*-2.59*	-3.0778	*-2.99*
Dummy for village 6	-1.4424	*-1.09*	-1.2190	*-0.92*	-1.2549	*-1.00*
Age of head of household	0.1152	*1.24*	0.1168	*1.25*	0.1276	*1.43*
Age of head squared	-0.0013	*-1.47*	-0.0013	*-1.47*	-0.0014	*-1.67*
F-test statistic	F(18,385)	*3.44*	F(18,385)	*3.38*	F(18,412)	*3.40*
Level of significance		*0.00*		*0.00*		*0.00*
Number of observations	421		421		448	

Table 7. Ordered Probit Estimates of the Determinants of Net Livestock Sales

	Cattle				Goats and Sheep			
	Parameter estimates	*t-ratio*	Parameter estimates	*t-ratio*	Parameter estimates	*t-ratio*	Parameter estimates	*t-ratio*
Income shock due to rainfall (x 10,000 CFAF)								
positive	0.0002	*0.13*			-0.0003	*-0.25*		
negative	-0.0016	*-1.10*			-0.0014	*-1.06*		
Village-level income shock (x 10,000 CFAF)								
positive			-0.0017	*-0.59*			0.0008	*0.30*
negative			-0.0017	*-0.44*			-0.0107	*-3.07*
Idiosyncratic income shock (x 10,000 CFAF)								
positive			-0.0004	*-0.28*			-0.0005	*-0.38*
negative			-0.0006	*-0.35*			0.0001	*0.04*
Rainfall deviation from mean	-0.0004	*-0.43*	-0.0002	*-0.21*	-0.0008	*-0.91*	-0.0014	*-1.44*
Lagged rainfall deviation	-0.0009	*-1.67*	-0.0010	*-1.82*	-0.0008	*-1.62*	-0.0007	*-1.31*
Household characteristics								
Share of lowland area	0.1737	*1.23*	0.1689	*1.19*	-0.0736	*-0.59*	-0.0672	*-0.53*
Share of near lowland area	0.1315	*0.93*	0.1203	*0.85*	-0.0011	*-0.01*	0.0098	*0.08*
Share of midslope area	0.1742	*1.25*	0.1613	*1.16*	-0.0017	*-0.01*	0.0091	*0.07*
Share of upland area	0.1745	*1.11*	0.1557	*1.00*	0.0647	*0.45*	0.0752	*0.53*
Total cultivated area	-0.2403	*-1.71*	-0.2222	*-1.59*	-0.0229	*-0.18*	-0.0301	*-0.24*
Number of adult males	0.0436	*1.58*	0.0439	*1.59*	0.0054	*0.21*	0.0076	*0.30*
Number of adult females	0.0742	*3.44*	0.0732	*3.37*	0.0311	*1.59*	0.0290	*1.48*
Dummy for village 2	-0.1286	*-0.59*	-0.1137	*-0.51*	-0.0612	*-0.31*	0.0409	*0.20*
Dummy for village 3	-0.9366	*-3.71*	-0.9279	*-3.49*	-0.1355	*-0.62*	-0.3381	*-1.46*
Dummy for village 4	-0.6576	*-2.46*	-0.6003	*-2.15*	-0.4018	*-1.72*	-0.2068	*-0.85*
Dummy for village 5	-0.6861	*-2.61*	-0.5829	*-1.90*	-0.5996	*-2.55*	-0.4358	*-1.59*
Dummy for village 6	-0.8834	*-2.92*	-0.7695	*-2.24*	-0.2510	*-0.94*	-0.1395	*-0.46*
Age of head of household	-0.0077	*-0.36*	-0.0061	*-0.28*	0.0288	*1.56*	0.0309	*1.67*
Age of head squared	0.0001	*0.66*	0.0001	*0.59*	-0.0003	*-1.84*	-0.0003	*-1.96*
Chi-square statistic	Chi(18)	*61.29*	Chi(20)	*61.05*	Chi(18)	*37.74*	Chi(20)	*43.03*
Level of significance		*0.00*		*0.00*		*0.01*		*0.00*
Number of observations	421		421		421		421	

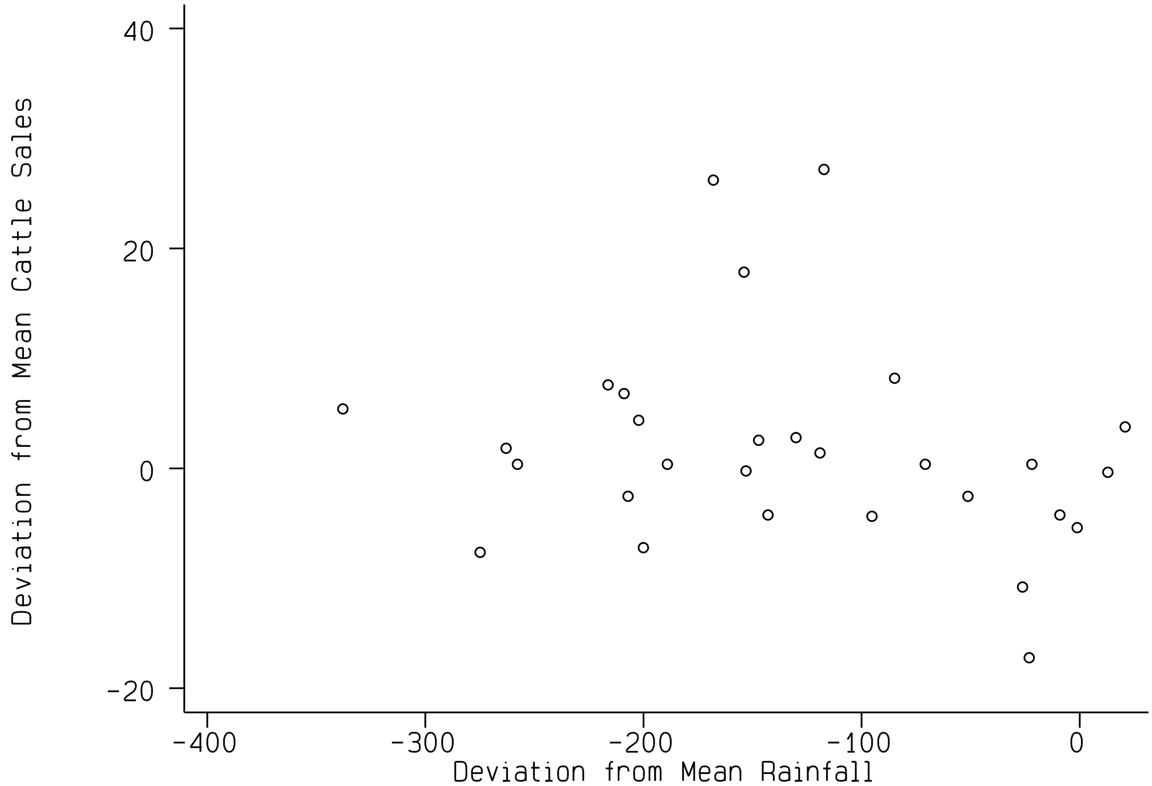

Figure 1: Annual Village Cattle Sales and Rainfall

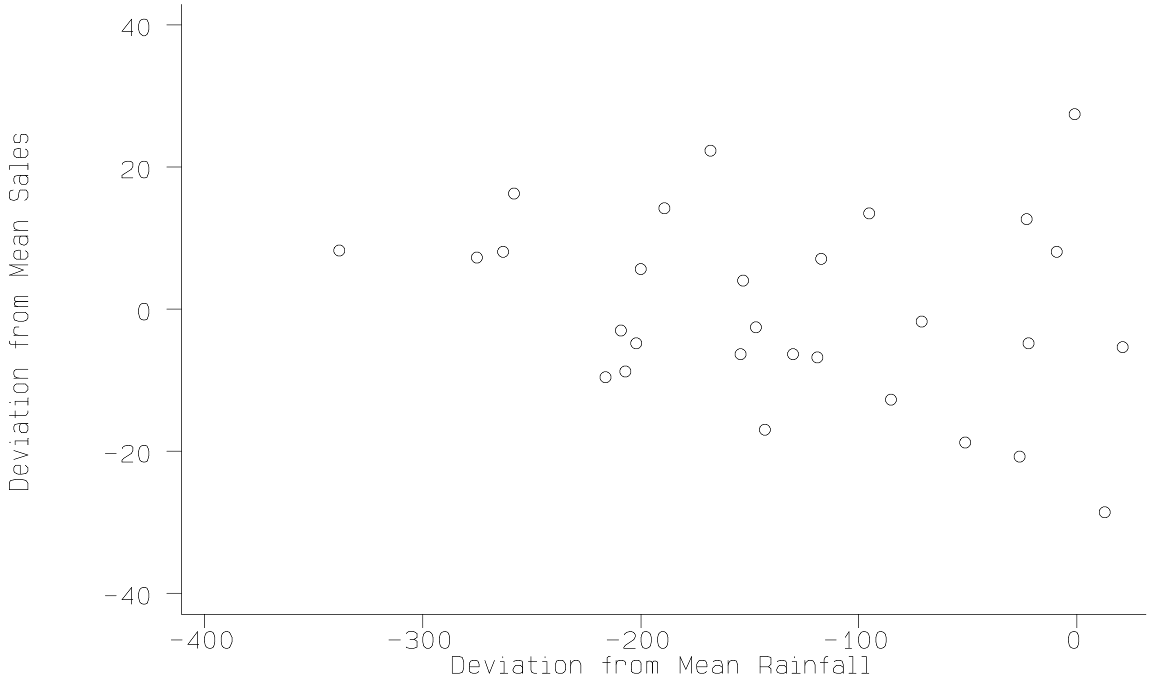

Figure 2: Annual Village Goat/Sheep Sales and Rainfall

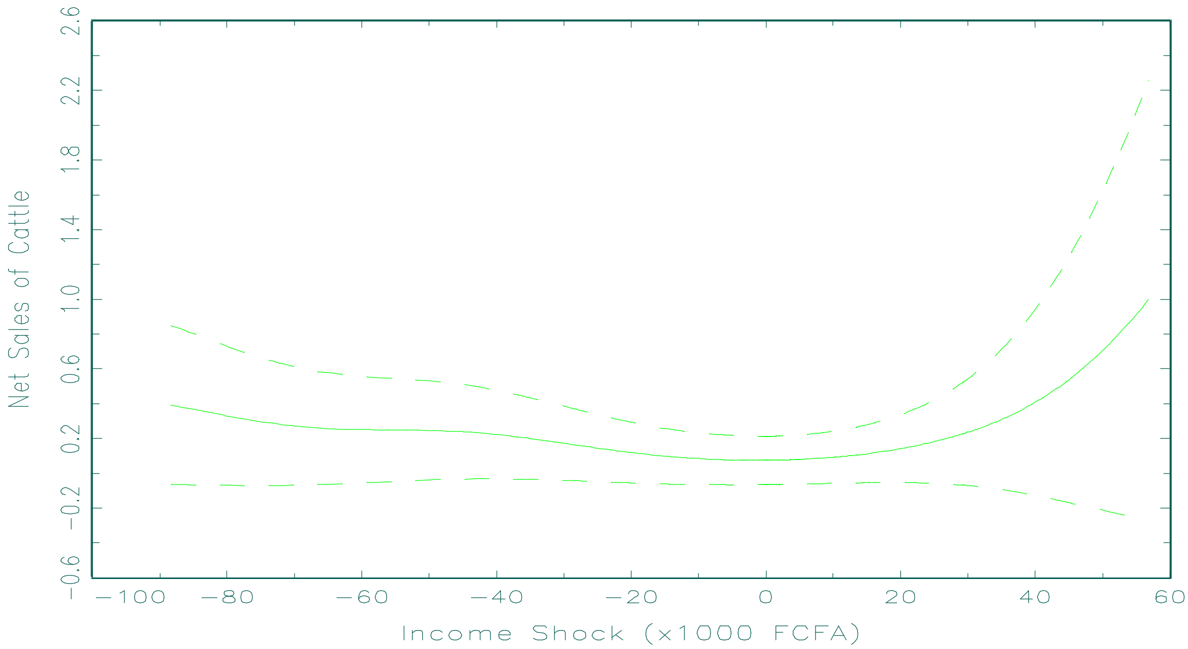

Figure 3: Response of Net Cattle Sales to Income Shocks

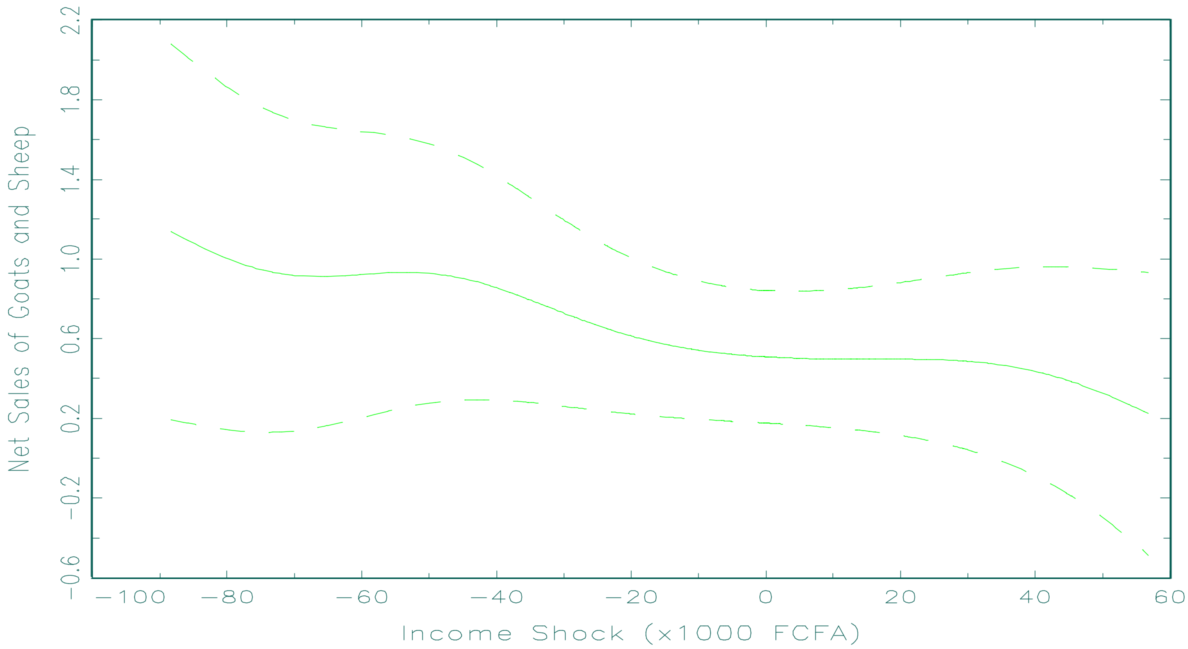

Figure 4: Response of Net Sales of Goats and Sheep to Income Shocks