

# Drought and saving in West Africa: are livestock a buffer stock?

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## Abstract

Households in the West African semi-arid tropics (WASAT) 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 income fluctuations. This paper tests this hypothesis. Results indicate that livestock transactions play less of a consumption smoothing role than often assumed. Livestock sales compensate for at most thirty percent, and probably closer to fifteen percent of income shortfalls due to village-level shocks alone. We discuss possible explanations for these results and suggest directions for future work. © 1998 Elsevier Science B.V.

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## 1. Introduction

Households in the West African semi-arid tropics (WASAT), as in much of the developing world, face substantial risk—an inevitable consequence of engaging in

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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 were 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 et al., 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, 1993). 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 discuss the setting in which the data were 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 15% 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.

## **2. 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 live-

stock, 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.<sup>3</sup> We, however, know of no formal tests which show that livestock inventories are used to smooth income fluctuations in Africa.

## 2.1. 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 WASAT, as they have been described in Binswanger and McIntire (1987), Bromley and Chavas (1989) and Binswanger et al. (1989).

Each household  $i$  in population  $N$  maximizes its discounted expected utility  $E_0 \sum_{t=0}^T \delta^t U^i(c_{it})$ . We assume that households are risk averse, i.e., that  $[(\partial^2 U^i)/(\partial c_{it}^2)] < 0$ , and that they have decreasing absolute risk aversion. Each household is endowed with a random stream of crop income  $y^i(S_t)$ . The random variable  $S_t$  denotes the realized state of nature at time  $t$ ; it represents a vector of all the income shocks that affect households in the economy, either jointly (e.g., rainfall) or individually (e.g., pests).<sup>4</sup> Both consumption and crop income are

<sup>3</sup> The literature on coping with drought in Africa is large. Much of it focuses on the Sahelian droughts of the 1970s. See Van Apeldoorn (1977), Campbell (1984), Silberfein (1989), Sen (1981) and Dasgupta (1993).

<sup>4</sup> If, for example, the income of each household takes a finite number of values  $\{y_1^i, \dots, y_S^i\}$ , then  $S_t$  can be thought of as an index of all possible vectors of joint realization of individual incomes  $\{y_{S_1}^1, \dots, y_{S_N}^N\}$ .

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.<sup>5</sup> 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 revolve around single rural communities. They are largely ineffective against shocks that are highly correlated over space, such as droughts (Cashdan, 1985, 1989; 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, 1992 for reviews of the large literature on rural credit). To capture these features in a stylized fashion, we assume that 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.

Total liquid wealth of household  $i$  at the beginning of period  $t$ , denoted  $W_t^i$ , yields a stochastic return  $r_t^i$ . The distribution of this return in general depends on the level and portfolio composition of  $W_t^i$ . If we ignore portfolio effects for a moment, the Belman equation corresponding to household  $i$ 's intertemporal decision problem takes a usual form:

$$V^i(X_t^i, s_t) = \max_{W_{t+1}^i \geq 0} U^i(X_t^i - W_{t+1}^i) + \delta^i EV^i(y^i(s_{t+1}) + (1 + r_{t+1}^i)W_{t+1}^i, s_{t+1}) \quad (1)$$

where  $X_t^i$  represents cash-in-hand—or rather, ‘grain-in-hand’, that is, current income plus liquid wealth measured in grain units. Shocks  $s_t$  enter the value function if returns to wealth are serially correlated.

The above model has been used extensively to analyze savings behavior under risk. It has been used to show that, given decreasing absolute risk aversion, precautionary saving is one motive for holding wealth (Deaton, 1990; Kimball, 1990); if the household's discount rate is high enough, it is the only one (Zeldes,

<sup>5</sup> See, however, Carter (1997).

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, 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., Paxson, 1992; 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 substitutes. 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 latter has a high expected return. Together they account for most of liquid wealth in the hands of WASAT small farmers (Udry, 1995; Binswanger et al., 1989; Swinton, 1988).<sup>6</sup>

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  $L_t^i$ . Due to desiccation 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, 1993). 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  $\lambda$  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  $P_t \equiv P(s_t|s_{t-1})$ . Relative prices vary with factors that affect the demand and supply of grain and livestock. There are two sources of demand for livestock: farmers' desire to invest in cattle and

<sup>6</sup> 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.

smaller animals; and urban consumers' desire to eat meat (Shapiro, 1979; Eicher and Baker, 1982; Fafchamps and Gavian, 1997). Local demand is modeled here; urban demand is taken as exogenous. The extent to which urban demand for meat affects rural livestock prices depends on the spatial integration of livestock markets (Staatz, 1979; Fafchamps and Gavian, 1996). Because of lagged effects in the demand and supply of livestock as investment good, prices are typically correlated over time (Rosen et al., 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  $\eta_t^i \equiv \eta^i(s_t|s_{t-1})$ , come from offspring and weight gain (Shapiro, 1979). They depend on collective and idiosyncratic shocks (e.g., disease, death) and on the available stock of pasture, which in turn varies with current and past rainfall—hence the dependence on  $s_t$  and  $s_{t-1}$ . Unlike in India, cattle is seldom used as draft power in the WASAT (Barrett et al., 1982).<sup>7</sup> For simplicity, we include milk consumption in the physical returns to herding. Labor is assumed proportional to the number of livestock head, i.e., it is equal to  $\theta^i L_t^i$ .<sup>8</sup> The shadow cost of labor  $\theta^i$  is expressed in grain-equivalent. We abstract from wage fluctuation issues which are largely irrelevant given the way livestock is taken care of.<sup>9</sup> The combined return on grain stocks and livestock is:

$$\begin{aligned} & (1 + r_{t+1}^i)W_{t+1}^i \\ &= (1 - \lambda)(W_{t+1}^i - L_{t+1}^i P_t) + (1 + \eta_{t+1}^i)L_{t+1}^i P_{t+1} - \theta^i L_{t+1}^i \end{aligned} \quad (2)$$

$W_{t+1}^i$ , as before, denotes total liquid wealth in grain equivalent.  $L_{t+1}^i$  is the number of livestock heads, purchased at the end of period  $t$  at price  $P_t$ .

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 begin by replacing return to liquid wealth in Eq. (1) by its value given by Eq. (2).

<sup>7</sup> 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).

<sup>8</sup> If a fixed labor cost is added to capture increasing returns in livestock raising, it becomes optimal for households to abandon herding below a certain herd size. The presence of a fixed cost thus induces more livestock sales when households are hit by a large income shock. Fixed costs are ignored here for notational simplicity. If 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 et al., 1992). In this case, livestock assets increase more slowly with liquid wealth.

<sup>9</sup> Livestock labor is typically supplied by household members themselves—in large part, children and young adults. The opportunity cost of herding is essentially in terms of reduced crop output or wage income.

The decision problem facing the household is made of two distinct, though simultaneous steps: choosing how much liquid wealth  $W_{t+1}^i$  to hold; and choosing how much of that wealth to keep in the form of livestock  $L_{t+1}^i$ . Formally, we can write:

$$\begin{aligned}
 V^i(X_t, s_t) = & \text{Max}_{W_{t+1}^i \geq 0} \left[ U^i(X_t^i - W_{t+1}^i) \right. \\
 & + \text{Max}_{L_{t+1}^i \text{ s.t. } W_{t+1}^i \geq P_t L_{t+1}^i \geq 0} \delta^i EV^i[y^i(s_{t+1})] \\
 & + (1 - \lambda)(W_{t+1}^i - L_{t+1}^i P_t) + (1 + \eta_{t+1}^i) L_{t+1}^i P_{t+1} \\
 & \left. - \theta^i L_{t+1}^i, s_{t+1} \right] \quad (3)
 \end{aligned}$$

The aggregate savings decision has been extensively analyzed in the literature on precautionary savings (e.g., Deaton, 1991; Zeldes, 1989; Kimball, 1990; see supra). We need not dwell on it. Less is known about portfolio allocation in an intertemporal setting. We therefore focus the remainder of this section on the choice between livestock and grain, treating the aggregate level of savings  $W_{t+1}$  as given.<sup>10</sup>

We wish to develop some intuition about the relationship between total wealth and livestock. To do so, let us take a mean-variance approximation of the expected value function, i.e.,  $E[V^i(X)] \approx E[X] - 1/2 A^i \Sigma[X]$  where  $\Sigma[X]$  is the variance of  $X$  and  $A^i$  is the coefficient of absolute risk aversion  $-[V'''(E[X])]/[V''(E[X])]$ .<sup>11</sup> This is a reasonable approximation if returns are nearly normal and utility is approximately exponential.<sup>12</sup> To simplify the notation, set  $E[(1 + \eta^i(s_{t+1}|s_t))p(s_{t+1}|s_t)] \equiv 1 + \bar{\eta}^i(s_t)$  and set  $\Sigma[(1 + \eta^i(s_{t+1}|s_t))p(s_{t+1}|s_t)] \equiv \sigma_{y_t}^2(s_t)$ . We denote the mean and variance of crop income as  $\bar{y}_t$  and  $\sigma_{y_t}^2$ , respectively. The correlation coefficient between crop income and livestock returns is written  $\rho_{y_t}^i(s_t)$ ; it is probably positive since livestock pasture and crops are subject to the same weather shocks. Households

<sup>10</sup> Of course,  $W_{t+1}$  ultimately depends on the return to wealth  $r_t$ , which itself depends on the portfolio choice between livestock and grain and thus on the choice of  $L_{t+1}$ . Treating the two jointly, however, is beyond the scope of this paper.

<sup>11</sup> For simplicity, the dependence of the value function on  $S_t$  through the possible serial correlation of shocks is ignored.

<sup>12</sup> If these assumptions are not satisfied, the mean-variance approximation can do rather badly. It nevertheless suffices for the limited purpose of the model, which is to provide an intuitive motivation for the empirical section that follows.

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

$$\begin{aligned} \text{Max}_{L_{t+1}^i \text{ s.t. } W_{t+1}^i \geq P_t L_{t+1}^i \geq 0} \quad & \bar{y}^i + (1 - \lambda) W_{t+1}^i + L_{t+1}^i (1 + \bar{\eta}^i(s_t) \\ & - (1 - \lambda) P_t - \theta^i) - 1/2 A^i (\sigma_{y_i}^2 + \sigma_{L_i}^2(s_t) (L_{t+1}^i)^2 \\ & + 2 \rho_{yL}^i(s_t) \sigma_{y_i} \sigma_{L_i}(s_t) L_{t+1}^i) \end{aligned} \quad (4)$$

An interior solution to the above optimization problem requires that:

$$L_{t+1}^{i*} = \frac{1 + \bar{\eta}^i(s_t) - (1 - \lambda) P_t - \theta^i - \rho_{yL}^i(s_t) \sigma_{y_i} \sigma_{L_i}(s_t)}{A^i \sigma_{L_i}^2(s_t)} \quad (5)$$

Eq. (5) makes intuitive sense: it indicates that livestock holdings are an increasing function of expected returns  $\bar{\eta}^i(s_t)$  and storage losses  $\lambda$ ; they are a decreasing function of the livestock purchase price  $P_t$ , labor requirements  $\theta^i$ , correlation between crop and livestock returns  $\rho_{yL}^i(s_t)$ , aversion to risk  $A^i$ , and variance of livestock returns  $\sigma_{L_i}^2(s_t)$ .

We now examine the relationship between total liquid wealth and livestock holdings. For the simplicity of exposition,  $L_{t+1}$  is treated as a continuous variable.<sup>13</sup> Since we have assumed that  $U^i(C)$  exhibits decreasing absolute risk aversion,  $A^i$  is in general a declining function of wealth.<sup>14</sup> In this case, Eq. (5) indicates that, other things being equal,  $L_{t+1}^i$  increases with  $W_{t+1}^i$ . 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  $A^i(W^i) = (\bar{A}^i)/((W^i)^\gamma)$  with  $\gamma > 0$ . Eq. (5) then becomes:

$$L_{t+1}^{i*} = \frac{1 + \bar{\eta}^i(s_t) - (1 - \lambda) P_t - \theta^i}{\bar{A}^i \sigma_{L_i}^2(s_t)} (W_{t+1}^i)^\gamma - \rho_{yL}^i(s_t) \frac{\sigma_{y_i}}{\sigma_{L_i}(s_t)} \quad (5')$$

Provided that crop and livestock income are uncorrelated, livestock holdings constitute a constant proportion of liquid wealth if relative risk aversion is constant, that is, if  $\gamma = 1$ . 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.<sup>15</sup> It is generally believed that relative risk aversion is either constant or

<sup>13</sup> Although livestock are bought and sold in discrete units, a household can change its stock of animals in minute amounts by changing the age and animal composition of its herd, e.g., by selling a cow and buying goats.

<sup>14</sup> In the absence of credit constraints the value function  $V^i(X)$  exhibits decreasing (increasing) risk aversion if the underlying utility function  $U^i(C)$  itself exhibits decreasing (increasing) risk aversion (Deaton, 1991).

<sup>15</sup> Diamond and Stiglitz (1974), corollary 2, derive a similar result without resorting to approximations. For  $W_{t+1}^i$  large enough, all wealth is held in the form of livestock. At that point, the  $W_{t+1}^i \geq P_t L_{t+1}^i$  constraint is binding and Eq. (5) no longer holds.

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 Eq. (5')—that does not depend on household wealth. We have thus shown that, if WASAT households have constant relative risk aversion, they will respond to an income shock by selling livestock roughly in proportion to its share in liquid wealth. If they have decreasing risk aversion, Eq. (5') then predicts that they will *overreact* to income shocks by liquidating livestock more than other assets. 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 doing so, general equilibrium effects must also be considered. So far we have implicitly assumed that households can sell their livestock to the market without affecting its price. In practice, their ability to do so depends critically on the integration of village grain and livestock markets with the rest of the world. If grain and livestock markets are perfectly integrated, relative prices are not influenced by local events and 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. If markets are poorly integrated, however, collective income shocks will affect the relative prices of livestock and grain in ways that prevent individuals from using livestock as buffer stock. To see why, consider what would happen to totally isolated WASAT farmers. For simplicity, continue to assume that they do not consume livestock directly and that they behave as price takers. In a closed economy, net sales of livestock must sum to zero at the village level, i.e.,  $\sum_{i \in V} S_{it} = 0$  or:<sup>16</sup>

$$\sum_{i \in V} \left[ \frac{1 + \bar{\eta}^i(s_t) - (1 - \lambda)P_t - \theta^i - A^i \rho_{yL}^i(s_t) \sigma_{y_i} \sigma_{L_i}(s_t)}{A^i \sigma_{L_i}^2(s_t)} \right] = \sum_{i \in V} (1 + \eta_i^i) L_i^i \quad (6)$$

where  $V$  is the set of households residing in the village. The supply of livestock—the right hand side of Eq. (6)—is predetermined. 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 Eq. (6)—goes down. 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  $1 + \bar{\eta}(S_t) - (1 - \lambda)P_t - \theta^i$  rises. This induces some farmers to hold onto their animals so that, in

<sup>16</sup> In the presence of heterogeneity among agents, the existence of a closed-economy equilibrium with endogenous livestock prices cannot be as easily established as in the case of a representative agent model. We assume here that a stable equilibrium exists.

equilibrium, there are no aggregate net sales of livestock. In a closed economy, 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 (1996) show that in Niger, a Sahelian country bordering Burkina Faso, the spatial integration of livestock markets is poor in spite of strong evidence that local livestock prices respond to shifts in urban meat demand (Fafchamps and Gavian, 1997). Rainfall shocks then may 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, livestock transactions respond *more* to collective than idiosyncratic shocks, this can be interpreted as evidence that WASAT farmers rely on mechanisms other than livestock sales to share risk among themselves. Candidates include transfers and consumption credit (Udry, 1990, 1994; Fafchamps, 1992, 1994; Lund, 1996). Modeling formally the interactions between livestock assets and risk pooling mechanisms is beyond the scope of this paper.<sup>17</sup>

Other dynamic processes may also affect livestock holdings. Jarvis (1974) and, more recently, Rosen et al. (1994) demonstrate that gestation lags in livestock production can generate cycles in livestock prices and assets. Fafchamps (1996) demonstrates that, in the presence of common access to pasture, sales and losses of livestock during droughts raise the expected returns to surviving animals  $\bar{\eta}^i(s_t)$ . This effect dampens the response of livestock transactions to rainfall shocks and can also generate livestock cycles. These complicated dynamic effects may contribute to the observed patterns of livestock sales and purchases. Since they all ultimately depend on aggregate rainfall shocks, we 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 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 are 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.

<sup>17</sup> Townsend (1994, 1995) and Udry (1994) discuss and partially model the relationship between precautionary saving and village-level risk pooling.

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.

### **3. 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 intercroops 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 (Sudanese 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, Sudanese 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 (1997) estimates that aggregate rainfall shocks are responsible for approximately 50% 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

Table 1  
Village rainfall data

Village	1981	1982	1983	1984	1985
<i>Sahelian region</i>					
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
<i>Sudanian region</i>					
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
<i>Northern-Guinean region</i>					
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.

months long in the North Guinean zone (Matlon, 1988; Matlon and Fafchamps, 1989). Rainfall data in the surveyed villages were 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

Table 2  
Livestock characteristics by household

	Cattle		Goats and sheep	
	Mean	Median	Mean	Median
<i>Inventories</i>				
Sahelian zone	6.5	2	16.0	8
Sudanian zone	4.6	0	26.6	20
Guinean zone	14.4	2	10.2	5
<i>Transactions</i>				
Sales	5.1	0	9.7	5
Purchases	3.0	0	5.5	3
Number of observations	168		1168	

Source: ICRISAT data.

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% of the households retained goats and sheep and about 70% 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 et al. (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.

### 3.1. 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% 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, 1997) or to test the hypothesis that transitory income has no effect on consumption (e.g., Mace, 1991; Cochrane, 1991; Townsend, 1994, 1995; 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.

#### 4. 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.

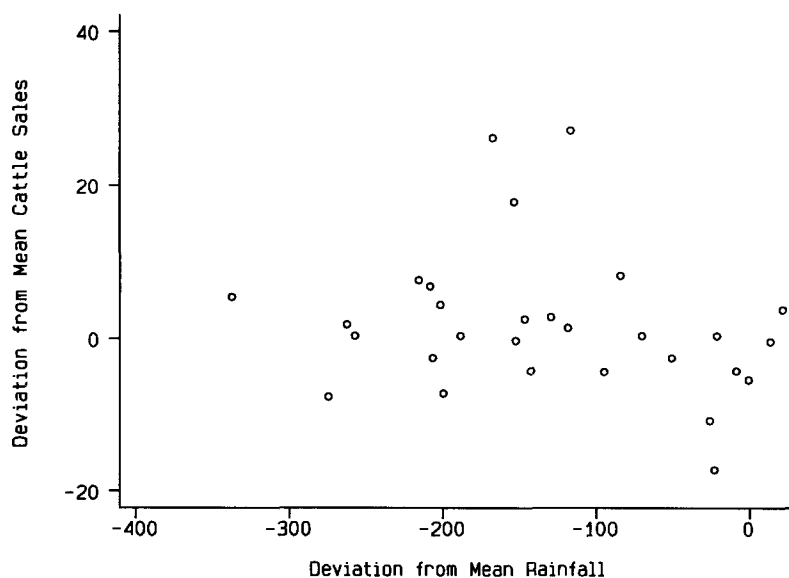


Fig. 1. Annual village cattle sales and rainfall.

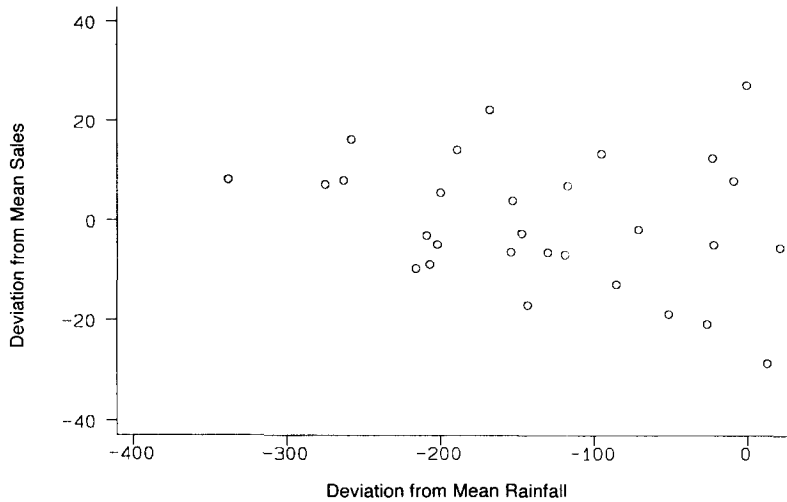


Fig. 2. Annual village goat/sheep sales and rainfall.

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. Fig. 1 and Fig. 2 display the relationship between annual rainfall (deviated from its long-run average) and annual aggregate livestock sales in each village (deviated from their five 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 Figs. 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.

## 5. 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 Alderman and Paxson, 1992 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:

$$y_{ivt} = \alpha_1 F_{vt} + \alpha_2 X_{ivt} \otimes F_{vt} + \lambda_i + \varepsilon_{ivt} \quad (7)$$

where  $y_{ivt}$  denotes either crop income in CFA Francs (first set) or cereal output in quintals (second set) accruing to household  $i$  in village  $v$  in year  $t$ . The vector  $X_{ivt}$  represents household characteristics that are determinants of income, such as the demographic structure of the household and detailed information on its land holdings and their quality.  $F_{vt}$  is a village level measure of rainfall, comprised of the deviation of rainfall in year  $t$  from its long-term average and this deviation squared. Carter (1997) finds that total rainfall and rainfall squared are good summaries of the overall effect 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 Eq. (7) is included in recognition of the fact that production on different types of land responds differently to similar levels of rainfall.  $\lambda_i$  is a household fixed effect reflecting the effect on income of unobserved characteristics of the household, and  $\varepsilon_{ivt}$  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.

Given consistent estimates of  $\alpha_1$  and  $\alpha_2$ ,  $\hat{y}_{ivt} \equiv \hat{\alpha}_1 F_{vt} + \hat{\alpha}_2 X_{ivt} \otimes F_{vt}$  provides a consistent estimate of a component of income for household  $i$  in village  $v$  and period  $t$  that is transitory and could not be anticipated. Estimates of Eq. (7) are presented in Table 3. The null hypothesis that there are no individual fixed effects is strongly rejected: the F test statistic is  $F(131,486) = 2.621$ ,  $p = 0.00$ . The individual rainfall coefficients are not significantly different from zero, but they

Table 3  
Fixed effect estimates of the determinants of crop income and cereal output

Variable	Crop income		Cereal output	
	Parameter estimates	<i>t</i> -ratio	Parameter estimates	<i>t</i> -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	

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  $X_{it} \otimes F_{it}$  regressors is  $F(12,485) = 9.36$  ( $p = 0.00$ ).

The second part of Table 3 presents estimates of Eq. (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 occurred over the sample period. The joint  $F$ -statistic for the  $X_{it} \otimes F_{it}$  regressors is 17.09 ( $p = 0.00$ ).

### 5.1. 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,

Table 4  
Reported motives for livestock sales

Income shock quartile	Cattle				Goats and sheep			
	Bad shock (%)	Med. bad (%)	Med. good (%)	Good shock (%)	Bad shock (%)	Med. bad (%)	Med. good (%)	Good shock (%)
<i>Reported motive for sale</i>								
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.

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.

### 5.2. Crop income shocks and livestock: A non-parametric analysis

When we turn to actual livestock transaction data, however, the pattern becomes less clear. Figs. 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 Fig. 3, goats and sheep in Fig. 4) sold by the household following that shock. The curve represents the non-parametric regressions of net livestock sales on income shock, calculated

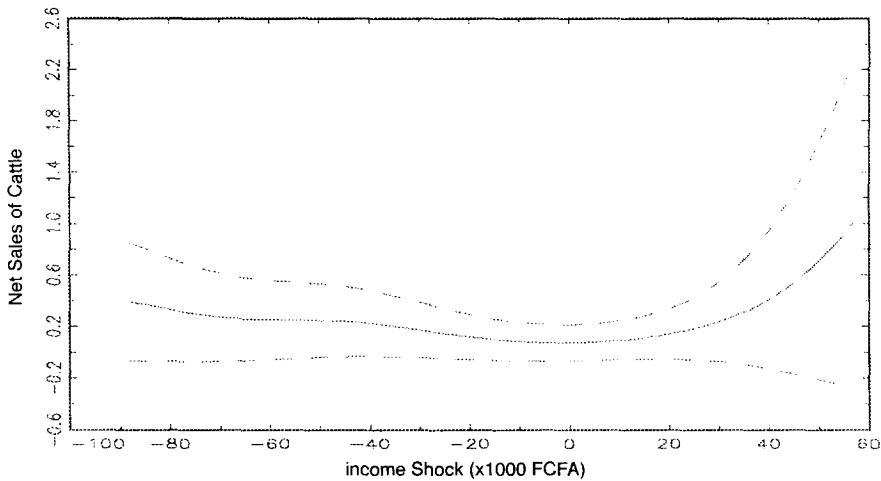


Fig. 3. Response of net cattle sales to income shocks.

using a Gaussian kernel with bandwidth of 20. Pointwise, 90% confidence intervals are reported for every 10th observation.<sup>18</sup>

The figures reveal at most a weak relationship between net livestock sales and transitory income. Net cattle sales (Fig. 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

<sup>18</sup> 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 placed upon the data points. For the Gaussian kernel,

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

where

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

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.

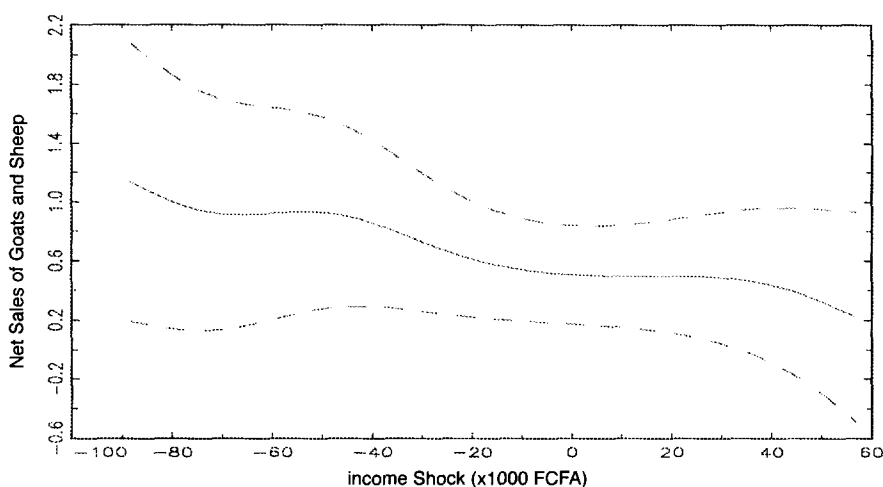


Fig. 4. Response of net sales of goats and sheep to income shocks.

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% 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 2), then the proportion of the income shock offset by livestock sales is even lower.

The pattern of net sales of goats and sheep, depicted in Fig. 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% confidence interval for livestock sales. Fig. 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% 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 Figs. 3 and 4.

### 5.3. Crop income shocks and livestock: a multivariate analysis

The non-parametric regressions presented in Figs. 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:

$$s_{ivt} = \beta_1 Z_{iv} + \beta_2 F_{vt} + \beta_3 \hat{y}_{ivt} + v_{ivt} \quad (8)$$

where  $s_{ivt}$  is the net number of livestock (either cattle or small stock) sold by household  $i$  in village  $v$  and year  $t$ , and  $Z_{iv}$  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.<sup>19</sup>  $\hat{y}_{ivt}$  is one of the three measures of the transitory income shock derived above.  $v_{ivt}$  is a random error term.  $F_{vt}$  stands for rainfall shocks. Current rainfall is added to control for its possible direct effect on the price and productivity of livestock production through fodder growth, the availability of water, and the disease environment. Lagged rainfall is included as well in an effort to capture the influence of speculative investment motives, past productivity shocks, and general equilibrium effects on livestock prices (see Section 2). Because common village resources are used for herding livestock, the interaction effects  $X_{ivt} \otimes F_{vt}$  influence net livestock sales only through their effect on farm income. Interaction effects can thus be excluded from the determinants of net livestock sales, thereby providing the required identification restriction.

Estimates of Eq. (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.<sup>20</sup> 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

<sup>19</sup> Eq. (8) was also estimated replacing household characteristics with household fixed effects. The hypothesis that there are no household fixed effects cannot be rejected: the joint  $F$ -statistic is  $F(125,274) = 1.12$  ( $p = 0.22$ ). Estimates with fixed effects and with household characteristics are very similar. Only the former are reported here for the sake of brevity.

<sup>20</sup> 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

$$\Sigma = \sigma_v^2 (A'A)^{-1} + \sigma_e^2 \hat{\beta}_3 (A'A)^{-1} A'B(B'B)^{-1} B'A(A'A)^{-1}$$

where  $A_{ivt} \equiv [Z_{iv}, F_{vt}, \hat{y}_{ivt}]$ ,  $B_{ivt} \equiv [F_{vt}, X_{iv} \otimes F_{vt}]$  and  $B$  is in deviated form, with the household mean over the 5 years substrated from each observation. In practice, this adjustment increases the estimated standard errors by less than 1%.

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
<i>Income shock due to rainfall ( × 10,000 CFAP)</i>						
Positive	−0.0014	−0.29				
Negative	−0.0040	−0.80				
<i>Cereal output shock due to rainfall ( × 100 kg)</i>						
Positive			−0.0158	−0.44		
Negative			−0.0173	−0.76		
<i>Income deviation from hh mean ( × 10,000 CFAP)</i>						
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	<i>F</i> (18,385)	2.37	<i>F</i> (18,385)	2.37	<i>F</i> (18,412)	2.25
Level of significance		0.00		0.00		0.00
Number of observations	421		421		448	

Figs. 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% confidence interval, a −80,000 FCFA income shortfall is associated with the sale of about 90% of a cow—the equivalent of 22,000 FCFA.

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
<i>Income shock due to rainfall ( × 10,000 CFAF)</i>						
Positive	−0.0019	−0.30				
Negative	−0.0112	−1.74				
<i>Cereal output shock due to rainfall ( × 100 kg)</i>						
Positive			−0.0265	−0.58		
Negative			−0.0395	−1.36		
<i>Income deviation from hh mean ( × 10,000 CFAF)</i>						
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	<i>F</i> (18,385)	3.44	<i>F</i> (18,385)	3.38	<i>F</i> (18,412)	3.40
Level of significance		0.00		0.00		0.00
Number of observations	421		421		448	

Estimates of Eq. (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 ninetieth percentile of cereal production shock is equivalent to a drop in grain output of 1800 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 1800 kg grain shortfall translates into the sale of only a third of a cow. Even evaluated at the most negative edge of the 90% 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% confidence interval, a –80,000 FCFA income shortfall is associated with the 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% 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 3750 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 1800 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.

#### *5.4. 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 Eq. (8) using OLS thus, results in model misspecification. Could it be that the regression results reported in Table 5 and 6 are due to this misspecification? To test this possibility, we reestimate Eq. (8) using ordered probit. Results using the first set of crop income shock estimates are presented in Table 7.<sup>21</sup> 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

<sup>21</sup> Standard errors are not corrected for the presence of the estimated shock variables. <sup>13</sup> suggests that the bias introduced is small.

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		
<i>Income shock due to rainfall (<math>\times 10,000</math> CFAF)</i>						
Positive	0.0002	0.13	–0.0003	–0.25	0.0008	0.30
Negative	–0.0016	–1.10	–0.0014	–1.06	–0.0107	–3.07
<i>Village-level income shock (<math>\times 10,000</math> CFAF)</i>						
Positive						
Negative						
<i>Idiosyncratic income shock (<math>\times 10,000</math> CFAF)</i>						
Positive						
Negative						
Rainfall deviation from mean	–0.0004	–0.43	–0.0008	–0.91	–0.0014	–1.44
Lagged rainfall deviation	–0.0009	–1.67	–0.0008	–1.62	–0.0007	–1.31
Household characteristics						
Share of lowland area	0.1737	1.23	–0.0736	–0.59	–0.0672	–0.53
Share of near lowland area	0.1315	0.93	–0.0011	–0.01	0.0098	0.08
Share of midslope area	0.1742	1.25	–0.0017	–0.01	0.0091	0.07
Share of upland area	0.1745	1.11	0.0647	0.45	0.0752	0.53
Total cultivated area	–0.2403	–1.71	–0.0229	–0.18	–0.0301	–0.24
Number of adult males	0.0436	1.58	0.0054	0.21	0.0076	0.30
Number of adult females	0.0742	3.44	0.0311	1.59	0.0290	1.48
Dummy for village 2	–0.1286	–0.59	–0.0612	–0.31	0.0409	0.20
Dummy for village 3	–0.9366	3.71	–0.1355	–0.62	–0.3381	–1.46
Dummy for village 4	–0.6576	2.46	–0.4018	–1.72	–0.2068	–0.85
Dummy for village 5	–0.6861	–2.61	–0.5996	2.55	–0.4358	–1.59
Dummy for village 6	–0.8834	–2.92	–0.2510	–0.94	–0.1395	–0.46
Age of head of household	–0.0077	–0.36	0.0288	1.56	0.0309	1.67
Age of head squared	0.0001	0.66	–0.0003	–1.84	–0.0003	–1.96
Chi-square statistic	Chi(18)	61.29	Chi(18)	37.74	Chi(20)	43.03
Level of significance		0.00		0.01		0.00
Number of observations	421		421		421	

relationship, consider a household with median characteristics. If this household is subjected to an extremely adverse income shock of  $-80,000$  FCFA, and if we evaluate its response at the uppermost boundary of the 90% confidence interval, we see an increase in the probability of selling a cow of about ten percentage points. 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 two 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  $-80,000$  FCFA income shock, we find that expected sales increase by less than two goats or sheep, offsetting about five percent of the income shortfall.

### 5.5. 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 weak relationship we have uncovered so far is that livestock and grain markets are not spatially integrated. As discussed in Section 2, 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  $\hat{y}_{vt} = \alpha_1 F_{vt} + \alpha_2 F_{vt} \otimes \bar{X}_v$ , and an idiosyncratic component  $\hat{y}_{it} = \alpha_2 F_{vt} \otimes (X_{iv} - \bar{X}_v)$  where the village mean of  $X_{iv}$  is denoted  $\bar{X}_v$ . Variable  $\hat{y}_{it}$  should have no effect on livestock transactions if risk is shared efficiently. Variable  $\hat{y}_{vt}$  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.<sup>22</sup> They provide at most marginal support for the idea that risk is shared within the village. 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 idiosyncratic 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

<sup>22</sup> Similar qualitative results obtain if OLS is used instead of ordered Probit.

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 one animal. At the upper bound of the 90% confidence interval, expected sales increase by almost two animals, thereby offsetting about 5% 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 villagers rely on institutional arrangements other than the sale of livestock to share idiosyncratic risk among themselves. Likely candidates include transfers and consumption credit (e.g., Rosenzweig, 1988; Udry, 1990, 1994; Fafchamps, 1992, 1994; Lund, 1996).

### *5.6. 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 WASAT. 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., Binswanger and McIntire, 1987; 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.

One possible explanation for our results is the presence of systematic mismeasurement of livestock transactions. The Burkina Faso ICRISAT surveys were conducted with unusual care: enumerators resided in the villages in which they worked and they visited sample households every seven to ten days to record livestock transaction data. The possibility nevertheless remains that respondents regarded livestock transactions as such a sensitive matter that they withheld information from enumerators. If the livestock transactions recorded in the data systematically understate the actual quantities transacted, then our estimates of the responsiveness of livestock transactions to income shocks are biased downward.

If, however, the livestock transaction data are accurate, then our 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 the theory predicts? 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 et al. (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 control 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 (1981) who remarked 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 et al. (1988) show that food aid comprised a substantial portion (almost 60%) of all transfers received by the poorest of the Sahelian households during the 1984 drought (see also Reardon and Matlon, 1989). Transfers, however, constituted only a tiny proportion of total income: less than 3%. 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% 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 plays a substantial role in coping with droughts and whether 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 (1997) 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 et al. (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 be undertaken, as in Lim and Townsend (1994), but in the absence of complete consumption expenditure data, such an exercise 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 2 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 imply 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 et al. (1994) and

Fafchamps (1996) model some of these dynamic effects. Fafchamps and Gavian (1997) document the rapid recovery of livestock prices in Niger in the aftermath of the 1984 drought.

Another possible explanation is that livestock are less liquid than we assumed in the sense that a household who sells in a hurry would not get a price commensurate with the true value of the animal. This would happen if livestock markets are thin and fairly inactive, especially for cattle (see Table 2). If distress sales lead to a much reduced price, livestock purchases must be seen as partially irreversible investments (e.g., Dixit and Pindyck, 1994; Fafchamps and Pender, 1997). Households may then choose to protect their productive investment in cattle by sacrificing consumption. This explanation is consistent with the more intensive use of goats and sheep for consumption smoothing purposes. Whether hopes of high returns to livestock after a drought, lagged dynamic effects, or illiquidity are the driving force behind what we observed remains to be shown empirically.

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