Effect of Heavy Rainfall Shock on Asset Dynamics in Rural Zambia
- an examination of fluctuations in cattle numbers -

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Abstract

In rural Africa, the liquidation and accumulation of productive assets, such as large livestock, lie at the heart of livelihood strategies to smooth consumption against fluctuating income (the buffer stock hypothesis). Previous studies have tested this hypothesis but have reported inconsistent results. A possible explanation for such results, and one noted in the growing literature on asset dynamics, is that poorer households may choose to maintain and smooth productive assets rather than to smooth consumption. However, very little empirical evidence exists on the matter.

This study re-examines the buffer stock hypothesis regarding cattle by taking wealth-differentiated smoothing tendencies into account. First, this paper introduces measurable definitions of sensitivity and resilience in terms of asset fluctuations. The former is defined as the level of impact a shock has on household assets, while the latter is the recovery level after the shock.

Second, this paper employs a high-frequency panel data set of agricultural households from Southern Province, Zambia, one of the most drought-prone areas in the country. The data were collected between 2007 and 2009, a period that includes the occurrence of a rare heavy rainfall year within the study site. This study uses panel estimation techniques to investigate whether a threshold exists in asset holding level that distinguishes between asset smoothing and consumption smoothing, and to estimate the determinants of asset sensitivity to a heavy rainfall shock for each regime.

Results reveal that household sensitivity depends on the number of cattle held before the shock, suggesting the existence of multiple dynamic asset equilibria. However, those who preserve their cattle holdings during a flood-year may be affected by a lagged rainfall shock in the following year, with implications for the long-term relationship between asset dynamics and economic mobility. This paper also suggests that the determinants of sensitivity may be distinct in each wealth quartile.

1. Introduction

Many of the poor living in rural Africa face significant risks and are highly vulnerable to unexpected negative income shocks such as family illness and natural disasters (Dercon, 2005). Their responses to these shocks are twofold: *ex-ante* risk-management strategies and *ex-post* risk-coping strategies (Morduch, 1995). Traditionally, with regard to the latter, it has been hypothesized that households liquidate productive assets, such as large livestock, to maintain their consumption standards. This strategy is very costly in terms of forgone future income and has a direct relationship with poverty dynamics. There have been a great number of studies to test this hypothesis.

Such studies, however, have reported inconsistent results and have provided very little evidence of consumption smoothing (Rosenzweig and Wolpin, 1993; Kurosaki, 1995; Fafchamps et al., 1998). For example, Fafchamps et al. (1998) found that livestock sales in Burkina Faso offset 15–30%, at most, of the crop income shortfalls during severe drought years in the 1980s, and the majority of the surveyed households still held livestock by the end of the drought. One possible explanation for these results is that poorer households may choose to maintain and smooth productive assets rather than to smooth consumption, implying the existence of a threshold level of asset holding between the two types behavior (Zimmerman and Carter, 2003). To our knowledge, only Lybbert and Carter (2010) have provided empirical evidence of this threshold. Using the same data as Fafchamps et al. (1998), they directly estimated a dynamic asset threshold that divided asset smoothers and consumption smoothers by using sample splitting techniques.

This study also examines the buffer stock hypothesis with regard to cattle and provides evidence of a threshold in asset holdings. However, unlike Lybbert and Carter (2010) who used yearly livestock transaction data, this paper uses a high-frequency panel data set of agricultural households from Southern Province, Zambia, which allows us to examine asset dynamics after a shock in detail and distinguish clearly between a coping period and a recovery period. The data were collected between 2007 and 2009, a period that includes a year of extremely heavy rain, a rare event in one of the most drought-prone zones in the country. This heavy rainfall produced a deluge that damaged crops, washed away fields, and destroyed infrastructure such as roads and bridges. To discern between the different behavioral regimes, this paper first constructs a monthly stock series for cattle using a wealth quartile. Then, panel estimation techniques are employed to investigate the existence of an asset level threshold that separates the asset smoothing regime and consumption smoothing regime, and to estimate the determinants of sensitivity to the rainfall shock for each regime.

The remainder of this paper proceeds as follows. Section 2 introduces definitions for sensitivity, resilience, and vulnerability with regard to asset fluctuations. A data description is provided in Section 3. Section 4 presents the econometric models used to estimate the determinants of the defined sensitivity and discusses the estimation results. Conclusions, including suggestions for future research, are offered in the paper’s final section.

2. Analytical Framework

2.1 Definitions

To empirically analyze asset responses to shock and the subsequent recoveries, this section introduces three concepts concerning asset dynamics: sensitivity, resilience, and vulnerability.

Figure 1 schematically presents definitions for sensitivity and resilience, following Carter et al. (2006) with regard to assets and Sakurai et al. (2010) with regard to consumption. The x-axis measures time and the y-axis measures asset stocks. At the time (t_b) when the shock occurs, disposable household income may be reduced below its normal level. In response to the shock, the

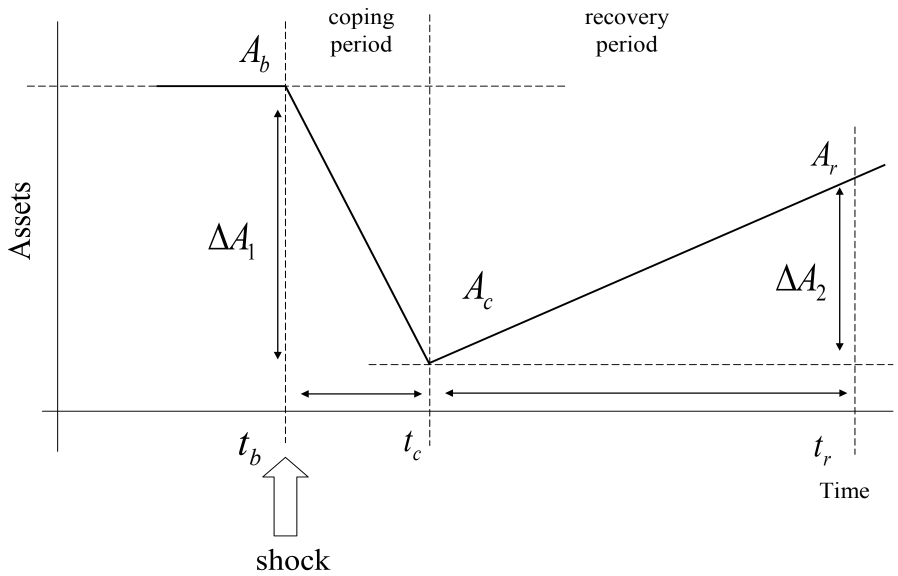

Figure 1: Schematic diagram of sensitivity and resilience

household may liquidate their assets, such as cattle, to stabilize consumption. This hypothesis is termed the buffer stock hypothesis (Rosenzweig and Wolpin, 1993). The decline in household assets is shown in Figure 1 by a drop in assets from A_b to A_c[1]. Then, the household exits from the shock and starts accumulating productive assets again for the purpose of precautionary savings or simply, production. The recovery of household assets is shown by the A_c to A_r trajectory.

Sensitivity (S) and resilience (R), as shown in Figure 1, can be defined as:

$$S \equiv A_c - A_b = \Delta A_1 \quad R \equiv A_r - A_c = \Delta A_2 \qquad (1)$$

S refers to the level of impact a shock has on household assets, while R refers to the recovery level after a shock.

As shown in Figure 1, the full economic effects of an environmental shock can be traced via two stages: the coping period when households deal with the immediate losses created directly or indirectly by the shock; and the recovery period when households use coping strategies to rebuild depleted assets. To calculate sensitivity and resilience as defined above, it is necessary to identify a shock where the impact and the following coping and recovery periods can be investigated, including specific start- and stop-times for both periods.

Sakurai et al. (2010) defined sensitivity and resilience with regard to household consumption in a similar way to this study. However, in their empirical analysis they dealt with only the case of a single equilibrium, and adapted the speed of return to the steady state as a

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[1] Subscript “b” refers to levels before the shock, “c” refers to levels after the coping period, and “r” refers to levels after the recovery period.

workable definition of resilience. Multiple equilibria are critical in the context of household assets and thus, in this study, different definitions are provided[2]. This point is discussed further in the following subsection.

2.2 Shocks, Asset Fluctuations, and Poverty

Previous studies on asset dynamics have suggested that at least two distinct asset thresholds exist: an asset poverty line and the Micawber threshold. The former was employed in studies investigating economic mobility using asset information (Carter and Barrett, 2006). This asset-based approach to poverty can reduce observed household economic transitions into structural poverty changes versus stochastic mobility, which is driven by temporary shocks and recovery. To distinguish between these two variants, Carter and May (2001) introduced the asset poverty line. This line is the level of assets that predicts the money metric poverty line, $\underline{c}$. In a mathematical sense, the asset poverty line, denoted by $\underline{A}$, is defined as $\underline{A} = \{A|\hat{c}(A) = \underline{c}\}$, where $\hat{c}(A)$ is a function of a vector regarding asset stocks to expected expenditure flows, termed livelihood mapping.

The asset poverty line enables us to immediately define a vulnerable household with regard to asset fluctuations as one with a high probability of falling below the asset poverty line, in an *ex-ante* sense. Vulnerability is empirically defined in this paper as a vulnerable household that has fallen below the asset poverty line after a shock, in an *ex-post* sense[3]. With a measurable definition of vulnerability and an estimated asset poverty line, we will be able to observe economic mobility with regard to assets.

The Micawber threshold, denoted by A_m, is defined as an asset level where wealth dynamics naturally bifurcate. The existence of the Micawber threshold has been suggested in several recent studies that have provided evidence of asset dynamics within a particular context as being nonconvex, compared with the standard assumption that asset dynamics are convergent (Zimmerman and Carter, 2003)[4]. The Micawber threshold theoretically influences how households cope with negative shocks: those who sit just above the Micawber threshold, but are in danger of falling below it, would choose asset smoothing rather than consumption smoothing. Hoddinott (2006), for example, found strong evidence of asset smoothing above the dynamic asset threshold among the poor in rural Zimbabwe. Moreover, Lybbert and Barrett (2010) theoretically illustrated a possibility that nonconvex asset dynamics with multiple equilibria systems could lead those just below the Micawber threshold to engage in excessive risk-taking behavior to escape the poverty trap. This asset smoothing hypothesis could offer a possible explanation for the inconsistent results regarding the use of livestock as buffer stock (Rosenzweig and Wolpin, 1993; Kurosaki, 1995; Fafchamps et.al., 1998).

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[2] The concept of resilience originated in the ecological literature. According to Gunderson et al. (2002), there are two different ways of definition, depending on the assumption of the number of equilibria: engineering resilience and ecological resilience. The former is "the speed of return to the steady state following a perturbation," conceiving ecological systems to exit close to a stable steady state. On the other hand, the latter assumes multiple stability domains and is measured by "the magnitude of disturbance that can be absorbed" before instabilities shifts or flip a system into another regime of behavior (Sakurai et al., 2010).

[3] This definition is applied by one of practical consumption vulnerability measures.

[4] Note that this finding is under the strong assumption that this threshold is the same for every household.

It is important to note that the order of the two asset levels is theoretically obscure. Thus, it is necessary to distinguish the following two cases: case 1, $\underline{A} \leq A_m$ and case 2, $\underline{A} > A_m$. For example, case 1 occurs if the asset poverty line is lower than the minimum asset threshold required to obtain high rates of return under local increasing returns to assets.

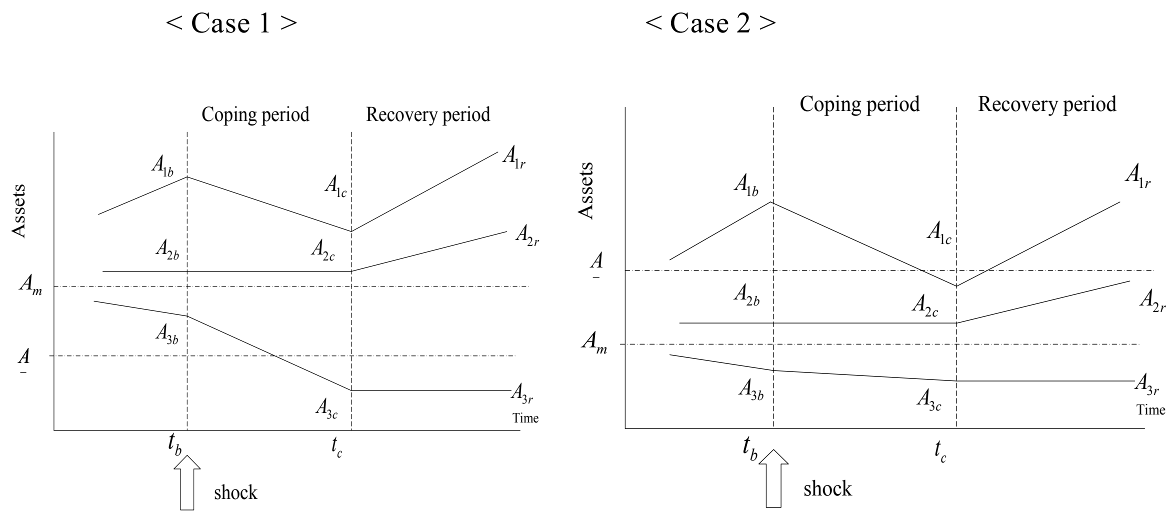

Figure 2: Asset responses to shock

Figure 2 shows asset responses to shock for households with different levels of initial asset endowment (i.e., asset levels before the shock), where A_{ip} denotes the asset level of a household (i) during a particular period (p) (i = 1, 2,3, and p = *b, c, r*). As illustrated in Figure 2, households who are just above the Micawber threshold (i.e., household 2) will not draw down their assets even after the shock in both cases 1 and 2. However, distinguishing between the two cases is a useful step in considering asset vulnerability. With regard to the definition of vulnerability given above, household 3, in case 1, is recognized as a vulnerable household, as is household 1 in case 2. However, in case 2, household 3 is more problematic than household 1 because it is trapped within the lower equilibrium. Thus, it is necessary to ascertain whether the economy lies, in case 1 or case 2, as the answer will vary policy implications induced by the asset based approach toward poverty.

3. Data

This paper uses a panel data set regarding rural households in Zambia. The data were collected from October 2007 to December 2009 as part of the Research Institute for Humanity and Nature's (RIHN) Resilience Project. Zambia is situated in the Semi-arid Tropics (SAT) where people's livelihoods depend largely on rain-fed agriculture. Climatic variation, especially regarding rainfall, is a substantial covariate risk that threatens the subsistence of Zambian farmers. In Zambia the crop year runs from November to October and can be divided into a rainy season (November–April) and a dry season (May–October). Thus, the data used in this paper includes two crop years, 2007/08 and 2008/09.

The Project's study area lies alongside Lake Kariba in Southern Province, Zambia, the most drought-prone area in the country. Within the research area, the Project chose three ecologically distinctive sites for the high-frequency household survey, based on an extensive village census conducted in 2007 (Sakurai, 2008). The three sites are a lower flat lake-side area, site A, a middle escarpment area, site B, and an upper terrace on the Zambian plateau, site C. From each site, 16 households were selected to participate in the household survey, which was based on a 2007 village census (Sakurai, 2008). Thus, 48 households in total were interviewed weekly during the survey period.

The sample possesses a number of desirable properties with regard to the examination of the cattle buffer stock hypothesis. First, livestock accumulation is considered to be a store of wealth as there are no local financial institutions (e.g., banks) in which to hold money. Table 1 presents summary statistics of the respective assets for the sampled households. The ratio of livestock value, especially cattle value, to total asset value is relatively high. Second, two oxen (or cows in several cases) are needed to plough, suggesting that the ownership of two cattle may be the critical threshold perceived by farmers[5].

Table 1: Annual value of household asset holding

	2007				2008				2009			
	Mean	Percent to total value	Std. Dev	Median	Mean	Percent to total value	Std. Dev	Median	Mean	Percent to total value	Std. Dev	Median
Livestock	2601641	76.2%	3333403	1280240	1768259	79.6%	1989629	935618	2190404	72.6%	2802043	988190
large stock	1955415	57.2%	2787516	780033	1368691	61.6%	1611831	507352	1872243	62.1%	2583214	527035
small stock	646227	18.9%	1278434	203607	399568	18.0%	784262	133043	318161	10.5%	340104	247542
Durable assets	814772	23.8%	1268101	410121	453974	20.4%	748930	271985	799769	26.5%	987663	370361
productive	380471	11.1%	699725	197966	203497	9.2%	337329	91895	395444	13.1%	550040	236824
unproductive	434301	12.7%	780347	147173	250477	11.3%	457595	167123	404325	13.4%	572454	174530
Total	3416413	100.0%	4456390	2112963	2222232	100.0%	2556149	1365375	3016308	100.0%	3555639	1211994

Source: Household survey data, Resilience Project.
Note:[1] Value in Kwacha, the local currency in Zambia. The values of the respective assets in this table are deflated by the local food price index calculated by the authors using the household survey data.

The dataset is comprised of three types of data: annual, monthly, and weekly data. This paper uses both the annual and weekly data. The annual data were collected at the beginning of each crop year and contained information regarding household demographic characteristics and asset holdings, including livestock. In contrast, the weekly data were collected using weekly interviews and contained information regarding households' livestock transactions, consumption of their own livestock, and animal births/deaths[6]. Thus, by combining the initial annual livestock numbers with every livestock transaction from the weekly data, it is possible to construct a stock

[5] In the study sites, households with less than two oxen sometimes use cows to cultivate fields, although ploughing is typically done with two oxen.

[6] Although the weekly data also include household consumption, information on input/output related with agricultural activity, transfers received and sent, time allocation data of each household member and health condition of each member, this paper focuses only on livestock transactions. Future work will fully utilize this rich dataset.

series of the livestock. A further unique feature of this dataset is the collection of daily rainfall data from the land of the 48 sampled households. This will enable us to treat rainfall as an idiosyncratic shock, even though the rainfall pattern is similar throughout the study area[7].

4. Asset Sensitivity to Rainfall Shock

4.1 Coping Period and Recovery Period

To measure sensitivity, the coping and recovery periods need to be specified using the rainfall data collected from the households' land. The data were collected during the 2007/08 and 2008/09 crop years.

Table 2: Annual precipitation for 2007/08 and 2008/09 crop years[1]

		Mean annual precipitation (mm)	Standard Deviation (mm)	Coefficient of variation	Maximum (mm)	Minimum (mm)	Number of rain gauges	Percent of long-run regional average rainfall[2], 802 mm
2007/08	site A	1596	40	0.025	1699	1559	16	198.8
	site B	1574	59	0.037	1677	1488	16	196.1
	site C	1404	66	0.047	1538	1313	16	174.9
2008/09	site A	1312	78	0.059	1419	1166	16	163.5
	site B	1383	50	0.036	1478	1303	16	172.3
	site C	1378	67	0.048	1519	1262	16	171.6

Source: Household survey data, Resilience Project.
Note: [1] Not all rainfall data is complete because of technical problems with the automatic rain gauges. In the case of missing data, rainfall amount is spatially estimated from available data.
[2] There are no long-term rainfall data from the study sites. We used rainfall data from the closest weather station located in Choma, 30–60km from the study sites.

Table 2 presents summary statistics regarding annual rainfall by agricultural year and study site. The 2007/08 crop year was a year of extremely heavy rains (with a peak rainfall in December 2007), with levels higher than the long-term regional average, especially for sites A and B. The heavy rainfall damaged crops, washed away fields, and destroyed infrastructure such as roads and bridges. According to local villagers, such an event is very rare and only occurs once every several decades. Thus, the heavy rainfall in 2007/08 could be considered as an unexpected risk event that would have been a shock to villagers. Table 2 shows that the rainfall for the 2008/09 crop year was also relatively higher than the long-term average[8]. Thus, this paper categorizes the coping period as a two-year period from December 2007 to December 2009, and will focus mainly on the analysis of sensitivity.

4.2 Description

The previous sections have established that cattle are the main assets for both wealth accumulation and production in the study areas. In addition, a description has been provided

[7] This idea follows the work of Sakurai (2006), in which plot level rainfall data were collected and used as idiosyncratic shock variables.

[8] However, less damage to field and infrastructure was observed in 2008/09 than in 2007/08, and some sampled households might recover their asset holdings after the harvest. Such scenario of resilience will be also examined.

regarding the heavy rainfall shock that occurred in the 2007/08 crop year, and how livelihoods were damaged. Thus, the focus of this paper is on the fluctuations in the number of cattle owned by the sampled households and investigates whether cattle numbers decreased in response to the rainfall shock. This subsection will use descriptive statistics regarding cattle numbers to conduct a preliminarily investigation into the relationship between cattle number variations and rainfall.

Table 3: Mean number of cattle holdings by quartile

Quartile	2007	2008	2009	Range (Number)	Number of Households
Q4	8.56	5.67	6.78	5～17	9
	[3.43]	[2.74]	[5.80]		
Q3	3.22	6.11	4.56	2～4	9
	[0.83]	[4.31]	[2.40]		
Q2	1.00	3.00	2.75	1	8
	[0.00]	[4.47]	[4.30]		
Q1	0.00	0.75	0.42	0	20
	[0.00]	[2.02]	[1.02]		

Source: Household survey data, Resilience Project.
Note: Standard deviations are in parentheses.

Table 3 presents information regarding cattle inventories among the sampled households by wealth quartile. The quartile is based on the number of cattle holdings as of October 2007, at the beginning of the rainy season in the first year of the survey. As shown in Table 3, most households have no cattle in 2007. While the top quartile (Q4) experienced a decrease in the number of cattle during 07/08, and then recovered during 08/09, the other quartiles show the opposite.

Table 4: Changes in the number of cattle per household during the 2007/08 crop year

		Number of Cattle as of October 2007		Total
		Cattle≧2	Cattle<2	
Annual Rainfall in 2007/08	Above median	1.75 (5.39) N = 8	0.18 (1.55) N = 17	0.68 (3.26) N = 25
	Below median	0.60 (2.41) N = 10	1.27 (2.45) N = 11	0.95 (2.40) N = 21
Total		1.11 (3.92) N = 18	0.61 (1.99) N = 28	0.80 (2.87) N = 46

Note: The numbers represent the averages for the changes in cattle numbers and their standard deviations are in parenthesis.

The theory of consumption smoothing predicts that where households have no other means to compensate for a reduction in income, households with more crop damage (i.e., heavier rainfall) will reduce cattle in greater numbers than those with less crop damage (i.e., lower rainfall).

In addition, the asset smoothing hypothesis predicts that among the households suffering from the heavy rainfall, and with no other means to recompense, those with more cattle will liquidate greater numbers of cattle than those keeping less cattle. Table 4 provides a matrix of changes in cattle numbers during 2007/08, classified by rainfall level in the heavy rainfall year and cattle numbers as of October 2007. The criterion for cattle holdings is set at two cattle. As seen in Table 4, changes in the number of cattle held by households experiencing the heavier rainfall was less on average than that of households with the lower rainfall. Thus, households with greater damage reduced more cattle as predicted by the theory of consumption smoothing. In contrast, results also showed that households with two or more cattle increased their cattle numbers during 2007/08, a rate greater than those with less than two cattle. These results are not consistent with the asset smoothing hypothesis' prediction. This counter-intuitive result, in view of the asset smoothing hypothesis, may be caused by uncontrolled factors such as household demographic information. In addition, the assumed criterion of sample splitting could be invalid[9].

Table 5: Changes in cattle number per household during the 2008/09 crop year

		Number of Cattle as of October 2007		Total
		Cattle≧2	Cattle<2	
Annual Rainfall in 2007/08	Above median	-1.63 (5.48) N = 8	0.38 (1.86) N = 16	-0.29 (3.51) N = 24
	Below median	0.80 (3.01) N = 10	-0.85(2.54) N = 13	-0.13 (2.82) N = 23
Total		-0.28 (4.32) N = 18	-0.17(2.24) N = 29	-0.21 (3.15) N = 47

Note: The numbers represent the averages for the changes in cattle numbers and their standard deviations are in parenthesis.

Table 5 presents the same matrix for the 2008/09 crop year. In Table 5, we can observe a lagged effect for rainfall in 2007/08 on the change of cattle numbers. Furthermore, among the households with relatively small rainfall in 2007/08, those with larger cattle holdings increased more than those with less, suggesting the existence of multiple dynamic asset equilibria.

Figure 3 shows the evolution of mean numbers for cattle per household using the quartiles presented in Table 3. Q4 experienced a fall in the number of cattle holdings, while the other quartiles increased numbers during the 2007/08 crop year (see Figure 3), suggesting the existence of an asset threshold that distinguishes between the two regimes for Q4 and the other quartiles.

The above proposition requires further discussion and so we will examine the relationship between cattle number fluctuations and rainfall shock using a more rigorous method. To control for

[9] A similar result was attained from the cross-section estimation. However, the degree of freedom is too small to be reliable. Thus, that result is not reported here.

other factors that may influence cattle number fluctuations, we will use panel estimation techniques to investigate the existence of an asset level threshold and estimate the determinants of sensitivity with regard to rainfall shock.

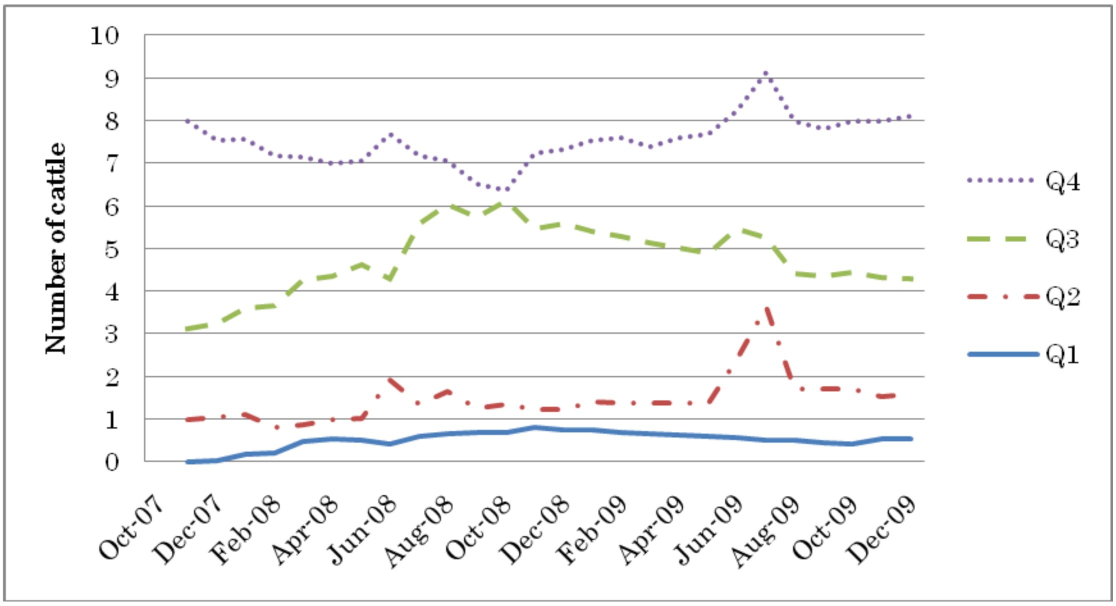

Figure 3: Monthly mean cattle numbers per household by quartile, 2007–2009

Source: Household survey data, Resilience Project.

4.3 Econometric Analysis of Sensitivity

This section presents an econometric approach in the examination of sensitivity regarding rainfall shock. Two factors influencing household sensitivity must be considered in the construction of estimation equations. First, attention should be given to a household's ability to employ alternative coping strategies such as *ex-post* labor adjustments (Rose, 2001) and non-productive asset dispositions (Udry, 1995). To capture these factors, this paper uses the ratio of working adult males to all household members and the value of small livestock such as pigs and goats. Second, the relative price of cattle to the price of food must be acknowledged. However, sufficient information regarding cattle prices was not available due to a limited number of cattle transactions. Instead, this paper uses the price of goats as a proxy variable for cattle prices.

With regard to rainfall shock, we employ two specifications based on rainfall data recorded on each household's plot: annual precipitation at plot level and monthly precipitation at plot level. The former is the total yearly rainfall, which differs among households but is constant throughout a given crop year. The latter is the total monthly rainfall, which varies both among households and during every month in the rainy season. Thus, the monthly variable is expected to capture households' immediate responses (with one or two months delay) to rainfall variability. Since we did not know in advance which specification will better explain households' responses with regard to livestock holdings in a rainfall shock, we used both rainfall shock variables together in estimation equations.

Thus, we will use the following econometric model, based on the previously defined sensitivity:

$$A_{it} - A_{it-1} = \alpha + \beta_R R_{it-1} + \beta_p p_{st} + \beta_x x_i + \mu_{it} \quad where \ \mu_{it} = \rho\mu_{it-1} + \epsilon_{it}, \quad (2)$$

where A_{it} is the number of cattle for a household (i) during a particular month (t); R_{it} is a vector of rainfall shocks experienced by a household (i) during a particular month (t); p_{st} is the price of goats[10] during a particular month (t) at the site (s) ; x_i is a vector of household characteristics, including working adult males ratio; and μ_{it} is a random error term assumed to follow the AR (1) process[11]. Thus, the dependent variable in this specification is the monthly change in the number of cattle owed by a household (i).

As noted above, the theory of asset smoothing predicts that productive assets drive smoothing tendencies, so this analysis aims to discern between the different smoothing regimes using cattle numbers as of October, 2007. Thus, sample households are split as follows:

$$A_{it} - A_{it-1} = \begin{cases} \alpha^h + \beta_R^h R_{it-1} + \beta_p^h p_{st} + \beta_x^h x_i + \mu_{it} & if \ \ 5 \leq A_{ib} \Leftrightarrow \ i \in Q4 \\ \alpha^l + \beta_R^l R_{it-1} + \beta_p^l p_{st} + \beta_x^l x_i + \mu_{it} & if \ \ 5 > A_{ib} \Leftrightarrow i \notin Q4 \end{cases} \quad (3)$$

where A_{ib} is the number of cattle of a household (i) before the shock (i.e., as of October 2007) and μ_{it} is the AR (1) error.

If livestock are used as a buffer against income shock, the coefficients of rainfall shock should be negative and significant. The first two columns of Table 6 present the full sample model (i.e., Eq. (2)) results. As shown in these columns, this coefficient is significantly positive rather than negative, suggesting that the use of cattle as buffer stock is a limited practice, consistent with the findings by Fafchamps et al. (1998)[12].

The remaining columns show results regarding the two regimes as defined by Eq. (3). While monthly changes in cattle numbers are positively responsive to total rainfall among households with lower livestock numbers in 2007, this rainfall shock variable has a significantly negative effect on changes in cattle numbers among Q4 households, implying that to prevent a reduction in consumption levels they may have sold their cattle. These results are consistent with the asset smoothing hypothesis prediction that only those with a certain level of assets pursue the traditional consumption smoothing strategy of selling assets. Furthermore, it should be noted that the sign for the ratio of working males is significantly different between the two samples: a positive coefficient in Q4 and a negative coefficient in the remaining quartiles. The positive coefficient implies that households with a weaker labor market access or simply less men are more likely to reduce cattle numbers, suggesting that such households may smooth consumption by selling cattle. However, the negative effect of working males in the lower quartiles may be

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[10] The prices of goats used here are deflated by the local food price index calculated by the authors using Household Survey data.

[11] The data in this estimation have many time periods for relatively few households, needing methods for stationary errors. In fact, the null hypothesis that there is no first order correlation in the Wooldridge test is rejected for each quartile at the 5% or less significance level. The same conclusion is reached by the test for serial correlation using fixed effect estimation. Thus, this specification assumes that the random error follows the AR (1) process.

[12] The significantly positive coefficient means that households with heavy rainfall increased the number of cattle, other things being equal. For this counterintuitive result, one possible explanation is that cattle are less liquid than small livestock, since distress sale after a covariate shock lead to a much reduced price if cattle markets are thin and fairly inactive (Fafchamps, et al., 1998). This paper leaves this as a topic for future work.

interpreted using the concept of human capital. If human capital is considered a critical productive asset influencing household welfare, households with less male labor would protect cattle numbers to smooth productive assets[13]. Table 6 also shows that the price of goats does not significantly influence cattle retention, suggesting that cattle transactions might not be particularly price responsive in the study sites.

Table 6: Determinants of sensitivity regarding rainfall shock on cattle numbers

	Pooled		Q4				Excluding Q4	
	FE	FE	FE	RE	FE	RE	FE	FE
Rainfall Shocks								
Total amount of rainfall (mm)	0.0003	0.0003	-0.0011	-0.0009	-0.0008	-0.0009	0.0005	0.0005
	[2.04]**	[1.99]**	[-1.47]	[-1.98]**	[-0.86]	[-1.76]*	[3.63]***	[2.99]***
Rainfall deviation from the	0.1588		0.2627	0.2861			0.0197	
village mean at t-1	[4.21]***		[4.98]***	[5.62]***			[0.36]	
×Site A dummy	-0.1283		-0.1806	-0.1856			-0.0269	
	[-0.71]		[-0.41]	[-0.44]			[-0.14]	
×Site B dummy	-0.1492		-0.0673	-0.1224			-0.0160	
	[-3.19]***		[-0.29]	[-0.54]			[-0.26]	
Rainfall deviation from the		-0.0468			-0.0724	-0.0458		0.0073
village mean at t-2		[-1.23]			[-1.27]	[-0.86]		[0.13]
×Site A dummy		0.0621			-0.2816	-0.1509		0.0158
		[0.34]			[-0.21]	[-0.13]		[0.09]
×Site B dummy		0.0517			-0.0533	-0.0596		0.0010
		[1.02]			[-0.16]	[-0.18]		[0.02]
Control Variables								
Monthly price of goats (10000K)	0.0100	0.0156	-0.0049	-0.0101	0.0358	0.0180	0.0186	0.0152
	[0.60]	[0.91]	[-0.12]	[-0.27]	[0.81]	[0.44]	[1.04]	[0.84]
Household Variables								
Value of small livestock (10000K)	0.0000	0.0000	0.0008	0.0003	0.0001	0.0005	0.0004	0.0005
	[-0.02]	[0.02]	[0.46]	[0.51]	[0.05]	[0.85]	[0.83]	[1.07]
Total Area for cropping (ha)	-0.0776	-0.0826	-0.2089	-0.0900	-0.228	-0.0777	-0.0571	-0.0683
	[-4.29]***	[-4.45]***	[-2.99]***	[-1.59]	[-2.99]***	[-1.30]	[-3.04]***	[-3.57]***
Value of Assets (10000K)	0.0000	-0.0001	-0.0002	0.0000	-0.0005	-0.0001	-0.0003	-0.0003
	[0.05]	[-0.83]	[-1.35]	[0.05]	[-2.27]**	[-0.98]	[-1.00]	[-0.88]
Rate of working males	-0.7420	-0.6632	0.7978	1.3142	0.6835	1.6127	-1.7860	-1.6948
	[-2.24]**	[-1.94]*	[1.25]	[2.59]***	[0.99]	[3.00]***	[-4.37]***	[-4.07]***
Rate of working females	-0.6833	-0.7180	-0.7451	-0.9840	-0.4819	-0.9587	-1.1242	-1.1602
	[-2.13]**	[-2.18]**	[-0.74]	[-1.23]	[-0.41]	[-1.14]	[-3.16]***	[-3.18]***
Constant	0.1784	0.1683	2.1251	3.5122	2.0261	3.5370	0.1102	0.2309
	[0.81]	[0.69]	[1.93]*	[2.98]***	[1.38]	[2.83]***	[0.50]	[0.95]
F-statistics	4.50	3.20	4.34		1.63		4.08	4.03
Chi-square statistics				101.00		68.14		
Level of Significance	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00
Hausman Statistics	22.98	20.56	-4.96[a)]		3.90		20.66	21.21
Number of Observations	913	865	168	176	159	167	745	706

* p<0.1, ** p<0.05, *** p<0.01

Notes: 1. The dependent variable is the monthly change in the number of cattle owed by the household.

2. t-statistics are in parentheses. The panel data is unbalanced because of missing data from household interviews.

3. With regard to random effects specifications, a number of variables were included but were not reported: rainy season dummies, cattle numbers as of October 2007, age of household head, years of education for household head, sex of household head, and site dummies.

4. With regard to fixed effects specifications, rainy season dummies were included as a variable but were not reported.

a). The negative Hausman statistic implies that the random effects model was not rejected due to the similarity of the covariance matrices. Thus, the Hausman test supports the use of the random effects model over the fixed effects model.

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[13] Such a multidimensional view of assets, as stressed by Hoddinott (2006), should be taken into account in future research on intertemporal smoothing behavior and poverty dynamics.

4.4 Lagged Effect of Rainfall Shock on Cattle Numbers

The results presented in the previous sub-section suggest that wealthier and poorer households have different smoothing behavior. However, the effect of the heavy rainfall shock in 2007/08 may have also elicited a different response in 2007/08 than it did for 2008/09. For example, households who had experienced the heavy rainfall and decreased cattle numbers in the first year may have increased cattle numbers in the second year, an example of resilience as defined earlier in the paper. In addition, other households who had smoothed or increased cattle numbers in the first year were unable to retain cattle the following year[14]. To test these scenarios, this section performs individual specifications for each crop year and then runs a comparison between Q4 and Q3 (compared with the previous evaluation between Q4 and Q1–3)[15]. These results are presented in Table 7.

With regard to the 2007/08 crop year, both rainfall shock variables (rainfall deviation from the village mean value and annual precipitation) had a negative significant effect on the stock series for cattle among households of Q4 and no significant effect on the same among households of Q3. This result is consistent with the previous specification results. Moreover, while household specific variables have a significant influence on cattle retention for both Q4 and Q3, the coefficients signs are different between the two regimes in some instances. For example, the value of household assets in Q4 significantly increases cattle numbers. This result suggests that households in Q4 suit typical consumption smoothing tendencies, because wealthier households with additional income have the ability to save more.[16] In contrast, the value of assets reduces the number of cattle in Q3, suggesting asset smoothing tendencies. These findings constitute evidence of wealth-differentiated behavior.

Table 7 also presents aspects of resilience to rainfall shocks. If the coefficient of rainfall shock variables in Q4 is positive and significant in 2008/09, this result represents a recovery from rainfall shock. As shown in Table 7, however, the estimation result does not offer robust evidence regarding resilience in Q4 because the signs for the two rainfall shock variables are different. In contrast, as can be seen in the two rightmost columns of Table 7, rainfall shock variables for 2007/08 have a significantly negative effect on cattle numbers in Q3 for the following crop year, suggesting that those who maintain their cattle numbers in the flood-year may be affected by lagged rainfall shocks. This also indicates a long-term relationship between asset dynamics and economic mobility.

5. Conclusion

This paper introduced measurable definitions for sensitivity, resilience, and vulnerability

[14] This possibility was also suggested by Sakurai et al. (2011). They showed that food price increased during the rainy season of 2008/09 more than during the rainy season of 2007/08 probably due to the reduction of agriculture production in 2007/08 and that average household consumption is much lower during the rainy season of 2008/09 than the previous year.

[15] Q1 and Q2 are not included in the analyses because households in these quartiles had zero or one cattle as of October 2007 and their change in the number of cattle during a short period, i.e. one year, is too small to obtain statistically significant estimates.

[16] Assets include farming equipments (ex; ox-drawn ploughs and hand hoes), durables (ex; hand hammer mills and radios) and houses including animal stalls and storages for grain. Thus, assets in this context are less liquid than small livestock and grain storages.

with regard to asset fluctuations. Using the specified sensitivity definition, this study employed

Table 7: Random effect estimates of determinants of sensitivity for each crop year

	2007_2008				2008_2009			
	Q4		Q3		Q4		Q3	
	RE	RE	RE	RE	RE	RE	RE	RE
Rainfall Shocks								
Rainfall deviation from the	-24.615		-4.538		9.614		-7.964	
village mean , 07/08	[-2.51]**		[-1.36]		[1.66]*		[-3.27]***	
Rainfall deviation from the					14.485		5.574	
village mean , 08/09					[4.35]***		[2.42]**	
Total amount of rainfall, 07/08 (mm)		-0.473		0.001		-0.005		-0.003
		[-2.51]**		[0.87]		[-1.48]		[-3.23]***
Total amount of rainfall, 08/09 (mm)						-0.001		0.003
						[-0.19]		[2.35]**
Rainfall deviation from the	0.257	0.257	0.005	0.019	0.330	0.330	0.288	0.288
village mean at t-1	[3.22]***	[3.22]***	[0.03]	[0.12]	[4.79]***	[4.79]***	[1.70]*	[1.70]*
×Site A dummy	-0.253	-0.253	-0.022	-0.061	-0.305	-0.305	-0.143	-0.143
	[-0.49]	[-0.49]	[-0.03]	[-0.08]	[-0.26]	[-0.26]	[-0.23]	[-0.23]
×Site B dummy	-0.172	-0.172	0.006	-0.006	-0.076	-0.076	-0.252	-0.252
	[-0.45]	[-0.45]	[0.03]	[-0.04]	[-0.26]	[-0.26]	[-0.88]	[-0.88]
Control Variables								
Monthly price of goats (10000K)	0.013	0.013	-0.051	-0.026	-0.020	-0.020	0.024	0.024
	[0.18]	[0.18]	[-0.94]	[-0.44]	[-0.52]	[-0.52]	[0.67]	[0.67]
Household Variables								
Value of small livestock (10000K)	-0.001	0.055	0.008	0.009	0.005	0.009	0.001	0.000
	[-1.91]*	[2.51]**	[2.32]**	[2.51]**	[3.38]***	[2.60]***	[0.25]	[-0.06]
Total Area for cropping (ha)	-0.595	-49.996	-0.160	-0.067	-8.221	6.514	-1.136	-0.866
	[-2.85]***	[-2.52]**	[-1.78]*	[-0.80]	[-2.81]***	[1.23]	[-1.93]*	[-1.42]
Value of Assets (10000K)	0.003	0.129	-0.011	-0.005	-0.264	0.145	-0.132	-0.174
	[3.09]***	[2.53]**	[-2.71]***	[-1.37]	[-2.58]**	[0.97]	[-2.36]**	[-2.57]**
Rate of working males	-3.697	-143.677	-0.574	0.094	-0.001	-0.004	-0.002	-0.001
	[-2.88]***	[-2.53]**	[-0.52]	[0.09]	[-0.89]	[-2.05]**	[-2.15]**	[-0.75]
Age of HH head	0.033	4.246	-0.042	-0.024	0.044	-0.009	-0.008	0.008
	[2.47]**	[2.52]**	[-3.05]***	[-2.38]**	[2.88]***	[-0.56]	[-1.92]*	[1.29]
Education years of HH head	-0.044	2.718	-0.171	-0.035	0.191	0.019	-0.078	-0.025
	[-1.22]	[2.53]**	[-1.78]*	[-0.50]	[3.53]***	[0.52]	[-3.48]***	[-1.53]
Constant	-0.097	631.128	4.446	0.698	0.023	7.220	1.641	-0.026
	[-0.19]	[2.51]**	[2.33]**	[0.28]	[0.08]	[0.77]	[2.87]***	[-0.02]
Chi-square statistic	21.13	21.13	51.99	50.14	93.67	93.67	36.37	36.37
Level of Significance	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Hausman Statistics	0.14	0.14	6.17	2.60	1.35	1.35	-1.29	-1.29
Number of Observations	75	75	83	83	114	114	109	109

* p<0.1, ** p<0.05, *** p<0.01

Notes: 1. The dependent variable is the monthly change in the number of cattle owed by the household.
2. For the poorer quartile, this estimation only uses samples of Q3 because a significant result was not obtained using this specification when Q2 and Q1 were included.
3. t-statistics are in parentheses.
4. The panel data is unbalanced because of missing data from the household interviews.
5. The negative Hausman statistic implies that the random effects model is not rejected due to the similarity of the covariance matrices.

high-frequency panel data from Southern Province, Zambia to estimate the determinants of sensitivity to rainfall shocks and to investigate the existence of an asset threshold, marking a shift from asset to consumption smoothing. The data covered the period between the 2007/08 and 2008/09 crop years, which included a heavy rainfall year within the study sites. The results revealed patterns of asset smoothing or protection among the poorer households and asset liquidation or consumption smoothing among the wealthier, which suggests wealth-differentiated behavior regimes. In the context of the study sites, the Micawber threshold, an asset level that represents an unstable equilibrium at which dynamic behavior bifurcates, may sit at approximately five cattle rather than two cattle, the common number of cattle used for cultivation. This finding is consistent with the dynamic asset smoothing hypothesis predicted in previous studies. Our analysis also revealed that those who smooth assets in the first year may be affected in the second year by lagged rainfall shocks, probably through market price increases, suggesting a negative impact by environmental shocks on asset smoothers. In contrast, results for resilience, regarding those who decreased cattle numbers during the heavy-rainfall year, are diverse, suggesting that any recovery period might not even begin in the second year. Asset recovery experiences will be investigated in future work.

The present analysis has been unable to fully resolve the complexities of asset dynamics in rural Zambia. First, while this paper has found evidence that the wealthy have a greater ability to smooth consumption than the poor, the criteria for distinguishing between them may be ad hoc. This matter requires further investigation. Second, this paper does not examine vulnerability; future research will provide clarification of the Micawber threshold and the asset poverty line, promising tools with which to induce rich policy and development implications. Third, it would seem that future investigation is also required to better understand the relationship between asset-based analysis and traditional poverty analysis with regard to consumption or income level. In addition, giving micro foundations to the approach of this study based on dynamic household models is also left for a future study.

While future research to answer outstanding issues is always desirable, the main contribution of this paper is the provision of empirical evidence regarding wealth-differentiated tendencies using stock series data. Furthermore, the concepts of sensitivity and resilience, as defined in this paper, can be used in future studies regarding household *ex-post* coping strategies and the accumulation and liquidation of other productive and non-productive assets (e.g., land and small livestock).

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