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Shock and Livestock Transactions in Rural Zambia: a Re-examination of the Buffer Stock Hypothesis

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This study re-examines the buffer stock hypothesis regarding livestock by taking into account differences in wealth level, asset types, and periods after a shock. This paper takes advantage of a unique panel data set of agricultural households in Southern Province, Zambia. The data were collected by weekly interviews of 48 sample households from November 2007 to December 2009, covering two crop years in which an unusually heavy rainfall event took place. If we consider delayed responses to the heavy rain shock, our econometric analyses support the buffer stock hypothesis for cattle as well as small livestock. Overall, this paper suggests that conventional annual data sets used in the existing literature may miss the period-dependent transactions of assets after a shock.

Key words: asset smoothing, buffer stock, weather risk, livestock, Sub-Saharan Africa.

1. Introduction

Many people living in poverty in rural areas of developing countries, particularly in Sub-Saharan Africa, face significant risks and are highly vulnerable to unexpected negative income shocks such as family illness and natural disasters. It has long been hypothesized that in response to these shocks households liquidate productive assets, such as large livestock, to maintain their consumption standards (buffer stock hypothesis). Because this strategy is very costly in terms of forgone future income, and has a direct relationship with poverty dynamics, it has been the focus of many studies (Rosenzweig and Wolpin [10]; Kurosaki [7]; Udry [14]; Fafchamps, Udry, and Czukas [3]). Results of these studies are varied, providing little support for the buffer stock hypothesis. For example, Fafchamps, Udry, and Czukas [3] found that crop income shock has no significant effect on livestock sales in Burkina Faso during severe drought years in the 1980s, which indicates that livestock is not used as buffer stock. Using the

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same Burkina data, Kazianga and Udry [6] reached the same conclusion as to the buffer stock hypothesis.

One possible explanation for the weak support to the buffer stock hypothesis is that poorer households may choose to maintain and smooth productive assets rather than to smooth consumption by liquidating productive assets (asset smoothing hypothesis, suggested by Zimmerman and Carter [16]). Several studies conducted after that of Fafchamps, Udry and Czukas [3] attempted to test this alternative hypothesis. For example, Hoddinott [4] using data from Zimbabwe, and Lybbert and Carter [8] using the same Burkina data that Fafchamps, Udry, and Czukas [3] had used, showed that the sensitivity of livestock sales to income shock is significantly greater among those who have more livestock (asset-rich households) than those who have less livestock (asset-poor households). They conclude that the buffer stock hypothesis tends to be supported among asset-rich households, while the asset smoothing hypothesis is likely to be valid among asset-poor households.[1]

However, a major limitation of existing literature investigating the buffer stock or asset smoothing hypothesis is that the methods depend on annual panel data. In some cases, researchers use annual data because only annual data are available, but in other cases they use annual data because income such as crop income and non-agricultural income is defined at an annual level. But we would argue that the use of annual data may favor the asset smoothing hypothesis over the buffer stock hypothesis for the following three reasons. First is the case of apparent asset-smoothers. If a household buys and sells an equivalent number of livestock within a year, the household can be regarded as an asset-smoother because there is no net transaction of livestock for the year, even though the household may smooth consumption using the livestock as a buffer.[2] Second is the case of non-asset holders. This is where a household sells all their livestock at some point in the year to smooth consumption, and becomes unable to sell any more livestock within the year. This household is likely to be classified as an asset-smoother, because its livestock transaction is mostly inactive, despite the positive initial endowment at the beginning of the year.[3] Third is the case of delayed responses. Livestock sales as a response to a shock may not immediately take place, but rather a household will sell livestock when the household becomes in need of cash. If more than a year passes before the household sells livestock, the household is regarded as an asset-smoother in analyses based on annual data, although the household ultimately uses their livestock as buffer stock. Although even annual data can handle delayed responses in principle, most studies assume that livestock sales in response to a shock take place within the same year, probably because one year is too long to identify livestock sales in response to a shock in the previous year or the panel is too short to do efficient analyses of delayed responses.[4]

Therefore, the objective of this study is to reexamine the buffer stock hypothesis using newly collected monthly panel data instead of annual panel data. In order to take advantage of the monthly data, we use rainfall variation as a proxy of income shock like Hoddinott [4] and the test of the buffer stock hypothesis is based on the coefficients estimated for the rainfall shock. However, a major difference from Hoddinott [4] is that we use household-specific rainfall data measured on plots of each sample household, while the rainfall data that Hoddinott [4] uses are regional. The advantage in using household-specific rainfall data is that we can treat the rainfall as a combination of common and idiosyncratic shocks as in the case of crop income shock.

The remainder of this paper proceeds as follows. Section 2 provides a description of the collected data. Section 3 presents an econometric model to test the buffer stock hypothesis regarding livestock, and discusses the regression results. The final section presents our conclusions and suggestions for future research.

2. Data and Settings

1) Data

The panel data were collected as part of the "Vulnerability and Resilience of Socio-Ecological Systems" project in Southern Province, Zambia. Zambia is situated in the Semi-arid Tropics (SAT) where people's livelihoods depend mainly on rain-fed agriculture. Climatic variation, especially regarding rainfall, is a substantial covariate risk that threatens the subsistence of small-scale farmers. In particular, the Southern Province is known to be the most drought-

Table 1. Annual precipitation for the 2007/08 and 2008/09 crop years

	Mean annual precipitation (mm)	Standard deviation (mm)	Coefficient of variation	Maximum (mm)	Minimum (mm)	Number of rain gauges
2007/08	1,525	102	0.067	1,699	1,313	48
2008/09	1,358	72	0.053	1,519	1,166	48
December 2007	801	84	0.104	942	627	48

Source: Household survey data, Resilience Project.

prone area in the country.

In the Southern Province, the project selected three locations alongside Lake Kariba for the household survey, based on an extensive village survey conducted in 2007 (Sakurai [12]). The three locations were a lower flat lake-side area (location A); a middle escarpment area (location B); and an upper terrace on the Zambian plateau (location C). In each location, 16 households were selected for the interviews based on our own village census (Sakurai [12]), providing a total sample of 48 households.

The household survey began with an annual interview in November 2007, at the beginning of the 2007/08 crop year, followed by weekly interviews.[5] The annual interviews were conducted at the beginning of each crop year to collect information regarding household demographic characteristics and asset holdings, including livestock. The weekly interviews asked about all the economic activities conducted (including livestock transactions) and shocks experienced (such as illness of family members, insect infestations, and plant diseases in their field) in their household during the previous week. In addition, an automatic rain gauge in each field of the 48 sample households recorded daily rainfall data during the survey period. This enabled us to treat rainfall as an idiosyncratic shock, even though the pattern of rainfall is quite similar throughout the study area.[6] This paper uses data collected from November 2007 to December 2009, covering the two crop years of 2007/08 and 2008/09,[7] and aggregates the weekly data at a monthly level. Therefore, the structure of the dataset is a panel of 48 households for 26 months.

2) Shocks

To test the buffer stock hypothesis, risk events that would have caused a shock to villagers needed to be specified. Rainfall recorded in each field of the sample households is summarized in Table 1. Because no previous records of rainfall were available, we had no information on normal annual rainfall levels for the study site. However, based on a large-scale annual rainfall map created by the Meteorological Department of Zambia, as well as the crops and vegetation observed in the study site, we estimated that the long-term average annual rainfall should be around 700 mm. Compared with this estimation, the annual rainfall recorded in both 2007/08 and 2008/09 was much higher, particularly in 2007/08. In fact, the 2007/08 crop year was a year of extremely heavy rains. It is reported that heavy rainfall in December 2007 damaged crops, washed away fields, and destroyed infrastructure such as roads and bridges. According to the villagers at the study site, such an event is very rare and would occur only once within several decades. On the other hand, no damage to fields or infrastructure was observed in 2008/09. The heavy rainfall in December 2007 is confirmed by the monthly rainfall pattern shown in Figure. The total amount of rainfall in December 2007 is more than half of the annual amount of rainfall in the 2007/08 crop year, as shown in Table 1. Thus, this heavy rain event was considered as an unexpected covariate shock to the villagers.

The covariate shock caused by the heavy rainfall in December 2007 can be seen in the movement of the local price of maize. Maize is the staple food and almost all the households at the study site produce it for self-consumption. But because market transactions are also quite frequent, the market price of maize affects their welfare very much. As shown in Figure, the price increased after the rainy season of 2007/08 and continued to rise until the harvest of the 2008/09 crop in February 2009. In each crop year, the local maize price declined after the harvest, but the decline was much smaller after the harvest of the 2007/08 crop year than after

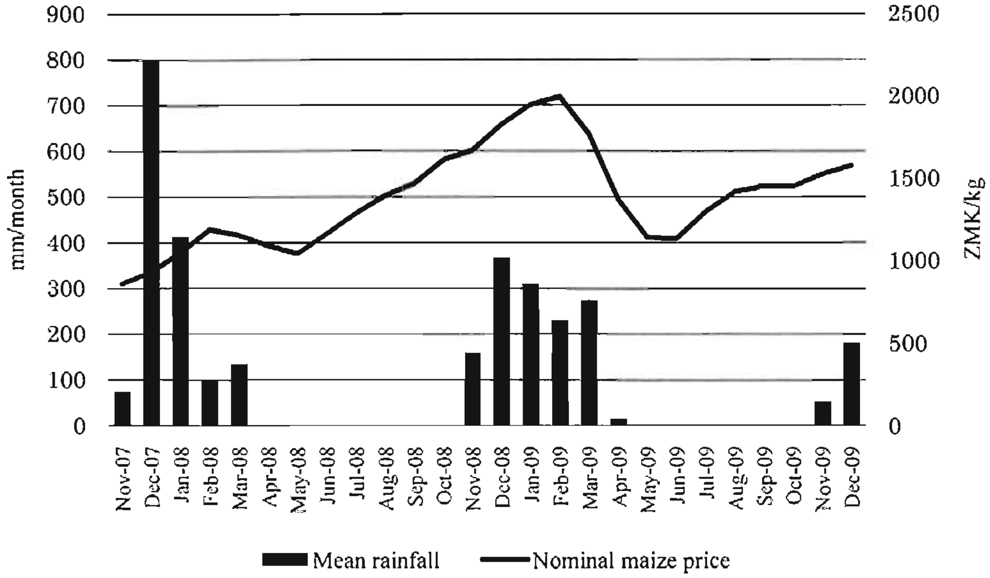

Figure. Monthly precipitation and local maize price at the study site

Source: Household survey data. Resilience Project.

Table 2. Shocks experienced by households during the survey period

Variable	Number of observations	Frequency of 1	Ratio of covariate variance to total variance (%)	Correlation
Illness: Dummy variable taking 1 when at least one family member gets sick	1,068	654	5.00	0.0613
Insect infestation: Dummy variable taking 1 when it is observed in the field	1,068	147	2.22	

Source: Household survey data. Resilience Project.

Note: The correlation between the two dummy variables is low and not statistically significant at $p<0.01$.

the harvest of the 2008/09 crop year, indicating a poor harvest in 2007/08. Crop production data from the sample households also confirms the poor harvest in 2007/08 (Sakurai et al. [13]).

The advantage of using our own field-level rainfall data is that we can treat them as an indicator of idiosyncratic shock. Although the coefficient of variation of the December 2007 rainfall is not large (as shown in Table 1), the crop production data indicate a negative relationship between rainfall amount and maize production among the sample households (Sakurai et al. [13]). Therefore this paper assumes that the more rainfall a field received in December 2007, the more negative shock the field's owner experienced.[8] However, it is important to note that the heavy rainfall in December 2007 may have only lowered the expected amount of harvest that would be realized in March/April 2008. In other words, the shock may have not created an immediate demand for cash to purchase food.

In addition to the field-level rainfall in December 2007, several other idiosyncratic shocks were reported at the study site. To avoid multicollinearity among idiosyncratic shocks, this paper selected the two idiosyncratic shocks that were the least correlated. One is illness of at least one family member, and the other is insect infestation in the field. We constructed a dummy variable for each that takes the value of 1 if the event occurred. Table 2 reports the frequencies of the two dummy variables, and indicates that the sample households frequently experienced family member illness. We confirmed that they are idiosyncratic by using the ratio of covariate variance to total variance, obtained by performing a regression of each dummy variable on a time dummy variable. As shown in Table 2, the ratio is quite low for both dummy variables, implying that the occurrence of each

Table 3. Value of household asset holdings at the beginning of the crop year

		Large livestock (Cattle)	Small livestock (Goats and pigs)	Productive assets (Excluding large livestock)	Unproductive assets (Excluding small livestock)	Total
2007/08	Mean	18.29	6.27	3.54	4.10	32.20
	Percent to total value	56.8%	19.5%	11.0%	12.7%	100.0%
	Std. Dev	25.75	12.49	6.37	7.43	41.62
	Median	7.35	1.94	1.94	1.38	19.47
2008/09	Mean	14.58	4.24	2.18	2.66	23.66
	Percent to total value	61.6%	17.9%	9.2%	11.3%	100.0%
	Std. Dev	17.14	8.28	3.63	4.83	27.15
	Median	5.58	1.41	0.94	1.76	15.03
2009/10	Mean	18.00	3.16	3.74	3.88	28.78
	Percent to total value	62.5%	11.0%	13.0%	13.5%	100.0%
	Std. Dev	24.89	3.38	5.15	5.60	34.00
	Median	4.48	2.28	2.19	1.67	12.00

Source: Household survey data. Resilience Project.

Note: The values are in 100.000 Kwacha at the time of November 2007. deflated by the local food price index obtained from the household survey data. US$1.00 = 3.700 Kwacha (November 2007).

event is little explained by the common variable (i.e.. they are idiosyncratic). Finally. Table 2 shows that the two dummy variables are not correlated. Unlike the heavy rain shock in December 2007. these two idiosyncratic shocks would have resulted in immediate (i.e.. within the same month as the shock) demand for cash to cover medical expenses or to purchase agricultural chemicals.

In summary. this paper treats field-level rainfall in December 2007. family illness. and insect infestation in the field as idiosyncratic shocks. The rainfall is assumed to have long-term impacts. while the illness and insect infestation are assumed to have immediate impact.

3) Livestock

As previously stated. this study analyzes households' livestock transactions to test the buffer stock and asset smoothing hypotheses. At the study site. agricultural households keep cattle. pigs. and/or goats.[9] As shown in Table 3, livestock is the most important household asset as its value is more than 70% of the total value of household assets. and the value of cattle is much higher than that of small livestock (pigs and goats). Cattle are used for agricultural production and transportation, but rarely consumed. with the exception of milk. Thus. cattle are considered to be productive assets at the study site. Unlike cattle. pigs and goats are not used for agricultural production. and are sometimes consumed. Thus. small livestock are not productive assets. Considering that households own more pigs and goats than they consume. the primary role of small livestock holdings seems to be storing wealth in an environment where there are no local financial institutions (e.g.. banks).

Table 4 provides the average number of cattle and small livestock held at the beginning of each crop year. The number of small livestock is expressed as a goat-equivalent where 1 pig is converted to 2 goats based on their market values. As shown in the table, households kept 2 or 3 cattle on average. with a median of 1 in each year. But almost half of the households had no cattle. 21 households as of November 2007. 21 households as of November 2008. and 22 households as of November 2009 owned no cattle. Note that although the numbers of households having no cattle are very close each year, households without cattle were not fixed during the 2 crop years; about 4 households are replaced each year. The average number of small livestock is much higher than that of cattle. as expected. Although the median is above 1. about 15 households did not have any small livestock.

Table 4. Number of livestock per household at the beginning of the crop year

		2007/08	2008/09	2009/10
Cattle	Mean	2.11	3.06	2.85
	Standard deviation	2.85	3.81	4.04
	Median	1	1	1
	Number of households without cattle	21	22	22
Small livestock (Goat-equivalent)	Mean	8.02	9.36	7.19
	Standard deviation	11.70	13.66	8.77
	Median	3	4	5
	Number of households without small livestock	14	17	15
Total number of households		46	47	47

Source: Household survey data. Resilience Project.

Concerning changes during the study period. Table 4 indicates the following two points. (I) the mean number and standard deviation of cattle holdings increased. and (II) the mean number and standard deviation of small livestock holdings decreased. The former implies that during the study period. (I-i) those who had a relatively large number of cattle increased their number of cattle (i.e.. net purchased). and (I-ii) those who had a relatively small number of cattle did not change. or marginally increased their number of cattle (i.e.. net purchased). On the other hand, the latter implies that during the study period. (II-i) those who had a relatively large number of small livestock decreased their number of small livestock (i.e.. net sold): and (II-ii) those who had a relatively small number of small livestock did not change. or marginally decreased their number of small livestock (i.e.. net sold). Given the heavy rain shock in December 2007. while (I-ii) is consistent with the application of the asset smoothing hypothesis to cattle. (I-i) is not supported by either the buffer stock or asset smoothing hypotheses. As for small livestock. (II-i) is consistent with the buffer stock hypothesis. but (II-ii) is not.

To test these hypotheses formally. we used quantitative analyses (in the next section) to see if the long-term change in the number of cattle and small livestock can be explained by the heavy rain shock in December 2007. As discussed above, the effect of the heavy rainfall may depend on the number of livestock owned by the household. Particularly in the case of productive assets like cattle. as suggested by Lybbert and Carter [8] , those who sit above a critical asset threshold (the so-called Micawber threshold) but are in danger of falling below it would choose to maintain productive assets rather than to smooth consumption (by selling those assets). In the context of our study. "two" is considered to be a critical number because farmers use a pair of oxen (sometimes cows) to plough. But "one" cattle beast is still much better than none. even as a productive asset. because farmers can rent another ox to make a pair for plowing. Thus. we consider three regimes in terms of cattle holdings: regime 1. a household with more than two cattle: regime 2. a household with one or two cattle: and regime 3. a household with no cattle. Because households sell and purchase livestock frequently. the regimes were not fixed throughout the study period. and therefore we classified sample households into the three regimes every month based on their number of cattle at the end of the previous month.

Table 5 presents livestock holding data for each regime at the beginning of the survey in November 2007. although as explained above. the regimes were not fixed during the survey period. As can be seen in the table. households in regime 1 were generally asset-rich in terms of both cattle and small livestock. Households in regime 3 had no cattle (consistent with the definition). but they had more small livestock than households in regime 2. Although households in

Table 5. Number of livestock per household at the beginning of the 2007/08 crop year

		Regime 1	Regime 2	Regime 3
Cattle	Mean	5.67	1.20	0
	Standard deviation	2.29	0.42	0
	Median	5	1	0
	Minimum	3	1	0
	Maximum	9	2	0
Small livestock (Goat-equivalent)	Mean	9.87	5.10	8.10
	Standard deviation	15.00	6.35	11.21
	Median	4	2	3
	Minimum	0	0	0
	Maximum	56	20	38
Total number of households		15	10	21

Source: Household survey data, Resilience Project.

regime 2 had one or two cattle, their holding of small livestock is the smallest among the three regimes. Thus, in terms of buffer stock, households in regime 3 seem to be richer than those in regime 2. Households in regime 2 should then be those who do not predominantly rely on livestock for coping with shocks, and who have other coping measures such as non-agricultural income.

3. Econometric Tests of the Buffer Stock Hypothesis

1) Empirical specification

If a household sells livestock in response to its field-level heavy rain shock in December 2007, we conclude that the household used its livestock as buffer stock. Because livestock sales may not happen immediately after the heavy rainfall, we created a series of time-dependent rainfall shock variables to capture the delayed impact of the field-level rainfall in December 2007. We achieved this by interacting the field-level rainfall in December 2007 ($D7RainDev_i$ for household i) and time dummy variables for each month ($Month_t$, where t is the number of months after December 2007; $t=1$ in January 2008 and $t=24$ in December 2009). Note that field-level rainfall is calculated as a deviation from the sample mean in order to explicitly treat this variable as the indicator of an idiosyncratic shock.

A household's livestock sales may also depend on other idiosyncratic shocks that require immediate cash, as well as aggregate shocks at the study site that partially reflect the impact of the heavy rainfall of December 2007. As discussed earlier, this paper uses family illness (IL_{it}) and insect infestation (SC_{it}) as markers of idiosyncratic shocks. IL_{it} is a dummy variable with a value of 1 if at least one member of household i becomes sick in time t, and SC_{it} is a dummy variable with a value of 1 if household i observes an insect infestation in its field in time t. The two idiosyncratic shock variables form a vector of variables denoted by $IShock_{it}$. On the other hand, the aggregate shock including the impact of price change as shown in Figure is to be captured by dummy variables for time ($Month_t$). Because the sample households were spread over three locations, location-specific factors such as shared risks are controlled for with dummy variables for location (Loc_v, where $v=$ A, B, and C). Note that by including dummy variables for time and location, the field-level rainfall variable directly represents the magnitude of idiosyncratic shock.

Moreover, since livestock sales are affected by the number of cattle owned at the time of decision making (as discussed in the previous section), a variable for "regimes" is included to control for the household-specific, time-varying status of cattle holdings. The variable for regime j (R^j_{it}, where $j=1$, 2, and 3) is a dummy variable with a value of 1 if household i is in regime j in time t, which is determined by the number of cattle at the end of time t-1.[10)] The regime dummies are used to create interaction terms with shock variables. In addition to these interaction terms, we include the number of cattle owned at the end of time t-1 ($Cattle_{it-1}$), which defines the regime of household i in time t.

Thus, net livestock sales of household i in time t (NS_{it}), either cattle or small livestock, will be the function of the shock variables as below.

$$\begin{aligned} NS_{it}=&\Sigma_{j=1}^{3}\Sigma_{t=1}^{24}\alpha_t^j\,(R_{it}^j\times D7RainDev_i\times Month_t)\\ &+\Sigma_{j=1}^{3}\delta^j(R_{it}^j\times IShock_{it})+\beta_cCattle_{it-1}\\ &+\Sigma_{t=1}^{24}\beta_tMonth_t+\Sigma_r\beta_rLoc_r+\mu_xX_{iy}+\omega_{it} \end{aligned} \qquad (1),$$

where if α_t^j is positive and significant, livestock is used as a buffer against income shock incurred by the heavy rainfall in December 2007. In equation (1), X_{iy} is a vector of household i's characteristics at the beginning of crop year y (y = 2007/08, 2008/09, or 2009/10) and ω_{it} is unobservable heterogeneity. X_{iy} includes the number of working adult males at the beginning of crop year y to capture household i's ability to employ alternative coping strategies such as *ex post* labor adjustments (Rose [9]), and total area for cropping (ha) in crop year y, because the magnitude of the heavy rain shock might depend on land area. The other variables in X_{iy} are value of small livestock, assets and houses, number of adult females and children, education level of household head (years), and age of household head.[11]

As for the estimation, because livestock transactions are discrete events including many zeros, we cannot estimate equation (1) without causing bias. Instead, we define a categorical variable, denoted by LT_{it} as follows, and replace the dependent variable of (1) with LT_{it}.[12]

$$LT_{it}=\begin{cases}3 \text{ if } 0 < NS_{it}\\ 2 \text{ if } NS_{it}=0\\ 1 \text{ if } NS_{it}<0\end{cases} \qquad (2)$$

Then, the modified equation (1) is estimated by a pooled ordered probit model to obtain consistent estimators, assuming that the unobservable heterogeneity (ω_{it}) is strictly uncorrelated with observable household variables and normally distributed. However, the assumption of independence of heterogeneity is too strong, because it does not allow unobservable factors to affect both livestock transactions and observable household characteristics. To relax the assumption of independence of heterogeneity, parameters need to be identified by variations within a household, and hence we assume (following Contoyannis, Jones, and Rice [1]), that unobserved individual effects are a function of the average of time-varying explanatory variables over the survey period, and run a pooled ordered probit model including the individual means of the explanatory variables $\overline{IShock_i}$ and $\overline{X_i}$. The estimator obtained by this model is called a "fixed effect" ordered probit estimator (Wooldridge [15]; Kawaguchi [5]). We conducted a likelihood ratio test to compare the efficiency of the pooled ordered probit estimator with the "fixed effect" ordered probit estimator.

2) Regression results

This subsection begins with estimation results derived from a conventional specification adopted from the existing literature, that is, the impact of the heavy rain in December 2007 is constant throughout the survey period. This is achieved by estimating equation (1) without the interaction terms for $D7RainDev_i$ and $Month_t$. The result of this specification is presented in Table 6.[13] A pooled ordered probit regression is used for net cattle sales, because a likelihood ratio test supported the use of this estimation model. As shown in Table 6, the coefficient of the rainfall shock variable is not statistically significant for either of the regimes. As for net small livestock sales, a "fixed effect" ordered probit estimation is used, because a likelihood ratio test strongly rejected exogeneity for the regressors. The regression indicates that households with a relatively large number of cattle (i.e., regime 1) used small livestock as buffer stock in response to the idiosyncratic rainfall shock. In contrast, the coefficients of the rain shock variable are positive, but insignificant for households with fewer cattle (i.e., regimes 2 and 3). In addition, the coefficient of the dummy variable for illness for both regimes 1 and 3 are significantly positive, suggesting that not only asset-rich households, but households with no cattle, used small livestock to meet cash needs for family illness. On the other hand, none of the idiosyncratic shocks had significant impacts on small livestock transactions among households with few cattle, regime 2.

Estimations using the conventional specification suggest that all households, regardless of regime, may smooth cattle (productive assets), but some of them used non-productive small livestock as buffer stock to deal with weather shocks. This result agrees with most of the existing literature that provides mixed support for the buffer stock hypothesis, and is more sup-

Table 6. Effect of heavy rainfall shock on net livestock sales, January 2008-December 2009[1]

Dependent variable	Net sales category Cattle		Net sales category Small livestock		
Explanatory variables[2]	Regime 1	Regime 2	Regime 1	Regime 2	Regime 3
Idiosyncratic shock					
Rainfall in December 2007 ($D7RainDev_i$)	0.0013	0.0020	0.0045*	0.0020	0.0032
	[0.0028]	[0.0026]	[0.0024]	[0.0023]	[0.0023]
Illness of household members (IL_{it})	0.1373	−0.1650	0.3342**	0.1283	0.2543*
	[0.1820]	[0.2698]	[0.1596]	[0.2130]	[0.1329]
Insect infestation (SC_{it})	−0.1795	0.0021	0.1333	−0.1524	−0.2201
	[0.2303]	[0.6251]	[0.2259]	[0.3620]	[0.1980]
Aggregate shock					
Time dummies	Yes		Yes		
Category Threshold 1	−1.6866***		−0.9754**		
	[0.5124]		[0.4179]		
Category Threshold 2	2.5156***		2.6058***		
	[0.5034]		[0.4462]		
Log pseudolikelihood	−144.58		−413.91		
Chi-square statistic for zero slope	Chi (42) 114.07***		Chi (61) 154.33***		
LR test for "fixed effects"	9.40		47.81***		
Number of observations	581		1,068		

Notes: 1) The numbers are the estimated coefficients of interaction terms between a shock variable and a regime dummy variable. A pooled ordered probit model was used for the estimation of cattle. A "Fixed effect" pooled ordered probit model was used for the estimation of small livestock. Robust standard errors are reported in brackets.
* p <0.1, ** p <0.05, *** p <0.01.

2) Explanatory variables that were included but not reported are: number of cattle, value of small livestock, total area for cropping (ha), value of assets and houses, number of adult males, number of adult females and children, education level of household head (years), age of household head, and location dummy variables. In addition to these variables, within-group means of demographic and idiosyncratic shock variables are included for small livestock because a "fixed effect" pooled ordered probit is used, but not reported in the table.

portive to asset smoothing. However, this conclusion may be influenced by failing to take time-dependent effects of the heavy rain shock into account.

To investigate this time-varying impact, we estimate equation (1) including the interaction terms for rainfall in December 2007 and the dummy variables for time. Results for net cattle sales are presented in Table 7. Because a likelihood ratio test supported the use of a pooled ordered probit model, Table 7 only shows results from this estimation method.

For regime 1, positive, significant coefficients indicating net sales of cattle are obtained for January 2009, October 2009, and November 2009, all of which are more than one year after the heavy rain shock. Because the response of net cattle sales depends on household-specific rainfall in December 2007, by controlling for aggregate shock effects with dummy variables for time, the regression result provides evidence of a lagged effect of the idiosyncratic heavy rain shock. January is the lean season at the study site, while October and November are the period when households need to find money to purchase agricultural inputs such as seeds and chemical fertilizers. On the other hand, the heavy rainfall had a negative effect on net cattle sales in July 2008 (p-value = 0.101). This is an unexpected response to heavy rain shock, but it occurred because some regime 1 households who had sold cattle in response to aggregate shock after the heavy rainfall purchased cattle in July, when cattle prices were low during the dry season.[14] According to our own field observations, asset-rich households could purchase

Table 7. Effect of heavy rain shock on net cattle sales[1]

	Dependent variable: Net sales category of cattle					
	Idiosyncratic shocks				Aggregate shocks (Time dummies)	
	Regime 1		Regime 2			
Explanatory variables[2]	Parameter estimates	Standard errors	Parameter estimates	Standard errors	Parameter estimates	Standard errors
Rainfall in December 2007 × Time dummies						
Jan-08	0.0021	[0.0029]	0.0010	[0.0032]	Reference	
Feb-08	−0.0039	[0.0049]	0.0090**	[0.0043]	0.9637***	[0.3261]
Mar-08	0.0016	[0.0030]	−0.0013	[0.0032]	0.4465	[0.2845]
Apr-08	0.0013	[0.0029]	−0.0014	[0.0029]	0.3824	[0.2626]
May-08	0.0052	[0.0038]	−0.0020	[0.0033]	0.9777**	[0.4491]
Jun-08	−0.0046	[0.0046]	−0.0010	[0.0052]	−0.3562	[0.4958]
Jul-08	−0.0090	[0.0055]	−0.0026	[0.0043]	−0.1335	[0.4149]
Aug-08	0.0019	[0.0027]	−0.0022	[0.0035]	0.3724	[0.2693]
Sep-08	0.0019	[0.0029]	−0.0017	[0.0030]	0.4079	[0.2637]
Oct-08	0.0092	[0.0084]	−0.0023	[0.0030]	0.7237	[0.4974]
Nov-08	−0.0001	[0.0061]	0.0001	[0.0039]	1.1333**	[0.4666]
Dec-08	0.0020	[0.0029]	0.0008	[0.0050]	−0.4283	[0.3991]
Jan-09	0.0088**	[0.0039]	0.0009	[0.0040]	0.4381	[0.5143]
Feb-09	0.0012	[0.0027]	−0.0016	[0.0028]	0.3039	[0.2485]
Mar-09	0.0018	[0.0048]	0.0013	[0.0039]	1.1190**	[0.4351]
Apr-09	0.0035	[0.0028]	−0.0030	[0.0038]	−0.1331	[0.4125]
May-09	−0.0036	[0.0037]	0.0004	[0.0031]	0.5786*	[0.3246]
Jun-09	0.0036	[0.0028]	−0.0074	[0.0071]	−0.2470	[0.4468]
Jul-09	0.0014	[0.0054]	0.0272**	[0.0124]	0.8591	[0.6084]
Aug-09	−0.0069	[0.0061]	0.0150**	[0.0072]	−0.0891	[0.4837]
Sep-09	−0.0052	[0.0039]	0.0024	[0.0045]	0.8455**	[0.3862]
Oct-09	0.0080**	[0.0038]	0.0024	[0.0053]	−0.4667	[0.3449]
Nov-09	0.0112**	[0.0052]	0.0009	[0.0039]	0.0963	[0.2929]
Dec-09	0.0007	[0.0026]	0.0005	[0.0033]	0.2752	[0.2613]
Illness (IL_{it})	−0.0135	[0.2041]	−0.2665	[0.2931]		
Insect infestation (SC_{it})	−0.2924	[0.2323]	0.3336	[0.5698]		
Category Threshold 1			−1.9235***	[0.5103]		
Category Threshold 2			2.7162***	[0.4903]		
Log pseudolikelihood			−130.52			
Chi-square statistic for zero slope			Chi (88) 140.71***			
LR test for "fixed effects"			8.68			
Number of observations			581			

Notes: 1) The numbers are the estimated coefficients of interaction terms between a shock variable and a regime dummy variable. A pooled ordered probit model was used for the estimation. Robust standard errors are reported in brackets. * p <0.1. ** p <0.05. *** p <0.01.

2) Explanatory variables that were included but not reported are: number of cattle, value of small livestock, total area for cropping (ha), value of assets and houses, number of adult males, number of adult females and children, education level of household head (years), age of household head, and location dummy variables.

cattle because they were likely to have access to alternative coping strategies such as receiving remittances from relatives, and could cope better with the negative effects of heavy rainfall.

As for regime 2, positive significant coefficients were found in February 2008, July 2009, and August 2009. Compared with regime 1, the regime 2 cattle sales occurred earlier. This implies that households in regime 2 were more vulnerable to the heavy rain shock than those in regime 1. Particularly in February 2008, when households did not require cattle for plowing, those who needed immediate cash to purchase food during the rainy season may have sold them. This is considered a quick response, occurring only a few months after the shock, which may have caused those households to be trapped in poverty, because they lost productive assets and there were no indications of them buying cattle back during the two-year period. This immediate impact will be missed if we use an annual data set, because it is difficult for the conventional method to separate this from livestock transactions before a shock.

To assess the difference between regimes 1 and 2 in the sensitivity of cattle transactions to the heavy rainfall shock, we calculate marginal probabilities for the interaction terms which are statistically significant. Note that the marginal probabilities are evaluated at the sample means of explanatory variables. Calculation results for regime 1 households suggest that an increase in the rainfall amount in December 2007 by 167 mm (two standard deviations) leads to an increase in the probability of selling cattle by 4.05 percentage points in January 2009, 3.69 percentage points in October 2009, and 5.18 percentage points in November 2009, respectively. The same numerical exercise for regime 2 households shows a 4.13 percentage point increase in February 2008, 12.58 percentage point increase in July 2009, and 6.91 percentage point increase in August 2009. According to the marginal probabilities, it seems that the difference of responses using cattle transactions among the two regimes is not so large. In fact, a null hypothesis that the six significant interaction terms are statistically equal is not rejected even at the 10 percent significance level. The frequency of obtaining statistically significant coefficients in the survey period is the same among the two regimes, which also supports the above interpretation.

Thus, the estimation results, taking into account the time-dependent impacts of the weather shock, support the buffer stock hypothesis among not only asset-rich households, but also asset-poor households. The primary reason for this lagged impact is that turnover in cattle ownership is a last resort of self-insurance, since cattle are valuable assets for agricultural production. Hence, during the one-year period after the weather shock, statistically significant impacts are rarely observed. This result is consistent with previous literature in that the results do not fully support the buffer stock hypotheses. However, our analysis does provide evidence of buffer stock by showing that statistically significant impacts of heavy rainfall occurred ,more than one year after the weather shock. On the other hand, the delayed response implies that households used other coping measures during the succeeding one-year period to mitigate the negative impacts of the heavy rainfall event. Therefore, small livestock transactions are investigated using equation (1) for net small livestock sales.

"Fixed effects" ordered probit estimation results with respect to net small livestock sales are presented in Table 8. It can be seen that the weather shock induced small livestock transactions among households in regimes 1 and 3 during the rainy season of the 2007/08 crop year, suggesting that they liquidated small livestock in the aftermath of the rainfall shock. Please note that the coefficients of the interaction term for households in regime 2 are marginally significant and positive in April 2008 and June 2008 (their p-values are 0.107 and 0.100, respectively). This finding suggests that households with few cattle used not only large livestock, but also small livestock, to cope with the negative weather shock, supporting the previous view that they were relatively vulnerable to the heavy rain shock.

Moreover, households especially in regime 3 continually sold small livestock during the year after the heavy rainfall event. This implies that households without cattle are specializing in keeping small livestock, and pursing defensive portfolio strategies characterized by the savings of low-return buffer assets, as suggested by Zimmerman and Carter [16]. Thus, our results support the buffer stock hypothesis regarding small livestock among asset-rich households, as

Table 8. Effect of heavy rain shock on net small livestock sales[1]

	Dependent variable: Net sales category of small livestock							
	Idiosyncratic shocks						Aggregate shocks (Time dummies)	
	Regime 1		Regime 2		Regime 3			
Explanatory variables[2]	Parameter estimates	Standard errors	Parameter estimates	Standard errors	Parameter estimates	Standard errors	Parameter estimates	Standard errors
Rainfall in December 2007 × Time dummies								
Jan-08	0.0075	[0.0052]	0.0020	[0.0028]	−0.0004	[0.0033]	Reference	
Feb-08	0.0071*	[0.0039]	0.0030	[0.0023]	0.0019	[0.0024]	0.1223	[0.3230]
Mar-08	0.0090*	[0.0047]	0.0030	[0.0028]	0.0024	[0.0022]	0.1158	[0.3130]
Apr-08	0.0113***	[0.0038]	0.0041	[0.0026]	0.0062**	[0.0026]	−0.2112	[0.3700]
May-08	−0.0014	[0.0040]	0.0037	[0.0028]	0.0036	[0.0024]	−0.0113	[0.3278]
Jun-08	0.0065	[0.0052]	0.0051	[0.0031]	−0.0039	[0.0057]	−0.2563	[0.3942]
Jul-08	0.0092*	[0.0050]	0.0042	[0.0041]	0.0027	[0.0025]	0.4441	[0.3776]
Aug-08	0.0034	[0.0043]	0.0037	[0.0037]	0.0068*	[0.0038]	0.2236	[0.4056]
Sep-08	0.0071	[0.0060]	−0.0041	[0.0043]	−0.0049	[0.0042]	0.2230	[0.3650]
Oct-08	0.0072	[0.0047]	0.0038	[0.0030]	0.0014	[0.0026]	0.2023	[0.3817]
Nov-08	0.0033	[0.0038]	0.0056	[0.0041]	0.0049**	[0.0024]	0.0762	[0.3374]
Dec-08	0.0000	[0.0048]	−0.0036	[0.0060]	0.0037	[0.0031]	0.3081	[0.4371]
Jan-09	0.0041	[0.0059]	−0.0024	[0.0056]	0.0001	[0.0072]	0.4049	[0.4023]
Feb-09	−0.0026	[0.0042]	−0.0095*	[0.0056]	0.0065	[0.0076]	0.4005	[0.4312]
Mar-09	−0.0008	[0.0048]	0.0028	[0.0050]	0.0040	[0.0057]	0.2797	[0.3975]
Apr-09	0.0011	[0.0034]	0.0050	[0.0033]	0.0116**	[0.0050]	−0.1220	[0.3492]
May-09	0.0029	[0.0040]	0.0033	[0.0032]	0.0042	[0.0028]	−0.1407	[0.3805]
Jun-09	0.0053	[0.0053]	0.0071	[0.0058]	0.0080**	[0.0031]	−0.1270	[0.4956]
Jul-09	0.0020	[0.0037]	−0.0038	[0.0094]	0.0044*	[0.0024]	0.1977	[0.3694]
Aug-09	0.0057**	[0.0028]	0.0180***	[0.0054]	0.0043*	[0.0024]	−0.0996	[0.3117]
Sep-09	0.0077**	[0.0036]	−0.0066	[0.0063]	0.0061	[0.0047]	0.0591	[0.3758]
Oct-09	−0.0018	[0.0040]	−0.0053	[0.0059]	0.0009	[0.0028]	−0.0236	[0.3859]
Nov-09	−0.0005	[0.0047]	0.0035	[0.0039]	0.0017	[0.0022]	0.3113	[0.3259]
Dec-09	0.0107*	[0.0062]	−0.0028	[0.0045]	0.0054	[0.0038]	0.2897	[0.3485]
Illness (IL_{it})	0.3001*	[0.1753]	0.0736	[0.2258]	0.2573*	[0.1451]		
Insect infestation (SC_{it})	0.2263	[0.2223]	−0.0814	[0.2781]	−0.3524	[0.2161]		
Category Threshold 1				−1.1606***	[0.4373]			
Category Threshold 2				2.5744***	[0.4603]			
Log pseudolikelihood				−392.02				
Chi-square statistic for zero slope				Chi (130) 244.20***				
LR test for "fixed effects"				42.63***				
Number of observations				1068				

Notes: 1) The numbers are the estimated coefficients of interaction terms between a shock variable and a regime dummy variable. A "Fixed effect" ordered probit model was used for the estimation. Robust standard errors are reported in brackets. * p <0.1. ** p <0.05. *** p <0.01.

2) Explanatory variables that were included but not reported are: number of cattle, value of small livestock, total area for cropping (ha), value of assets and houses, number of adult males, number of adult females and children, education level of household head (years), age of household head, location dummy variables, and within-group means of demographic and idiosyncratic shock variables.

well as among households without productive assets.

As for regime 2 (asset-poor households), unexpected coefficients were obtained in February 2009, as shown in Table 8. The negative sign indicates that those who experienced a smaller shock (i.e., less rainfall) tended to liquidate their small livestock more than one year after the shock, while those who had a bigger shock (i.e., more rainfall) bought livestock for the following reason. February is just before the harvest period, and farmers whose food-stocks had been exhausted by February 2009 had to depend on purchased food in this month. Furthermore, the maize price reached a peak in this month, as described by the previous section. Therefore, the liquidation of small stock would have been for purchasing food, particularly in response to the higher food price. However, since households in regime 2 did not have a large number of small livestock at the beginning, as shown in Table 5, those who experienced a severer shock (i.e., heavier rainfall) and sold small livestock immediately after the shock could not sell them further in this month. On the other hand, those who had a smaller shock (i.e., less rainfall) could manage without immediate sales of small livestock, but started selling small livestock one year after the shock to cope with the price increase. As this is considered to cause the negative sign, it is not inconsistent with the buffer stock hypothesis. Therefore, despite the unexpected negative sign, these regression results also support the buffer stock hypothesis regarding small livestock among asset-poor households.

In summary, these empirical results fully support the buffer stock hypothesis regarding cattle as well as small livestock. Sample households used livestock transactions as coping strategies against the idiosyncratic heavy rain shock, not only in its immediate aftermath, but also more than one year later. Even households below the critical asset threshold for production (i.e., regime 2) used cattle as buffer stock.

In addition, the analysis provides evidence of wealth-differentiated coping strategies for weather shocks. Coping strategies differed according to wealth in terms of what kind of livestock was used as a buffer, and when the buffer was liquidated. An important finding is that some impacts of the idiosyncratic heavy rain shock on livestock transactions were lagged, suggesting that conventional annual data sets used in the existing literature may miss the period-dependent transactions of assets after a shock. Moreover, asset-poor households tended to sell cattle immediately after the heavy rain shock if the shock was large, even though they had only one or two cattle, but there was no indication of them purchasing cattle during the two-year period investigated. This implies that some of the asset-poor households became trapped in poverty.

4. Conclusions

This study used high-frequency panel data from the Southern Province, Zambia, to examine the buffer stock hypothesis with regard to livestock for each wealth regime and period, and to empirically investigate wealth-differentiated as well as period-dependent coping strategies towards weather shocks. This data set was ideal for the analysis of livestock transactions after a shock because the data were collected every week from November 2007 to December 2009, a period that included an unusual heavy rain event at the study site.

Among households above the critical threshold of cattle holdings, cattle were used as a buffer against the idiosyncratic heavy rain shock, not only during the first year after the shock, but also during the second year. For those households, non-productive small livestock were used as buffer stock in the aftermath of the heavy rainfall, but they were also sold more than one year after the shock. Our results support the buffer stock hypothesis regarding livestock among asset-rich households.

Households with fewer than two cattle also used cattle transactions as a response to the household-specific rainfall shock during the two crop years, but with different timing. Asset-poor households tended to sell cattle earlier than asset-rich households, indicating that the former are less robust against shock, and are likely to become trapped in poverty following the loss of a productive asset. Asset-poor households who did not sell cattle, on the other hand, tended to use small livestock to cope with idiosyncratic shocks. Therefore, the buffer stock hypothesis is also supported among asset-poor households. We also found that households without cattle relied on small livestock as buffer stock against the idiosyncratic weather shock. Our comparison among households in three regimes provides evidence of wealth-differentiated and period-dependent coping strategies towards weather shocks.

The present analysis has focused on testing the buffer stock hypothesis, and hence the complexities of coping strategies against environmental shocks in rural Zambia still remain unsolved. First, this paper does not identify how much the liquidation of livestock mitigates income shock and smooths consumption. Second, the effects of the distress sale of productive assets (i.e., cattle) on future household income were not investigated. This issue is important for poverty dynamics and requires further research. Third, further investigation is required to better understand the relationship between asset disposal and other *ex post* risk-coping strategies by providing a comprehensive picture of farmers' behavior towards shocks.

While future research to answer outstanding issues is always desirable, the main contribution of this paper is the provision of empirical evidence regarding period-dependent coping strategies, controlling for types of assets and periods after a shock in relation to dynamic wealth regimes. The results presented in this paper suggest that conventional annual data sets used in the existing literature may miss the period-dependent transactions of assets after a shock, and thus underestimate the total impact of a negative shock.

1) Methodologically the two studies differ in several ways. One point to mention here is that Hoddinott [4] uses rainfall variation as a proxy of income shock, while Lybbert and Carter [8] use transitory and unexplained crop income induced by rainfall variation as a proxy of income shock. The latter method is common among studies that use the same household data from Burkina Faso such as Fafchamps, Udry, and Czukas [3] and Kazianga and Udry [6]. The use of crop income can be more appropriate because it will tell us directly to what extent the livestock sales cover the crop income loss and provide a straightforward implication for households' welfare. Although it is desirable, the problem of using crop income is that crop income is endogenous, could have a lot of measurement error, and is difficult to disaggregate into monthly levels. The use of rainfall, on the other hand, is an indirect measure of crop income but can avoid the problems in using crop income. Because it is technically difficult to correct those problems, this paper uses rainfall variation as a proxy of income shock.

2) Hoddinott [4] uses gross annual livestock sales rather than net annual livestock sales. Although the author does not explain the reason for doing so, it can obviously avoid the problem of apparent asset-smoothers. However, from the viewpoint of the buffer stock hypothesis, net sales are more appropriate because investment in livestock cannot be ignored, particularly in the case of cattle. Moreover, Hoddinott [4] misses the important issue of the timing of livestock transaction, i.e., when (in which month of the year) farmers tend to sell livestock, and when farmers tend to purchase livestock.

3) Since households without livestock cannot sell livestock, any analysis on gross livestock sales and even that on net livestock sales should treat such households accordingly. Moreover, from the view of poverty dynamics, the case where a household sells all their livestock and becomes unable to sell livestock is very important. However, detailed analyses on the dynamics of livestock holdings have rarely been performed, and therefore this paper tries to tackle the issue using monthly panel data in which we classify each household into a regime every month based on the number of livestock held in the month. Then, based on the monthly regime, households without cattle are excluded from the analysis and households without small livestock are controlled for by a dummy variable.

4) There are several studies on consumption smoothing that show that the impact of a shock persists for more than a year. For example, Dercon, Hoddinott and Waldehanna [2] find that a drought that had taken place in 1999-2000 significantly lowered per capita consumption in 2004. However these studies usually only deal with consumption on an annual basis, and do not trace detailed livestock transactions during the period investigated.

5) In Zambia the crop year runs from November to October of the next year, consisting of the rainy season (November-April) and the dry season (May-October).

6) This idea follows the work of Sakurai [11], in which plot level rainfall data were collected and used as idiosyncratic shock variables.

7) The data collection has continued until November 2011, the end of 2010/11 crop year. Future work will extend the analysis by utilizing the data for the entire sample period.

8) Because the field-level rainfall is distributed in quite a small range, we do not need to consider the reverse relationship between rainfall and crop production that may be observed when rainfall is low (that is, the higher the rainfall, the more crop production).

9) Most households also keep chickens, but in this paper chickens were excluded because the value of chickens is much smaller than the value of goats and pigs.

10) The regime dummy may be endogenous due to unobservable factors such as attitude towards risks (omitted variable bias). To deal with this problem, we employ a "fixed" effect method which will be explained later.

11) Summary statistics for household characteristics used in the empirical analysis are as follows

(mean [standard deviation]): number of adult males, 1.582 [0.927]; number of adult females, 1.870 [1.002]; number of children, 3.907 [2.637]; age of household head as of October 2007, 39.452 [14.150]; education years of household head as of October 2007, 4.490 [3.256]; total area for cropping as of October 2007 in hectares, 2.853 [1.740]; value of small livestock (K10,000), 50.339 [100.280]; value of houses (K1,000,000), 0.845 [1.471]; value of productive assets (K10,000), 29.401 [51.491]; value of unproductive assets (K10,000), 34.594 [61.842]. Summary statistics for all variables used for estimation and full estimation results are available on request.

12) This construction of the categorical dependent variable makes interpretation of the estimated coefficients much easier compared with the use of actual numbers of livestock net sales. If a coefficient is positive, the probability of positive net sales must increase and that of negative net sales (or positive net purchases) must decline. Note that the estimation results essentially did not change when the actual number of net sales instead of the defined categorical variable was used as the dependent variable.

13) As for net cattle sales, the regression excludes households in regime 3 because they have no cattle to sell. On the other hand, the regression for net small livestock sales controls for households with no small livestock by including a dummy variable for them, because the transactions of small livestock are more frequent than those of cattle, and it is much easier to change livestock holding status from "no animals" to "with animals."

14) Of course, a simpler interpretation of the negative coefficient is that households experiencing a less heavy rain shock tended to sell cattle in this month. But this neither sounds very plausible nor is supported by the observations.

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