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Livestock Transactions as Coping Strategies in Zambia:New Evidence from High-Frequency Panel Data

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Livestock Transactions as Coping Strategies in Zambia: New Evidence from High-Frequency Panel Data

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Abstract

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 by existing literature may miss the period-dependent transactions of assets after a shock.

Keywords: Asset smoothing; Buffer stock; Weather risk; Livestock; Sub-Saharan Africa

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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 [9]; 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 livestock sales in Burkina Faso offset 15-30% (at most) of crop income shortfalls during severe drought years in the 1980s, although the majority of surveyed households still held livestock at the end of the drought.

One possible explanation for the disagreement among studies 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] used data from Zimbabwe, and Kazianga and Udry [6], and Lybbert and Carter [8] used the same Burkina data that Fafchamps, Udry and Czukas [3] had used. Among them, Lybbert and Carter [8] directly estimated a dynamic asset threshold that divides asset smoothers and consumption smoothers (i.e. those who use assets as buffer stock) by using sample splitting techniques, and provided empirical evidence of wealth-differentiated smoothing tendencies. This research suggests 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.

However, a major limitation of existing literature investigating the buffer stock or asset smoothing hypothesis is that their methods depend on annual panel data, whereby a production shock is assumed to occur at the beginning of a harvest year (as an initial condition) and the responses to the shock manifest within the same harvest year.[1)] This assumption is mainly a product of the limitations of available data, but the issue is that it 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. 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.[4)]

Therefore, the objective of this study is to fill the gap in existing literature and shed new light on the buffer stock hypothesis. Considering that the gap is due to the use of annual data, this paper uses monthly panel data collected over two years from agricultural households. This data includes not only detailed livestock transactions, but also household-level shocks in each month.

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-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 are: 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 1. 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 1, 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 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 incurred 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 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 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 incurred 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.

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 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.

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 taking 1 if at least one household i's member becomes sick in time t, and SC_{it} is a dummy variable taking 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 1, 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 previous section), a variable for "regimes" is included to control for the household-specific, time-varying status of cattle holdings. The variable for the regime j (R_{it}^{j}, where j = 1, 2, and 3) is a dummy variable taking 1 if household i is in regime j in time t, which is determined by the number of cattle in the previous period (t-1).

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.

$$NS_{it} = \sum_{j=1}^{3}\sum_{t=1}^{24} \alpha_t^j \left(R_{it}^j \times D7RainDev_i \times Month_t\right) + \sum_{t=1}^{24} \beta_t \, Month_t + \sum_{v} \beta_v \, Loc_v + \sum_{j=1}^{3} \delta^j \left(R_{it}^j \times IShock_{it}\right) + \mu X_{iy} + \omega_{it} \quad (1),$$

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 [10]), and total area for cropping (ha) in crop year y, because the magnitude of the heavy rain shock might depend on land area.

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}.[10)]

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

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. Table A1 in Appendix provides summary statistics for the variables used in the empirical analysis.

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.[11)] 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 of 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 addition, the coefficient of the dummy variable for illness for regime 1 is significantly positive, suggesting that small livestock were used to meet cash needs for family illness. In contrast, none of the idiosyncratic shocks had significant impacts on small livestock transactions among households with fewer cattle (i.e., regimes 2 and 3).

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 supportive 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. [12]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. 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.[13)] According to our own field observations, asset-rich households could purchase 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, 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.

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. [14]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. Moreover, households 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 well as among households without productive assets.

As for regime 2 (asset-poor households), unexpected coefficients were obtained, 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. That is, among regime 2, those who experienced a more severe shock (i.e. heavier rainfall) sold cattle immediately after the shock, as shown in Table 7, while those who had a smaller shock (i.e. less rainfall) could manage without immediate sales of cattle, but started selling small livestock one year after the shock. As shown in Table 5, households in regime 2 did not have a large number of livestock, and the analyses in Table 8 suggest that the use of livestock as buffer stock depends on the magnitude of the shock. 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 by 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 includes 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 less 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 been unable to fully resolve the complexities of coping strategies against environmental shocks in rural Zambia. First, this paper does not identify how much the liquidation of livestock mitigates income shock and smoothes consumption. Second, the effects of 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 by existing literature may miss the period-dependent transactions of assets after a shock, and thus underestimate the total impact of a negative shock.

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Footnotes

1) Harvest year is commonly used in the literature on West Africa Semi-arid Tropics. Harvest year assumes that harvest is done instantly at the end of each harvest year, and the next harvest year starts with all of the harvest of the previous year at hand.

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.

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] 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 actual number of net sales instead of the defined categorical variable was used as the dependent variable.

[11] See Table A2 for the full estimation result. 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."

[12] See Table A3 for the full estimation result.

[13] 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.

[14] See Table A4 for the full estimation result.

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	1525	102	0.067	1699	1313	48
2008/09	1358	72	0.053	1519	1166	48
December 2007	801	84	0.104	942	627	48

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	1066	654	4.96	0.0604
Insect infestation: dummy variable taking 1 when it is observed in the field	1066	147	2.23	

Source: Household survey data, Resilience Project.

Note: The correlation between the two dummy variables is low and not statistically significant at $p<0.1$.

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	1828572	626867	353959	410408	3219807
	Percent to total value	56.8%	19.5%	11.0%	12.7%	100.0%
	Std. Dev	2575123	1248932	637269	743368	4162403
	Median	735188	193741	194336	137875	1947248
2008/09	Mean	1458048	423848	217900	266463	2366259
	Percent to total value	61.6%	17.9%	9.2%	11.3%	100.0%
	Std. Dev	1714186	828163	362591	483329	2714883
	Median	558423	141248	93964	176104	1502814
2009/10	Mean	1800056	315681	374467	388004	2878208
	Percent to total value	62.5%	11.0%	13.0%	13.5%	100.0%
	Std. Dev	2489301	338459	515152	559912	3400381
	Median	447834	227933	219310	166844	1199503

Source: Household survey data, Resilience Project.

Note: The values are in Kwacha, deflated by the local food price index obtained from the household survey data.

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.

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	9.67	4.90	7.81
	Standard deviation	14.96	6.28	10.93
	Median	2	2	3
	Minimum	0	0	0
	Maximum	54	20	37
Total number of households		15	10	21

Source: Household survey data, Resilience Project.

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 ($D7RainDev_i$)	0.0003	0.0007	0.0043*	-0.0015	0.0019
	[0.0029]	[0.0030]	[0.0023]	[0.0023]	[0.0024]
Illness of Household Members (IL_{it})	0.1489	-0.0595	0.3178*	0.0856	0.1977
	[0.2010]	[0.2538]	[0.1699]	[0.2406]	[0.1531]
Insect Infestation (SC_{it})	-0.0935	-0.0524	0.1915	-0.1040	-0.3240
	[0.2357]	[0.6267]	[0.2146]	[0.3371]	[0.2087]
Aggregate shock					
Time dummies	YES		YES		
Category Threshold 1	-1.8929***		-1.5944***		
	[0.5329]		[0.4701]		
Category Threshold 2	2.3959***		2.0877***		
	[0.5109]		[0.4812]		
Log pseudolikelihood	-146.03		-398.71		
Chi-square statistic	Chi (43) 115.78		Chi (65) 185.73		
Level of significance	0.00		0.00		
LR test for "fixed effects"	8.98		52.42***		
Number of observations	591		1066		

[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, regime dummy variables, 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.

Table 7. Effect of Heavy Rain Shock on Net Cattle Sales[1]

Explanatory Variables[2]	Dependent Variable: Net Sales Category of Cattle					
	Idiosyncratic Shocks				Aggregate Shocks (time dummies)	
	Regime 1		*Regime 2*			
	Parameter estimates	Standard errors	Parameter estimates	Standard errors	Parameter estimates	Standard errors
Rainfall in December 2007 × Time Dummies						
Jan-08	0.0012	[0.0031]	0.0005	[0.0033]	REFERENCE	
Feb-08	-0.0048	[0.0050]	0.0082*	[0.0045]	0.9350***	[0.3220]
Mar-08	0.0003	[0.0031]	-0.0019	[0.0031]	0.3756	[0.2754]
Apr-08	0.0004	[0.0030]	-0.0020	[0.0033]	0.4026	[0.2678]
May-08	0.0048	[0.0039]	-0.0025	[0.0036]	1.0627**	[0.4580]
Jun-08	-0.0050	[0.0045]	-0.0014	[0.0050]	-0.2534	[0.4683]
Jul-08	-0.0089*	[0.0052]	-0.0026	[0.0043]	0.0132	[0.4139]
Aug-08	0.0013	[0.0028]	-0.0022	[0.0035]	0.4800*	[0.2847]
Sep-08	-0.0007	[0.0029]	-0.0022	[0.0039]	0.3479	[0.2768]
Oct-08	0.0083	[0.0083]	-0.0029	[0.0035]	0.7897	[0.4921]
Nov-08	-0.0003	[0.0067]	-0.0038	[0.0036]	1.2280**	[0.4771]
Dec-08	0.0021	[0.0029]	-0.0028	[0.0041]	-0.1493	[0.4067]
Jan-09	0.0082**	[0.0040]	0.0006	[0.0042]	0.4666	[0.5225]
Feb-09	0.0004	[0.0028]	-0.0023	[0.0033]	0.3378	[0.2548]
Mar-09	0.0010	[0.0049]	0.0005	[0.0043]	1.1579***	[0.4384]
Apr-09	0.0022	[0.0031]	-0.0035	[0.0040]	-0.0886	[0.4126]
May-09	-0.0046	[0.0038]	-0.0004	[0.0034]	0.6171*	[0.3301]
Jun-09	0.0026	[0.0029]	-0.0078	[0.0066]	-0.1820	[0.4367]
Jul-09	0.0005	[0.0053]	0.0268**	[0.0121]	0.9191	[0.6250]
Aug-09	-0.0050	[0.0052]	0.0231*	[0.0131]	0.2634	[0.6084]
Sep-09	-0.0061	[0.0041]	0.0024	[0.0048]	0.8803**	[0.3914]
Oct-09	0.0068*	[0.0041]	0.0030	[0.0056]	-0.4034	[0.3554]
Nov-09	0.0110**	[0.0044]	-0.0016	[0.0038]	0.1019	[0.3083]
Dec-09	-0.0002	[0.0027]	0.0006	[0.0034]	0.3640	[0.2724]
Illness (IL_{it})	0.0157	[0.2294]	-0.2048	[0.2583]		
Insect Infestation (SC_{it})	-0.1768	[0.2396]	0.5721	[0.5205]		
Category Threshold 1	-1.9132*** [0.5184]					
Category Threshold 2	2.7064*** [0.4974]					
Log pseudolikelihood	-131.20					
Chi-square statistic	Chi(89) 138.94					
Level of significance	0.00					
LR test for "fixed effects"	6.45					
Number of observations	591					

[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, regime dummy variables, and location dummy variables.

Table 8. Effect of Heavy Rain Shock on Net Small Livestock Sales[1]

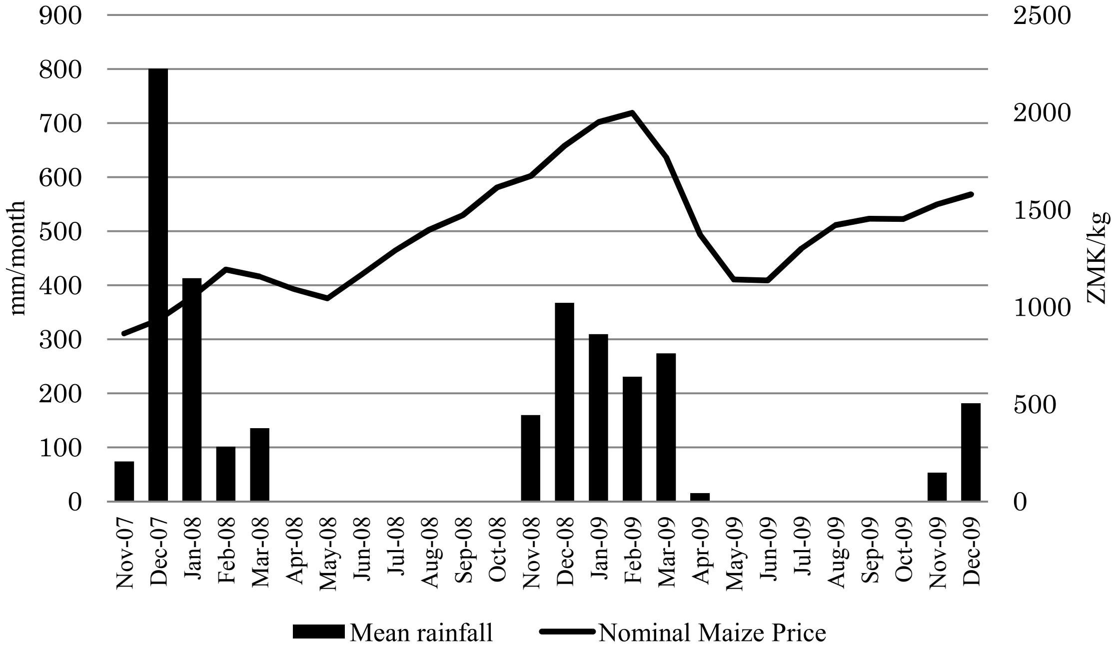
Explanatory Variables[2]	Dependent Variable: Net Sales Category of Small Livestock							
	Idiosyncratic Shocks						Aggregate Shocks (time dummies)	
	Regime 1		*Regime 2*		*Regime 3*			
	Parameter estimates	Standard errors	Parameter estimates	Standard errors	Parameter estimates	Standard errors	Parameter estimates	Standard errors
Rainfall in December 2007 × Time Dummies								
Jan-08	0.0059	[0.0047]	-0.0017	[0.0028]	-0.0015	[0.0034]	REFERENCE	
Feb-08	0.0064*	[0.0038]	-0.0003	[0.0026]	-0.00004	[0.0032]	0.1645	[0.3235]
Mar-08	0.0090*	[0.0047]	0.0016	[0.0025]	0.0003	[0.0027]	0.1691	[0.2950]
Apr-08	0.0108***	[0.0039]	0.0020	[0.0033]	0.0054**	[0.0027]	-0.1742	[0.3716]
May-08	-0.0011	[0.0041]	0.0009	[0.0030]	0.0027	[0.0025]	0.0315	[0.3245]
Jun-08	0.0065	[0.0046]	0.0017	[0.0031]	-0.0046	[0.0057]	-0.2007	[0.3883]
Jul-08	0.0076	[0.0049]	0.0020	[0.0028]	0.0026	[0.0029]	0.4402	[0.3769]
Aug-08	0.0025	[0.0042]	0.0044	[0.0032]	0.0072*	[0.0040]	0.2283	[0.3976]
Sep-08	0.0041	[0.0052]	-0.0068	[0.0071]	-0.0062	[0.0048]	0.0524	[0.3583]
Oct-08	0.0072	[0.0045]	0.0021	[0.0035]	0.00001	[0.0029]	0.2422	[0.3807]
Nov-08	0.0057	[0.0040]	0.0031	[0.0038]	0.0033	[0.0027]	0.1666	[0.3298]
Dec-08	0.0009	[0.0047]	-0.0098*	[0.0054]	0.0009	[0.0033]	0.3864	[0.4237]
Jan-09	0.0045	[0.0056]	-0.0099*	[0.0051]	-0.0017	[0.0061]	0.4315	[0.3960]
Feb-09	-0.0024	[0.0042]	-0.0137***	[0.0050]	0.0040	[0.0067]	0.3873	[0.4249]
Mar-09	-0.0012	[0.0043]	-0.0033	[0.0059]	0.0013	[0.0055]	0.2585	[0.3679]
Apr-09	0.0007	[0.0036]	-0.0007	[0.0039]	0.0108*	[0.0057]	-0.1038	[0.3601]
May-09	0.0026	[0.0038]	-0.0030	[0.0039]	0.0028	[0.0029]	-0.1365	[0.3735]
Jun-09	0.0054	[0.0049]	-0.0012	[0.0070]	0.0071**	[0.0033]	-0.1416	[0.5116]
Jul-09	0.0017	[0.0038]	-0.0087	[0.0093]	0.0029	[0.0027]	0.2135	[0.3732]
Aug-09	0.0055*	[0.0030]	-0.0042	[0.0058]	0.0021	[0.0024]	-0.2359	[0.3164]
Sep-09	0.0079*	[0.0041]	-0.0104	[0.0065]	0.0034	[0.0045]	0.1051	[0.3800]
Oct-09	-0.0023	[0.0042]	-0.0110*	[0.0058]	-0.0011	[0.0029]	0.0257	[0.3821]
Nov-09	0.0009	[0.0039]	-0.0026	[0.0035]	-0.0008	[0.0028]	0.2432	[0.3298]
Dec-09	0.0109*	[0.0065]	-0.0112**	[0.0054]	0.0031	[0.0034]	0.1954	[0.3511]
Illness (IL_{it})	0.2866	[0.1869]	0.1933	[0.2662]	0.2256	[0.1695]		
Insect Infestation (SC_{it})	0.3149	[0.2186]	-0.2360	[0.2843]	-0.4656**	[0.2291]		
Category Threshold 1	-1.4288*** [0.5159]							
Category Threshold 2	2.4052*** [0.5244]							
Log pseudolikelihood	-378.97							
Chi-square statistic	Chi(134) 270.19							
Level of significance	0.00							
LR test for "fixed effects"	47.57***							
Number of observations	1066							

[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, regime dummy variables, location dummy variables, and within-group means of demographic and idiosyncratic shock variables.

Figure 1. Monthly Precipitation and Local Maize Price at the Study Site



Source: Household survey data, Resilience Project.

Appendix

Table A1. Summary statistics of empirical variables used in regression analysis

Variable	Obs	Mean	Std. Dev.	Min	Max
Dependent variables					
Net sales of category of cattle (1=net purchase;2=no transaction; 3=net sale)	1066	1.997	0.196	1	3
Net sales of category of small livestock (1=net purchase;2=no transaction; 3=net sale)	1066	2.056	0.353	1	3
Independent variables					
Shock variables					
Rainfall deviation from the sample mean ($D7RainDev_i$)	1066	-3.315	82.155	-173.588	140.913
Dummy for illness of household members (IL_{it})	1066	0.614		0	1
Dummy for insect infestation (SC_{it})	1066	0.138		0	1
Regime dummy variables					
Regime dummy (regime 1)	1066	0.410		0	1
Regime dummy (regime 2)	1066	0.144		0	1
Regime dummy (regime 3)	1066	0.446		0	1
Dummy for households with no small stock	1066	0.303		0	1
Household characteristics					
Number of adult males	1066	1.583	0.927	0	5
Number of adult females	1066	1.869	1.002	0	7
Number of children	1066	3.913	2.637	1	13
Age of HH head as of October, 2007	1066	39.407	14.125	23	77
Education level of HH head(years) as of October, 2007	1066	4.498	3.253	0	12
Total area for cropping (ha) as of October, 2007	1066	2.856	1.741	0.25	7.75
Number of Cattle	1066	2.712	3.510	0	17
Value of small livestock (10,000ZMK)	1066	50.365	100.361	0	643.29
Value of houses (1,000,000ZMK)	1066	0.845	1.472	0	11.69
Value of productive assets (10,000ZMK)	1066	29.429	51.531	0	298.83
Value of durable assets (10,000ZMK)	1066	34.659	61.881	0	444.16

(continued)

Table A1 (continued).
Summary statistics of empirical variables used in regression analysis

Variable	Obs	Mean	Std. Dev.	Min	Max
Time dummy variables					
Dummy for January 2008	1066	0.042		0	1
Dummy for February 2008	1066	0.042		0	1
Dummy for March 2008	1066	0.042		0	1
Dummy for April 2008	1066	0.042		0	1
Dummy for May 2008	1066	0.042		0	1
Dummy for June 2008	1066	0.039		0	1
Dummy for July 2008	1066	0.039		0	1
Dummy for August 2008	1066	0.036		0	1
Dummy for September 2008	1066	0.042		0	1
Dummy for October 2008	1066	0.042		0	1
Dummy for November 2008	1066	0.044		0	1
Dummy for December 2008	1066	0.044		0	1
Dummy for January 2009	1066	0.043		0	1
Dummy for February 2009	1066	0.043		0	1
Dummy for March 2009	1066	0.043		0	1
Dummy for April 2009	1066	0.043		0	1
Dummy for May 2009	1066	0.043		0	1
Dummy for June 2009	1066	0.037		0	1
Dummy for July 2009	1066	0.037		0	1
Dummy for August 2009	1066	0.040		0	1
Dummy for September 2009	1066	0.043		0	1
Dummy for October 2009	1066	0.043		0	1
Dummy for November 2009	1066	0.043		0	1
Dummy for December 2009	1066	0.043		0	1
Location dummy variables					
Location dummy (location A)	1066	0.309		0	1
Location dummy (location B)	1066	0.352		0	1
Location dummy (location C)	1066	0.340		0	1

Table A2. Effect of Heavy Rainfall Shock on Net Livestock Sales, January 2008- December 2009 (full result)[1]

	Net Sales Category			
	Cattle		Small Livestock	
	Parameter estimates	Standard errors	Parameter estimates	Standard errors
Interaction terms between Regime 1 dummy and shock variables				
Rainfall in December 2007 ($D7RainDev_i$)	0.0003	[0.0029]	0.0043*	[0.0023]
Illness of Household Members (IL_{it})	0.1489	[0.2010]	0.3178*	[0.1699]
Insect Infestation (SC_{it})	-0.0935	[0.2357]	0.1915	[0.2146]
Interaction terms between Regime 2 dummy and shock variables				
Rainfall in December 2007 ($D7RainDev_i$)	0.0007	[0.0030]	-0.0015	[0.0023]
Illness of Household Members (IL_{it})	-0.0595	[0.2538]	0.0856	[0.2406]
Insect Infestation (SC_{it})	-0.0524	[0.6267]	-0.1040	[0.3371]
Interaction terms between Regime 3 dummy and shock variables				
Rainfall in December 2007 ($D7RainDev_i$)			0.0019	[0.0024]
Illness of Household Members (IL_{it})			0.1977	[0.1531]
Insect Infestation (SC_{it})			-0.3240	[0.2087]
Regime dummy				
Regime 1 dummy	-0.0567	[0.3015]	-0.0206	[0.2968]
Regime 2 dummy			-0.2433	[0.2645]
Dummy for households with no small stock			-0.7152***	[0.1400]
Household characteristics				
Number of adult males	-0.1127	[0.0861]	0.1259	[0.1094]
Number of adult females	0.0140	[0.0665]	-0.2887***	[0.0867]
Number of children	-0.0057	[0.0299]	-0.1321**	[0.0625]
Age of HH head as of October, 2007	0.0057	[0.0062]	0.0102**	[0.0041]
Education level of HH head(years) as of October, 2007	0.0377*	[0.0213]	0.0319*	[0.0184]
Total area for cropping (ha) as of October, 2007	-0.0754	[0.0613]	0.0514	[0.0425]
Number of Cattle	0.0381	[0.0315]	-0.0108	[0.0322]
Value of small livestock (10,000ZMK)	0.0017*	[0.0009]	-0.0001	[0.0008]
Value of houses (1,000,000ZMK)	-0.0947	[0.0646]	0.1226**	[0.0606]
Value of productive assets (10,000ZMK)	0.0025	[0.0022]	-0.0075***	[0.0025]
Value of durable assets (10,000ZMK)	-0.0026*	[0.0014]	-0.0022	[0.0022]
Time dummies				
Dummy for February 2008	1.1569***	[0.3489]	0.1716	[0.2643]
Dummy for March 2008	0.3066	[0.2368]	0.1364	[0.2773]
Dummy for April 2008	0.3484	[0.2395]	-0.1568	[0.3315]
Dummy for May 2008	0.7760*	[0.3994]	0.1821	[0.2857]
Dummy for June 2008	-0.0986	[0.4113]	-0.1630	[0.3517]
Dummy for July 2008	0.3990	[0.5137]	0.4310	[0.3512]
Dummy for August 2008	0.3868	[0.2519]	0.3185	[0.3392]
Dummy for September 2008	0.3033	[0.2479]	0.1433	[0.3546]
Dummy for October 2008	0.2680	[0.6473]	0.2490	[0.3482]

(continued)

Table A2 (continued). Effect of Heavy Rainfall Shock on Net Livestock Sales, January 2008- December 2009 (full result)

	Parameter estimates	Standard errors	Parameter estimates	Standard errors
Dummy for November 2008	0.9822**	[0.3988]	0.2130	[0.2847]
Dummy for December 2008	-0.1030	[0.3722]	0.4974	[0.3775]
Dummy for January 2009	0.3411	[0.5198]	0.4790	[0.3592]
Dummy for February 2009	0.3005	[0.2303]	0.6071*	[0.3667]
Dummy for March 2009	0.9407**	[0.3886]	0.3843	[0.3383]
Dummy for April 2009	-0.0370	[0.3776]	0.0697	[0.3327]
Dummy for May 2009	0.6873*	[0.3803]	-0.0301	[0.3198]
Dummy for June 2009	-0.0728	[0.3957]	-0.0794	[0.4212]
Dummy for July 2009	0.3922	[0.6463]	0.3617	[0.3147]
Dummy for August 2009	0.1475	[0.5760]	-0.1322	[0.2740]
Dummy for September 2009	1.0078**	[0.4090]	0.1981	[0.3438]
Dummy for October 2009	-0.5215	[0.3718]	0.2009	[0.3598]
Dummy for November 2009	-0.2924	[0.3861]	0.3312	[0.2954]
Dummy for December 2009	0.3642	[0.2508]	0.2240	[0.3600]
Location dummies				
Location B dummy	-0.1759	[0.3568]	0.2043	[0.2599]
Location C dummy	-0.2197	[0.6035]	0.5598	[0.4134]
Within-group means for a "fixed" effect estimation				
Regime 1 dummy			-2.3575***	[0.6185]
Regime 2 dummy			-0.2504	[0.8590]
Dummy for households with no small stock			0.4019	[0.2886]
Number of adult males			-0.1439	[0.1285]
Number of adult females			0.3507***	[0.1125]
Number of children			0.2236***	[0.0722]
Number of Cattle			0.1850***	[0.0603]
Value of small livestock (10,000ZMK)			0.0010	[0.0011]
Value of houses (1,000,000ZMK)			-0.2398**	[0.1020]
Value of productive assets (10,000ZMK)			0.0085**	[0.0036]
Value of durable assets (10,000ZMK)			-0.0015	[0.0030]
Interaction term between illness dummy and regime 1 dummy			0.5338	[0.7754]
Interaction term between illness dummy and regime 2 dummy			-1.7774	[1.4298]
Interaction term between illness dummy and regime 3 dummy			-1.3992**	[0.6103]
Interaction term between insect infestation dummy and regime 1 dummy			-0.3737	[0.8433]
Interaction term between insect infestation dummy and regime 2 dummy			5.8549***	[2.2724]
Interaction term between insect infestation dummy and regime 3 dummy			-0.5706	[0.7808]
Category Threshold 1	-1.8020***	[0.5329]	-1.5461***	[0.4226]
Category Threshold 2	2.3959***	[0.5109]	2.1361***	[0.4329]
Log pseudolikelihood	-146.03		-398.71	
Chi-square statistic	Chi (43) 115.78		Chi (65) 185.73	
Level of significance	0.00		0.00	
LR test for "fixed effects"	8.98		52.42***	
Number of observations	591		1066	

[1] 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. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A3. Effect of Heavy Rain Shock on Net Cattle Sales (full result)[1]

Explanatory Variables	Dependent Variable: Net Sales Category of Cattle					
	Idiosyncratic Shocks				Aggregate Shocks (time dummies)	
	Regime 1		*Regime 2*			
	Parameter estimates	Standard errors	Parameter estimates	Standard errors	Parameter estimates	Standard errors
Rainfall in December 2007 × Time Dummies						
Jan-08	0.0012	[0.0031]	0.0005	[0.0033]	REFERENCE	
Feb-08	-0.0048	[0.0050]	0.0082*	[0.0045]	0.9350***	[0.3220]
Mar-08	0.0003	[0.0031]	-0.0019	[0.0031]	0.3756	[0.2754]
Apr-08	0.0004	[0.0030]	-0.002	[0.0033]	0.4026	[0.2678]
May-08	0.0048	[0.0039]	-0.0025	[0.0036]	1.0627**	[0.4580]
Jun-08	-0.005	[0.0045]	-0.0014	[0.0050]	-0.2534	[0.4683]
Jul-08	-0.0089*	[0.0052]	-0.0026	[0.0043]	0.0132	[0.4139]
Aug-08	0.0013	[0.0028]	-0.0022	[0.0035]	0.4800*	[0.2847]
Sep-08	-0.0007	[0.0029]	-0.0022	[0.0039]	0.3479	[0.2768]
Oct-08	0.0083	[0.0083]	-0.0029	[0.0035]	0.7897	[0.4921]
Nov-08	-0.0003	[0.0067]	-0.0038	[0.0036]	1.2280**	[0.4771]
Dec-08	0.0021	[0.0029]	-0.0028	[0.0041]	-0.1493	[0.4067]
Jan-09	0.0082**	[0.0040]	0.0006	[0.0042]	0.4666	[0.5225]
Feb-09	0.0004	[0.0028]	-0.0023	[0.0033]	0.3378	[0.2548]
Mar-09	0.001	[0.0049]	0.0005	[0.0043]	1.1579***	[0.4384]
Apr-09	0.0022	[0.0031]	-0.0035	[0.0040]	-0.0886	[0.4126]
May-09	-0.0046	[0.0038]	-0.0004	[0.0034]	0.6171*	[0.3301]
Jun-09	0.0026	[0.0029]	-0.0078	[0.0066]	-0.182	[0.4367]
Jul-09	0.0005	[0.0053]	0.0268**	[0.0121]	0.9191	[0.6250]
Aug-09	-0.005	[0.0052]	0.0231*	[0.0131]	0.2634	[0.6084]
Sep-09	-0.0061	[0.0041]	0.0024	[0.0048]	0.8803**	[0.3914]
Oct-09	0.0068*	[0.0041]	0.003	[0.0056]	-0.4034	[0.3554]
Nov-09	0.0110**	[0.0044]	-0.0016	[0.0038]	0.1019	[0.3083]
Dec-09	-0.0002	[0.0027]	0.0006	[0.0034]	0.364	[0.2724]
Illness (IL_{it})	0.0157	[0.2294]	-0.2048	[0.2583]		
Insect Infestation (SC_{it})	-0.1768	[0.2396]	0.5721	[0.5205]		

Other explanatory variables	Parameter [Standard errors]
Regime dummy	
Regime 1 dummy	-0.0876 [0.3199]
Household characteristics	
Number of adult males	-0.1271 [0.0923]
Number of adult females	0.0227 [0.0704]
Number of children	-0.0088 [0.0313]
Age of HH head as of October, 2007	0.0078 [0.0059]
Education level of HH head(years) as of October, 2007	0.0601***[0.0212]

(continued)

Table A3 (continued).
Effect of Heavy Rain Shock on Net Cattle Sales (full result)

	Parameter [Standard errors]
Total area for cropping (ha) as of October, 2007	-0.0896 [0.0668]
Number of Cattle	0.0446 [0.0315]
Value of small livestock (10,000ZMK)	0.0022**[0.0010]
Value of houses (1,000,000ZMK)	-0.0929 [0.0666]
Value of productive assets (10,000ZMK)	0.0022 [0.0023]
Value of durable assets (10,000ZMK)	-0.0034**[0.0015]
Location dummies	
Location B dummy	-0.1901 [0.3655]
Location C dummy	-0.1381 [0.5896]
Category Threshold 1	-1.9132*** [0.5184]
Category Threshold 2	2.7064*** [0.4974]
Log pseudolikelihood	-131.2
Chi-square statistic	Chi(89) 138.94
Level of significance	0.00
LR test for "fixed effects"	6.45
Number of observations	591

[1] 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.

Table A4. Effect of Heavy Rain Shock on Net Small Livestock Sales (full result)[1]

Explanatory Variables	Dependent Variable: Net Sales Category of Small Livestock							
	Idiosyncratic Shocks						Aggregate Shocks (time dummies)	
	Regime 1		*Regime 2*		*Regime 3*			
	Parameter estimates	Standard errors	Parameter estimates	Standard errors	Parameter estimates	Standard errors	Parameter estimates	Standard errors
Rainfall in December 2007 × Time Dummies								
Jan-08	0.0059	[0.0047]	-0.0017	[0.0028]	-0.0015	[0.0034]	REFERENCE	
Feb-08	0.0064*	[0.0038]	-0.0003	[0.0026]	0.0000	[0.0032]	0.1645	[0.3235]
Mar-08	0.0090*	[0.0047]	0.0016	[0.0025]	0.0003	[0.0027]	0.1691	[0.2950]
Apr-08	0.0108***	[0.0039]	0.0020	[0.0033]	0.0054**	[0.0027]	-0.1742	[0.3716]
May-08	-0.0011	[0.0041]	0.0009	[0.0030]	0.0027	[0.0025]	0.0315	[0.3245]
Jun-08	0.0065	[0.0046]	0.0017	[0.0031]	-0.0046	[0.0057]	-0.2007	[0.3883]
Jul-08	0.0076	[0.0049]	0.0020	[0.0028]	0.0026	[0.0029]	0.4402	[0.3769]
Aug-08	0.0025	[0.0042]	0.0044	[0.0032]	0.0072*	[0.0040]	0.2283	[0.3976]
Sep-08	0.0041	[0.0052]	-0.0068	[0.0071]	-0.0062	[0.0048]	0.0524	[0.3583]
Oct-08	0.0072	[0.0045]	0.0021	[0.0035]	0.0000	[0.0029]	0.2422	[0.3807]
Nov-08	0.0057	[0.0040]	0.0031	[0.0038]	0.0033	[0.0027]	0.1666	[0.3298]
Dec-08	0.0009	[0.0047]	-0.0098*	[0.0054]	0.0009	[0.0033]	0.3864	[0.4237]
Jan-09	0.0045	[0.0056]	-0.0099*	[0.0051]	-0.0017	[0.0061]	0.4315	[0.3960]
Feb-09	-0.0024	[0.0042]	-0.0137***	[0.0050]	0.0040	[0.0067]	0.3873	[0.4249]
Mar-09	-0.0012	[0.0043]	-0.0033	[0.0059]	0.0013	[0.0055]	0.2585	[0.3679]
Apr-09	0.0007	[0.0036]	-0.0007	[0.0039]	0.0108*	[0.0057]	-0.1038	[0.3601]
May-09	0.0026	[0.0038]	-0.0030	[0.0039]	0.0028	[0.0029]	-0.1365	[0.3735]
Jun-09	0.0054	[0.0049]	-0.0012	[0.0070]	0.0071**	[0.0033]	-0.1416	[0.5116]
Jul-09	0.0017	[0.0038]	-0.0087	[0.0093]	0.0029	[0.0027]	0.2135	[0.3732]
Aug-09	0.0055*	[0.0030]	-0.0042	[0.0058]	0.0021	[0.0024]	-0.2359	[0.3164]
Sep-09	0.0079*	[0.0041]	-0.0104	[0.0065]	0.0034	[0.0045]	0.1051	[0.3800]
Oct-09	-0.0023	[0.0042]	-0.0110*	[0.0058]	-0.0011	[0.0029]	0.0257	[0.3821]
Nov-09	0.0009	[0.0039]	-0.0026	[0.0035]	-0.0008	[0.0028]	0.2432	[0.3298]
Dec-09	0.0109*	[0.0065]	-0.0112**	[0.0054]	0.0031	[0.0034]	0.1954	[0.3511]
Illness (IL_{it})	0.2866	[0.1869]	0.1933	[0.2662]	0.2256	[0.1695]		
Insect Infestation (SC_{it})	0.3149	[0.2186]	-0.2360	[0.2843]	-0.4656**	[0.2291]		
Illness ($\overline{IL_i}$)	0.7340	[0.7855]	-2.7905*	[1.5056]	-1.6075**	[0.6382]		
Insect Infestation ($\overline{SC_i}$)	-0.2985	[0.8502]	6.3044***	[2.2656]	-0.3990	[0.8019]		

Other explanatory variables	Parameter [Standard errors]
Regime dummy	
Regime 1 dummy	-0.0213 [0.3267]
Regime 2 dummy	-0.4121 [0.2940]
Dummy for households with no small stock	-0.7158***[0.1495]

(continued)

Table A4 (continued).
Effect of Heavy Rain Shock on Net Small Livestock Sales (full result)

Other explanatory variables	Parameter [Standard errors]
Household characteristics	
Number of adult males	0.1151 [0.1098]
Number of adult females	-0.2517***[0.0952]
Number of children	-0.1309**[0.0648]
Age of HH head as of October, 2007	0.0114***[0.0041]
Education level of HH head(years) as of October, 2007	0.0275 [0.0187]
Total area for cropping (ha) as of October, 2007	0.0565 [0.0433]
Number of Cattle	0.0001 [0.0361]
Value of small livestock (10,000ZMK)	-0.0002 [0.0009]
Value of houses (1,000,000ZMK)	0.1435**[0.0645]
Value of productive assets (10,000ZMK)	-0.0066**[0.0026]
Value of durable assets (10,000ZMK)	-0.0016 [0.0022]
Location dummies	
Location B dummy	0.2102 [0.2637]
Location C dummy	0.5444 [0.4141]
Within-group means for a "fixed" effect estimation	
Regime 1 dummy	-2.7089***[0.6396]
Regime 2 dummy	0.1430 [0.8848]
Dummy for households with no small stock	0.4109 [0.3056]
Number of adult males	-0.1146 [0.1288]
Number of adult females	0.3174*** [0.1196]
Number of children	0.2267*** [0.0747]
Age of HH head as of October, 2007	-0.2728*** [0.1054]
Education level of HH head(years) as of October, 2007	0.0011 [0.0012]
Total area for cropping (ha) as of October, 2007	0.0078**[0.0036]
Number of Cattle	0.1867***[0.0615]
Value of small livestock (10,000ZMK)	-0.2728***[0.1054]

(continued)

Table A4 (continued).
Effect of Heavy Rain Shock on Net Small Livestock Sales (full result)

Other explanatory variables	Parameter [Standard errors]
Value of houses (1,000,000ZMK)	-0.0020 [0.0030]
Value of productive assets (10,000ZMK)	0.0011 [0.0012]
Value of durable assets (10,000ZMK)	0.0078**[0.0036]
Category Threshold 1	-1.4288*** [0.5159]
Category Threshold 2	2.4052*** [0.5244]
Log pseudolikelihood	-378.97
Chi-square statistic	Chi(134) 270.19
Level of significance	0.00
LR test for "fixed effects"	47.57***
Number of observations	1066

[1] 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.