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# When shocks become persistent: Household-level asset growth in the aftermath of an extreme weather event☆

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**Abstract**

With the increasing frequency and intensity of extreme weather events due to climate change, assessing the potential long-term effects of these events for affected households is critically important. This study analyzes to what extent a one-off extreme weather event can have persistent effects on household-level asset growth. Our focus is on the effect of a once-in-50-year winter disaster on post-shock livestock accumulation among pastoralists in Mongolia. Building on a unique household panel dataset with three waves that we link to secondary climate and livestock census data, we investigate post-shock livestock dynamics 2-5 years after the disaster occurred. Using a Hausman-Taylor estimator, we show that the extreme event has a significant, negative, economically large, and persistent effect on households' asset growth rates. When analyzing potential underlying mechanisms, we find that households seek to mitigate the shock effect by reducing their livestock offtake to preserve their asset level. This effort is counteracted by a large, negative, and persistent shock effect on livestock fertility. In addition, the intensity of the extreme weather event is a strong predictor for abandoning the herding economy, which leads to lower overall welfare. Taken together, our findings suggest that most households are unable to fully offset the effects of the extreme weather event through their own herd management beha-

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vior. Findings are robust to using various measures of shock intensity derived from different data sources.

*Keywords:* Assets, extreme weather events, growth rates, post-shock recovery, Mongolia
*JEL:* O12, O13, Q5

## 1. Introduction

With climate change, extreme weather events are becoming more frequent and severe, with detrimental effects for households. Between 1995 and 2015, weather-related disasters claimed more than half a million lives and affected more than 4 billion people worldwide (United Nations Office for Disaster Risk Reduction, 2015). Storms, floods, and cold waves often cause immediate asset losses, thus reducing household welfare. In addition, the loss of productive assets may reduce a household's future consumption and income-earning potential and, thus, its future welfare. Furthermore, if the effects of extreme weather events go beyond immediate impacts on current asset levels and also affect asset growth rates, shock effects may be perpetuated. Thus, a onetime shock might have prolonged adverse consequences for welfare dynamics. Given the covariate nature of extreme weather events, informal risk sharing arrangements are often ineffective (Barnett et al., 2008). In the absence of functioning formal insurance markets, a particular concern in developing countries, households may be even more likely to tear down their asset base in order to smooth consumption in the aftermath of a shock (Zimmerman and Carter, 2003; Rosenzweig and Wolpin, 1993). Understanding the impact of extreme weather events on households is a pressing policy question, given that such events are predicted to become more frequent in the future and their consequences are felt disproportionately more in developing countries (World Bank, 2010; Seneviratne et al., 2012).

Yet, little is known about the persistence of the effects of extreme weather events on households in developing countries. The existing literature on growth effects of extreme weather events and other natural disasters is narrow and focuses mainly on the country level (Cavallo et al., 2013; Felbermayr and Gröschl, 2014; Strobl, 2012; Kellenberg and Mobarak, 2011; Loayza et al., 2012). The few existing studies taking a household-level approach document that exposure to extreme weather events and other natural disasters adversely impacts human capital accumulation, child health, remittances, and income (Caruso and Miller, 2015; Gignoux and Menéndez, 2016; Groppo and Kraehnert, 2016, 2017). However, the impact of these events on household-level growth rates – and, in particular, asset growth – is not well understood. This gap in research is surprising, given the importance of assets in shaping households' long-term welfare dynamics (Dercon et al., 2012; Carter and Barrett, 2006; Sahn and Stifel, 2003).

This study aims to address this gap in the literature by analyzing how an extreme weather event shapes households' post-shock asset growth. Furthermore, our analysis explores the mechanisms underlying the observed growth outcomes. Our focus is on pastoralist households in Mongolia that lost a significant share of their livestock when a once-in-50-year winter disaster hit the country in 2009/10. Extremely cold temperatures and excessive snowfall caused the death of more than 10 million livestock, about 23 percent of the national stock. The quasi-experimental nature of the extreme winter – referred to as *dzud* in Mongolian – makes it an interesting study setting: the shock was severe, its intensity varied strongly across space, and households could hardly predict its occurrence (Murphy, 2011). The shock had detrimental effects for many pastoralist households, for whom livestock is by far the most important asset, causing widespread poverty, malnutrition, and rural-urban migration (Sternberg, 2010). Our empirical analysis builds on three waves of a representative household panel survey that we implemented in western Mongolia between 2012 and 2015, 2-5 years after the winter disaster. The econometric analysis uses the Hausman-Taylor panel estimator, which allows us to estimate the impact of the shock while controlling for unobserved household characteristics that are potentially correlated with past and current livestock holdings.

Findings indicate that the effects of the extreme weather event are indeed persistent: Household-level asset growth rates are negatively affected by the shock even several years after its occurrence. Available disaster coping strategies and emergency aid were ineffective in mitigating the negative growth effects of the extreme weather event. Households seek to mitigate the shock effects by reducing livestock offtake to preserve their asset level. This effort is counteracted by a negative, economically large, and persistent shock effect on livestock fertility. In addition, the intensity of the extreme weather event is a strong predictor for dropping out of the herding economy, which leads to lower overall welfare. Furthermore, smaller idiosyncratic shocks have significantly weaker effects on asset growth compared to the extreme weather event, indicating that shock persistence depends both on the severity and the covariate nature of the shock. Findings are robust to using different measures of shock intensity derived from various data sources.

Our study advances the existing household-level literature on growth in developing countries in several ways. Research in this area is limited – mainly due to a lack of adequate data – and typically focusses on income or consumption as opposed to asset growth (Jalan and Ravallion, 2002; Lokshin and Ravallion, 2004; Dercon et al., 2012). Further, there is some interest in the role of risk for growth (Elbers et al., 2007). However, shock persistence is typically not accounted for in standard empirical growth models, particularly at the household level, where shocks are generally only seen as a temporary setback (see Dercon, 2004 for a discussion; Barrett et al., 2006). We add to this literature by showing both theoretically and empirically how a one-off shock can have persistent effects on household asset dynamics even years after the shock occurred. Moreover, we provide novel insights into how households reconstruct their asset base in the aftermath of a shock. So far, only a few studies unravel what strategies households apply to recover from shock-induced losses, as such strategies are seldom recorded in standard household surveys.

Moreover, our study contributes to the literature on asset-based poverty traps (e.g. Carter and Barrett, 2006; Barrett and Carter, 2013). This literature assumes that a locally positive relationship between asset holdings and marginal returns to assets exists, which implies multiple asset equilibria toward which households converge in the long term. Yet, empirical evidence for such multiple equilibria is scarce (Kraay and McKenzie, 2014). Furthermore, the small number of studies within this literature specifically exploring how shocks influence household asset dynamics are often beset with endogeneity problems caused by the nature of the shock. For instance, slow-onset, prolonged droughts cause little destruction in assets per se, but rather affect household assets indirectly through income losses (Carter et al., 2007; Giesbert and Schindler, 2012). Other studies focus on idiosyncratic shocks, such as illness and wedding expenses, which may strike some households with higher likelihood than others (Quisumbing and Baulch, 2013). In addition, most asset-based poverty traps studies mainly rely on nonparametric approaches (Carter and Barrett, 2006; Barrett and Carter, 2013; Naschold, 2012), thus leaving the underlying processes and the role of household heterogeneity unscrutinized. Our study expands this literature by documenting how household asset dynamics can be persistently shaped by a shock without requiring a framework of bifurcating asset dynamics. In addition, our focus on an extremely severe covariate shock that occurred over a short time period, immediately destroying household assets, allows for a straightforward identification of the shock effects, posing few endogeneity concerns. Moreover, the fundamental importance of livestock for the livelihood of Mongolian pastoralist as well as the ease with which it is observed greatly reduces measurement error problems inherent in studies that bundle various types of assets into one common index (Naschold, 2012; Michelson et al., 2013; McKay and Perge, 2013).

Lastly, our study contributes to the literature on welfare dynamics among pastoralists. Most existing studies are constrained by very small sample sizes, often less than 100 households (Lybbert et al., 2004; McPeak, 2006; Verpoorten, 2009). Some studies use time-series data on livestock obtained from a single survey interview during which households were asked about livestock transfers retrospectively, which renders checks on the quality of recall data difficult (e.g. Lybbert et al., 2004; McPeak, 2006). In contrast, our analysis builds on a sample of more than 850 pastoralist households that are representative of the population in the survey area. Moreover, data on livestock holdings is recorded from each household in three annual panel survey interviews in the post-shock period, while pre-shock herd size is asked retrospectively from households. This unique data allows us to observe households' asset growth over a medium-term time horizon.

The study proceeds as follows. Section 2 outlines the theoretical framework and section 3 introduces the household panel data and shock measures. Section 4 provides contextual information on the Mongolian herding economy. It then portrays the climatic conditions of the extreme winter of 2009/10 and shows that the intensity of the extreme event was the main determinant of livestock losses experienced by households. Sections 5 and 6 describe the identification strategy and the results, respectively. Section 7 concludes.

## 2. Asset growth under persistent shock effects: A theoretical framework

In this section, we propose a theoretical framework that outlines how the effects of a large covariate shock may become persistent. More specifically, the framework addresses two questions: (i) Can there be persistent effects of a large covariate shock on household-level asset growth even several years after the shock occurred; and, if so, (ii) how much of these effects is driven by a change in household behavior?[1] It seems intuitive that, in the case of serial dependence in asset growth, a shock influences the stock of assets and recovery is not immediate. However, the persistence of a shock effect on growth rates and the direction of such an effect is conceptually not straightforward.

[1]Directly and not just in expectations, as, for example, Elbers et al. (2007) analyze.

Building on standard growth and intertemporal choice models (Deaton, 1991), we set up a simple quasi-autarkic model into which we directly include asset shocks. Similar to the model of McPeak (2006), our model is tailored to the specific case of livestock, which is not just a productive asset that is an investment and saving good, but one that simultaneously determines the household's future income and consumption potential. At the same time, it is not risk free.

The capital stock (livestock) of household $i$ in period $t$ is $k_{it}$. Changes in the capital stock from one period to the next when capital is not only an investment and production but also a consumption good are brought about by three factors: natural reproduction ($r(\cdot)$), shock-induced losses ($\theta_{it}$), and active offtake ($ot_{it}$). Offtake is defined as the home consumption over the period $t-1$ to $t$. Reproduction $r(\cdot)$ of the capital stock is a function of the beginning-of-period stock ($k_{it}$) and shock effects ($\theta_{it}$).[2] The reproduction function is concave in the capital stock and bounded below by the loss of the entire herd and above by natural limits to reproduction rates.

Households can directly consume their capital without transaction costs in the form of offtake ($ot_{it}$) from their herd and consumption of livestock by-products, the production of which are a function of the capital stock and labor input:[3]

$$c_{it} = ot_{it} + f(k_{it}, l_{it}) \tag{1}$$

Given the quasi-autarkic setting, there are no alternative income-earning activities into which households can invest and capital (livestock) is the only form to store wealth.[4]

Put together, capital in our model obeys the following law of motion:

$$k_{it+1} = k_{it} + r(k_{it}, \theta_{it}) + \theta_{it} - ot_{it} \tag{2}$$

[2] Labor and land, household-specific herding skills, as well as geographic characteristics are assumed to be fixed. We abstract from those factors here but control for them in the empirical analysis below.

[3] For simplicity, we abstract from the fact that the shock may affect the production of by-products by weakening the livestock.

[4] Note the difference between the model developed here and standard buffer stock models (e.g. Fafchamps et al., 1998): Since income is derived entirely from livestock, households cannot use livestock to insure against fluctuations in income.

Thus, the shock can have both a direct effect on the beginning-of-year stock in the post-shock period as well as an indirect reproduction effect on capital in the following period. Such an effect is expected if young or female animals have a disproportionally higher mortality risk than other animals or if fertility is lower in animals weakened by the shock.

The following equation illustrates how the effects of a shock can become persistent as a result of accumulating stock and reproduction effects and their mutual feedbacks:

$$k_{it} = k_{i0} + \sum_{\tau=0}^{t-1} \theta_\tau - \sum_{\tau=0}^{t-1} ot_\tau + R(k_{i0}, \theta_{i0}, ..., \theta_{it-1}, ot_{i0}, ..., ot_{it-1}) \tag{3}$$

This is particularly likely for large covariate shocks, such as extreme weather events, which are intense and covariate, while their occurrence is difficult to predict for households. In line with Dercon (2004), if past shocks matter, then persistence is identified.

Furthermore, the household's offtake decision may also be persistently influenced by the shock experience. The following Bellman equation illustrates the household's decision problem and illustrates in which direction the shock effects could go (in line with standard notation, $\beta$ is the personal discount factor and $E$ the expectation operator):

$$V[k_{it}] \equiv \max_{ot_{it}} U(ot_{it} + f(k_{it}, l_{it})) + \beta E_t V[k_{it} + r(\cdot) + \theta_{it} - ot_{it}] \tag{4}$$

The household optimizes utility from consumption over time by choosing the optimal capital offtake. This results in the following first-order condition: $\frac{\partial U}{\partial c_{it}} = \beta E_t \frac{\partial V}{\partial k_{it+1}}$ and $\frac{\partial V}{\partial k_{it}} = \frac{\partial U}{\partial c_{it}} \cdot \frac{\partial f}{\partial k_{it}} + \beta E_t \frac{\partial V}{\partial k_{it+1}} \cdot (1 + \frac{\partial r}{\partial k_{it}})$. The former condition equates the marginal utility of one additional unit of consumption to the marginal value of keeping that unit for another period. The latter condition shows that the marginal value is equal to the contribution of the additional stock to current consumption (as livestock by-product) plus the expected discounted contribution to capital in the next period (including its contribution to herd reproduction).

Similarly, the marginal effect of a shock in the following period is $\frac{\partial V}{\partial \theta_{it}} = \beta E_t \frac{\partial V}{\partial k_{it+1}} \cdot (1 + \frac{\partial r}{\partial \theta_{it}})$ with $\frac{\partial r}{\partial \theta_{it}} > 0$ and $\frac{\partial \partial r}{\partial \partial \theta_{it}} < 0$ due to the concavity of the reproduction function. On the other hand, a shock that happened more than one period ago affects not only the value of future herd size, but also current consumption:

$\frac{\partial V}{\partial \theta_{it-1}} = \frac{\partial U}{\partial c_{it}} \cdot \frac{\partial f}{\partial k_{it}} \cdot (1 + \frac{\partial r}{\partial \theta_{it-1}}) + \beta E_t \frac{\partial V}{\partial k_{it+1}} \cdot (1 + \frac{\partial r}{\partial \theta_{it-1}})$. Thus, the shock reduces current consumption of by-products, implying increased marginal utility of current consumption. By reducing the capital stock and reproduction, the shock also increases the marginal value of keeping the livestock for the next period, thereby increasing the opportunity cost of consumption. The overall effect depends on the relative importance of the consumption motif and the asset smoothing motif. As the effect could go in either direction, it needs to be determined empirically.

Next, we relax the autarky assumption and allow for interactions between households. This has two implications. First, households can sell livestock and livestock by-products to satisfy other consumption needs and they can purchase livestock to restock their herd. This enters the model in the form of a wider offtake notion $ot_{it}$ that now comprises the combined consumption, investment, and sales decision. How would this affect the optimal offtake in response to a shock? If livestock prices were risky, the relative value of current compared to future livestock holdings and, thus, the optimal offtake at $t$ would change. If households were able to anticipate their own shock losses, we would expect a household with high predicted losses to preemptively sell its livestock, even at the cost of lower prices and returns. Households with low predicted losses would be expected to postpone sales to the post-shock period to profit from increased demand and prices. Thus, the effects of a shock on optimal offtake depend on the intensity and duration of the shock as well as the level of market integration. Second, households can transfer assets with each other in the aftermath of a shock without price intermediation, for example in the form of informal insurance arrangements. Therefore, we redefine total shock losses $\theta_{it}$ to also comprise these shock-related transfers. In turn, the effects of a covariate shock on asset growth also depends on the relative magnitude of a household's own shock losses compared to the average shock losses experienced by households in the same district, which is influenced by the nature of the shock. Total shock effects are expected to be weaker for affected households if the shock is not perfectly covariate.

From the theoretical framework, we deduct three hypotheses that are tested in the empirical part of the paper. First, both the optimal offtake decision and the natural reproduction in the post-shock period are influenced by the shock. This leads, second, to persistent effects on household-level asset growth that go beyond contemporary shock effects discussed in other studies. Third, the degree of shock persistence depends not only on the intensity of the shock, but also its covariate nature.

## 3. Data

The study builds on a novel panel dataset, the *Coping with Shocks in Mongolia Household Panel Survey*. The survey was collected by the authors and the National Statistical Office of Mongolia (NSO) between 2012 and 2015 and comprises three annual panel waves. Data collection took place in the provinces of Uvs, Zavkhan, and Govi-Altai in western Mongolia. The household survey covers 49 out of the 61 districts in the survey provinces.[5]

The survey was implemented on a rolling basis, with one twelfth of the sample households interviewed in each month. The data are also representative across seasons. Following the initial interview, each household was interviewed again exactly 12 months and 24 months later for the second and third survey waves. The first, second, and third panel waves were collected between June 2012 and May 2013, between June 2013 and May 2014, and between June 2014 and May 2015, respectively. This approach of implementing the household panel survey continuously for a total period of 36 months allowed us to employ the same field team throughout the entire survey period.

The Population and Housing Census, implemented November 11-17, 2010, provides the sampling frame. A multi-stage sampling design was employed to ensure that the survey is representative for urban areas and for rural areas in each of the three survey provinces. Each survey province was first subdivided into three mutually exclusive strata (province centers, district centers, and rural areas). From these nine strata, 221 primary sampling units (PSU, the smallest population unit in Mongolia's administrative division) were randomly drawn. Eight households were then randomly selected from each PSU.

The total sample consists of 1,768 households interviewed in the first panel wave, comprising both non-herding and herding households. The analysis of post-shock asset growth presented here builds on a subsample of 855 herding households that owned livestock in 2009, just before the extreme winter, and at the time of each panel interview. Overall, panel attrition is negligible, with less than 2.15 percent of the entire sample dropping out of the survey between the first and third panel waves.

[5] A province (*aimag*) is the top level of Mongolia's administrative structure. Each province is subdivided into several districts (*soums*), which are further subdivided in sub-districts (*bags*). There are 21 provinces, 329 districts, and 1,720 sub-districts in Mongolia. As of 2011, districts in western Mongolia have an average population of 3,154 and a size of 4,811 km$^2$.

The sample of pastoralist households reduces by 42 and 30 herding households in the second and third panel waves, respectively. The majority of those households stopped herding activities and no longer owned any livestock, while 3 and 6 households could not be reinterviewed in the second and third panel waves, respectively.

The survey consists of a household questionnaire, a district questionnaire capturing infrastructure and population characteristics, as well as a district price questionnaire. In addition to recording standard demographic and socioeconomic characteristics, the household questionnaire collects detailed information on the migration history of adult household members, including the district of birth and the district of residence just before the unfolding of the extreme winter of 2009/10. Moreover, it records the employment history of the head of household and his/her spouse as well as the occupation of the head's parents.

The questionnaire module on livestock records detailed information on households' livestock holdings at the time of each survey wave. This includes the total number of animals owned by the household, the number of reproductive female animals, and the number of newborn animals younger than one year, separately for each of the common five species (horses, cattle, camels, sheep, and goats). In addition, changes in households' livestock holdings over the past 12 months were recorded, again by species. Information is available on the number of animals purchased, sold, self-consumed by the household, received as in-kind wage income, inherited, received as remittances, sent as remittances, as well as the number of animals lost due to attacks by wild animals, livestock diseases, and theft. Currently, Mongolian pastoralists do not pay any livestock taxes. Hence, we do not expect survey respondents facing systematic incentives to underreport their true livestock holdings during the survey interview.

Another questionnaire module asked households retrospectively for their pre-shock livestock holdings (in 2009) and shock-induced losses (in 2010). This retrospective information was recorded twice, in the first panel wave and then again in the third panel wave. The livestock numbers reported by households were remarkably similar across the two waves, giving us confidence that herders have a good account of their past herd size even several years ago. However, a sizable number of households only reported livestock holdings in 2009 and/or livestock losses in 2010 in terms of total herd size, but not disaggregated by livestock species. It is common for Mongolian herders to only refer to the absolute number of livestock when speaking about herd size. This is also reflected in language: While there are specific terms in Mongolian for herders having a herd size of <100 heads, 100-200 heads, 200-500 heads, 500-1,000 heads, and >1,000 heads, all of those terms relate to total herd size, irrespective of the species (Murphy, 2011). In the Mongolian context, this is reasonable: Given the extreme remoteness of Mongolia's countryside, most herders spend many months of the year in isolated campsites. Hence, herders need to maintain a mix of several species that complement each other in terms of by-products and utility. Consequently, herd composition does not differ dramatically across pastoralist households.[6] Thus, we use total herd size – treating animals of different species as equal – in our main analysis.

We complement the household survey data with two sources of secondary data to measure spatial variation in shock intensity. First, we draw on aggregated data from the annual Mongolia Livestock Census, which has been implemented since the 1950s. Each year in mid-December, the NSO gathers data on herders' livestock holdings as well as livestock losses experienced in the past 12 months, separately for each species. This exercise is carried out collaboratively by enumerators and local officials, who maintain detailed records of herders and their livestock in their administrative division. From the Mongolia Livestock Census data, we construct aggregate measures of the mortality of adult animals in 2010 at the level of the district and the sub-district.

Second, we measure shock intensity with data on temperature from the ERA-Interim model outputs of the European Centre for Medium-Range Weather Forecasts. We use the average temperature at earth skin at midnight in each sub-district between December 20, 2009 and February 10, 2010, the time referred to as "cold period" in Mongolia. This average temperature during the 2009/10 winter is then standardized by subtracting the mean and dividing it by the standard deviation of the long-term average midnight temperature in each sub-district during the same period (mid-December until mid-February) between 1991 and 2008. We aggregate sub-district data to the district level by assigning each district the value of the sub-district with the most extreme deviation.

Furthermore, we employ district-level data on the total amount of emergency

[6]To a limited extent, local environmental conditions also affect the herd mix. For instance, herders in desert areas tend to have fewer cattle, while herders living in forest and mountain areas tend to have fewer camels. We control for the impact of environmental conditions in the empirical analyses presented below with either district-level controls for the ecological zone or district fixed effects.

aid delivered to households in 2010. The district-level dataset was compiled by the Mongolian Red Cross Society (MRCS), which was one of the key actors delivering aid during the winter disaster. The dataset comprises of aid provided by the central government, provincial governments, and NGOs. Information is available on the amount of food aid and animal fodder (in tons) distributed in each district directly after the shock.

## 4. The empirical context: Pastoralism in a risky environment

### *4.1. Herding in Mongolia*

Herding plays a vital role in the Mongolian economy. In 2012, it engaged 35 percent of the workforce, while 19 percent of the population depended on herding for their livelihood (National Statistical Office of Mongolia, 2013). For pastoralist households, livestock not only provides meat, milk, and other dairy products for daily consumption, but it is also a source of cash income through the sale of livestock or livestock by-products. Herders typically own a mix of horses, cattle, camels, sheep, and goats. A herd size of 100-150 animals (irrespective of the species) is typically considered to be the minimum needed in order to maintain a herding livelihood in Mongolia (Goodland et al., 2009).

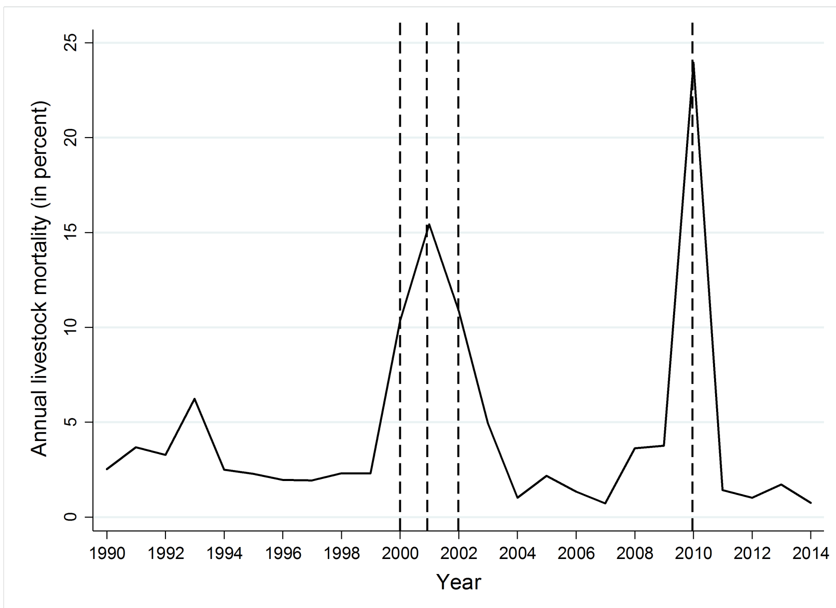
For the vast majority of households owning livestock, the stock of animals is by far the single most important asset. The value of livestock holdings amounts to 90 percent of the total value of all assets owned (evaluated at current sales prices) for the median household in our sample of pastoralists. Further, asset accumulation over time can be attributed almost entirely to livestock growth: median growth rates in livestock value are ten times larger than median growth rates in the value of non-livestock asset holdings.

In most parts of the country, the climate is not suitable for hay or fodder production. Thus, animals need to be grazed year-round. Herding typically involves extensive production techniques with grazing taking place on open rangelands that are state property. Most pastoralist households follow a nomadic or semi-nomadic lifestyle, moving their herds between 2 and 25 times per year, mainly in spring, summer, and autumn. Herders generally follow the same movement patterns every year as pasture access rights are regulated by a complex system of norms and customary law (Fernández-Giménez, 1999). Households underline their claims on particular campsites by investing in shelters or wells, which are considered private property. Use rights over camp sites are often passed on from generation to generation (ibid.).

*4.2. The 2009/10 extreme winter*

Unusually harsh winters present the greatest threat to herders. *Dzuds* are caused by a complex interplay of several unfavorable climatic conditions that reinforce each other, while the exact triggering conditions can differ across *dzuds*. They have in common that they cause sudden and mass livestock mortality, thus directly impairing the very livelihood of herding households. Since 1990, there have been four major *dzuds* in the winters of 1999/00, 2000/01, 2001/02, and 2009/10. The *dzud* of 2009/10 – which is the focus in this study – caused the largest livestock losses in a single winter in the past 50 years, with national-level livestock mortality amounting to more than 23.9 percent (see figure 1). Among sample households included in our panel survey, the average livestock mortality was 43 percent.

Figure 1: Annual livestock mortality in Mongolia, 1990-2014




Notes: Livestock include camels, cattle, horses, sheep, and goats. Only deaths of adult livestock are considered. Dashed lines indicate dzud years. Source: Authors' calculations based on the Mongolia Livestock Census.

Unfavorable weather conditions began in summer 2009, when below-average rainfall caused poor pasture conditions and prevented animals from building up enough fat reserves.[7] This was followed by early and heavy snowfalls in October 2009, impeding animals from reaching the grass and causing animal starvation. Conditions worsened even more with record low temperatures in December 2009 and January 2010, freezing weakened animals to death. Finally, snowmelt in May 2010 resulted in flash floods that further damaged livestock. In January 2010, the Government of Mongolia declared a national disaster and called for international support (International Federation of Red Cross and Red Crescent Societies (IFRC), Mongolian Red Cross Society (MRCS), 2010). Distribution of emergency aid to affected households started in March 2010.

Formal insurance opportunities were very limited in rural Mongolia in 2009, just prior to the shock analyzed here. Herders mostly relied on informal risk-management strategies (Skees and Enkh-Amgalan, 2002). Increasing the herd size is the most important informal risk management strategy to prepare for harsh winters (Goodland et al., 2009). Common short-term strategies applied in the midst of extreme winters include conducting additional nomadic movements and purchasing supplementary fodder (Fernandez-Gimenez et al., 2015; Murphy, 2011). However, informal risk management mechanisms often fail to work well in the presence of severe covariate shocks. Consequently, "high levels of livestock mortality are often unavoidable even for the most experienced herders" (Mahul and Skees, 2007, p.10). After an extreme winter, restocking is the most important goal for herders (Goodland et al., 2009).

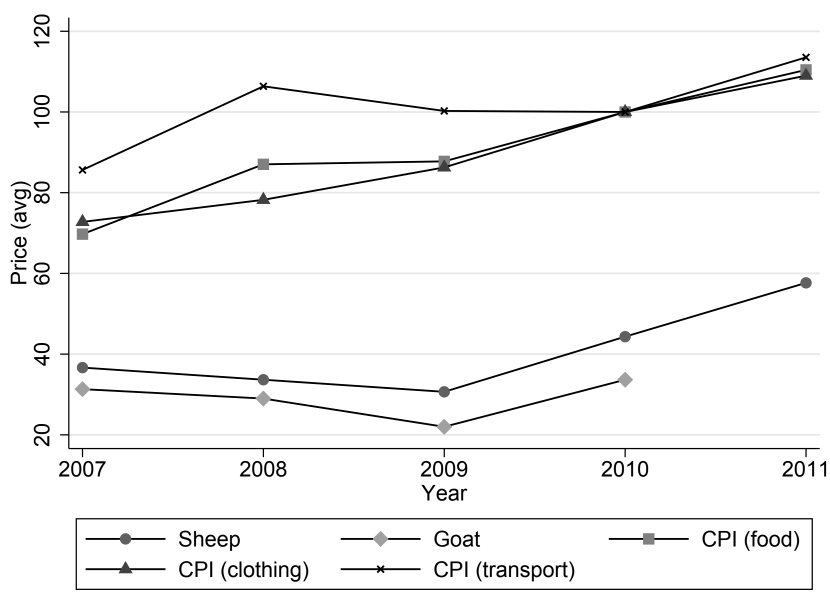
Precautionary livestock sales at the beginning of a *dzud* winter are not a major strategy applied by Mongolian pastoralists, at least not in the survey region. If such sales took place on a large scale, one would expect livestock prices to sharply drop during *dzud* years. Yet, figure 2 shows that this was not the case: In the survey region, prices for sheep and goats – the most commonly consumed types of meat – followed similar trends over the 2007-2011 period as the consumer price index of various other consumption goods.[8] There are also no excessive price increases in the aftermath of the shock that would incentivize postponed sales. We suggest that the lack of precautionary livestock sales at an early phase of the 2009/10 *dzud* is due to two reasons: First, it mirrors the unpredictability of the extreme weather event

[7] For a detailed account of the climatic conditions during the 2009/10 *dzud*, see Groppo and Kraehnert (2017, p.441).

[8] In addition, since livestock is a consumption good itself, households can always transform livestock into (food) consumption at no cost. Price risk is therefore unlikely to be an issue in the present setting.

and subsequent livestock mortality to pastoralists. Second, livestock markets are poorly integrated and only exist in provincial centers. Given the remoteness of the countryside, pastoralist households live up to 380 kilometers from the next provincial center, thus incurring high transportation costs. In average years, households tend to sell their livestock in bulk during the summer months (Murphy, 2011). During *dzud* winters, the snow cover on the ground and extremely low temperatures make transport of livestock to urban centers even more difficult and often prohibitively expensive. The lack of precautionary livestock sales among Mongolian pastoralists contrasts with findings from other empirical contexts, where distress sales during or shortly after shocks at unfavorable prices are identified as a particularly damaging shock coping strategy (e.g. Fafchamps et al., 1998; Janzen and Carter, 2013; Verpoorten, 2009).

Figure 2: Average prices of livestock and other consumption goods in western Mongolia, 2007-2011




Notes: Average annual prices (in Mongolian Tugrik) in provincial centers in the survey area (Uvs, Zavkhan, and Govi-Altai provinces). The base year for the consumer price indices is 2010. Source: Authors' calculation based on the Mongolian Statistical Yearbooks.

*4.3. Explaining household-level livestock mortality*

Next, we investigate the direct effect of the 2009/10 extreme winter on the livestock mortality experienced by households in 2010, using the *Coping with Shocks in Mongolia Household Panel Survey* data. Given the severity of the *dzud* and the short time period over which it occurred, we hypothesize that livestock losses experienced by sample households are largely explained by the extreme weather event, while we expect household-specific characteristics and behavior to have little explanatory power.

To test this hypothesis, we regress household-level livestock mortality in 2010 on objective measures of *dzud* intensity, household, herd and district controls, as well as province fixed effects as follows:

$$\begin{aligned} m_{ij2010} = & \beta_1 dzudintensity_{j2010} + \beta_2 herdcharacteristics_{ij2009} + \beta_3 experience_{ij} \\ & + \beta_4 volatility_j + \beta_5 coping_{ij2010} + \beta_6 X_{ij} + \eta_p + \epsilon_{ij} \end{aligned} \tag{5}$$

Livestock mortality $m_{ij2010}$ of household $i$ living in district $j$ is defined as the proportion of the number of animals lost by the household in 2010 relative to the household's herd size just prior to the shock. $Dzudintensity_{j2010}$ is measured by the district-level livestock mortality in 2010, derived from the Mongolia Livestock Census. Given that this measure is calculated from the entirety of herders in a given district, potential measurement errors in the household-level and district-level mortality should be uncorrelated. As alternative measures of *dzud* intensity, we employ livestock mortality in 2010 at the sub-district level, again derived from the Mongolia Livestock Census, as well as district-level standardized winter temperature (see section 3). To account for nonlinearities, the square of the standardized temperature measure is also included.

The vector $herdcharacteristics_{ij2009}$ captures various characteristics of the herd in 2009, just prior to the extreme weather event. Most importantly, this includes a household's livestock holdings. Rejection of the null hypothesis of $\beta_2 = 0$ in favor of a negative coefficient would indicate that households with smaller herds are hit proportionally harder by the *dzud*. Furthermore, livestock mortality may vary with herd composition if, for example, small ruminants are more vulnerable to extreme winter conditions. Therefore, we also control for the share of goats in the household's herd as of 2009.

Herders' $experience_{ij}$ might play a role in determining shock losses. Proxies for experience include whether the parents of the household head were herders, whether the head always lived in his/her district of birth, and whether the household was already engaged in herding in 1999, just before *dzuds* occurred in three consecutive winters between 2000 and 2002. These variables should capture the effects of both herding skills as well as pasture use rights and herder networks that are passed on across generations.

In addition, we control for the long-term $volatility_j$ in livestock growth at the district level by including the standard deviation of the annual livestock population between 1991 and 2009, calculated from Mongolia Livestock Census data. Rejecting the null hypothesis of $\beta_4 = 0$ in favor of a negative coefficient would suggest that herding households living in districts that were exposed to greater volatility in livestock growth in the past might have developed strategies to reduce their vulnerability to the 2009/10 *dzud*.

Moreover, we test whether shock $coping_{ij}$ strategies applied during the *dzud* influenced livestock losses experienced by households. Proxies for coping strategies include whether the household conducted additional movements with their herd during the winter months (*otor* in Mongolian) and whether the household sold livestock.

The vector $X_{ij}$ captures further household-level and district-level controls. These include the age of the household head, whether the household head is female, whether at least one household member completed secondary or higher education, whether the household head as well as the spouse reported herding as their main income earning activity in 2009, and whether the household lived in a rural area just before the shock. Given that geographic factors such as vegetation, wind exposure, and slope influence *dzud* intensity, we control for the dominant ecological zone in the district (mountain steppe, forest steppe, grassland, and desert steppe/desert). Mortality may also depend on the local stocking density if overgrazing had prevented animals from building up sufficient fat reserves during the summer. We capture this possibility by controlling for livestock density by district in 2009, calculated as the number of livestock (in log) per km$^2$. Lastly, province fixed effects $\eta_p$ control for any differences across the three survey provinces. We estimate the model by fitting a generalized linear model with a logit link function to account for the fact that the outcome is a proportion. Summary statistics of all outcome and control variables can be found in table 1.

Results displayed in table 2, column 1 show that *dzud* intensity has a significant

Table 1: Summary statistics - Part A

| Variable | Mean | Std. Dev. | Min. | Max. | N |
|---|---|---|---|---|---|
| *Outcome* | | | | | |
| Household-level livestock mortality in 2010, in percent | 0.43 | 0.23 | 0 | 1 | 1,079 |
| Abandoning herding after the dzud | 0.06 | 0.23 | 0 | 1 | 1,079 |
| *Dzud intensity* | | | | | |
| Livestock mortality in 2010 per district, in percent | 0.33 | 0.12 | 0.12 | 0.61 | 1,079 |
| Livestock mortality in 2010 per sub-district, in percent | 0.34 | 0.13 | 0.04 | 0.76 | 1,079 |
| Standardized winter temperature per district | -1.13 | 0.45 | -2.2 | -0.43 | 1,079 |
| Mortality covariance (within-district standard deviation) | 0.25 | 0.07 | 0.01 | 0.72 | 1,079 |
| Percent of households per district with zero dzud losses | 0.05 | 0.08 | 0 | 0.33 | 1,079 |
| *Pre-shock herd characteristics* | | | | | |
| Herd size in 2009 | 288.8 | 215.35 | 2 | 1800 | 1,079 |
| Herd size in 2000 | 286.5 | 185.79 | 0 | 1449 | 643 |
| Share of goats in 2009 | 0.38 | 0.21 | 0 | 1 | 934 |
| Household achieved full recovery after the 2000-2002 dzuds | 0.57 | 0.45 | 0 | 1 | 641 |
| *Experience* | | | | | |
| Parents of head were herders | 0.94 | 0.23 | 0 | 1 | 1,073 |
| Head always lived in current district | 0.82 | 0.36 | 0 | 1 | 1,079 |
| Household was herding during the 2000-2002 dzuds | 0.85 | 0.33 | 0 | 1 | 1,079 |
| *Volatility* | | | | | |
| Std. dev. of annual livestock population per district, 1991-2009 | 8.99 | 3.27 | 2.15 | 16.14 | 1,079 |
| *Shock coping* | | | | | |
| Household went on temporary migration during dzud | 0.20 | 0.38 | 0 | 1 | 1,062 |
| Household sold livestock | 0.13 | 0.31 | 0 | 1 | 1,062 |
| Tons of food aid and animal fodder per herding household per district | 0.05 | 0.04 | 0 | 0.19 | 1,079 |
| *Household and district characteristics* | | | | | |
| Age of head | 43.52 | 10.66 | 16 | 87 | 1,079 |
| Female head | 0.08 | 0.25 | 0 | 1 | 1,079 |
| Secondary or higher education | 0.63 | 0.45 | 0 | 1 | 1,079 |
| Head was full-time herder in 2009 | 0.77 | 0.39 | 0 | 1 | 1,079 |
| Spouse was full-time herder in 2009 | 0.65 | 0.45 | 0 | 1 | 1,079 |
| Household lived in rural area in 2009 | 0.73 | 0.42 | 0 | 1 | 1,079 |
| Stocking density (livestock in log per $km^2$) per district | 3.64 | 1.09 | 1.67 | 8 | 1,069 |
| Ecological zone of district is mountain steppe | 0.33 | 0.44 | 0 | 1 | 1,079 |
| Ecological zone of district is forest steppe | 0.14 | 0.32 | 0 | 1 | 1,079 |
| Ecological zone of district is grass steppe | 0.25 | 0.40 | 0 | 1 | 1,079 |
| Ecological zone of district is desert steppe or desert | 0.28 | 0.42 | 0 | 1 | 1,079 |
| *Province* | | | | | |
| Zavkhan | 0.34 | 0.44 | 0 | 1 | 1,079 |
| Govi Altai | 0.29 | 0.43 | 0 | 1 | 1,079 |
| Uvs | 0.37 | 0.45 | 0 | 1 | 1,079 |

Sources: Coping with Shocks in Mongolia Household Panel Survey, Mongolia Livestock Census, ERA-Interim, and MRCS emergency aid data.

and large effect on household-level livestock mortality in 2010. A 10 percentage point increase in the district-level livestock mortality increases household-level livestock mortality by about 6.8 percentage points. This finding is robust to measuring *dzud* intensity with livestock mortality at the sub-district level (column 2) and with winter temperature (column 3).[9] In contrast, pre-shock herd size does not significantly influence household-level livestock mortality: wealthier and poorer herders before the shock lost a similar share of their livestock during the *dzud* (column 1).[10] Only households with large herds of 100 heads and more experienced a 7-8 percentage points higher livestock mortality compared to households with small herds (column 4), which may mirror the lower livestock to labor ratio in wealthier households. Herd composition, measured by the share of goats in the herd directly before the shock, does not significantly affect household-level livestock mortality (column 5), neither does overgrazing in the district significantly influence mortality (column 6).

[9] Marginal effects are negative at the 10$^{\text{th}}$ percentile of the winter temperature distribution and positive above the 50$^{\text{th}}$ percentile. This implies an increase in the mortality rate with increasing temperatures in the upper half of the temperature distribution. This is likely due to the fact that "warmer" winter temperatures are correlated with higher snowfall. An exact modelling of livestock losses using climate data is beyond the scope of this paper, as *dzud* winters are characterized by a complex combination of different climatic phenomena. Therefore, we abstain from interpreting the point estimates on the winter temperature coefficients. Instead, we take the significant influence of winter temperature on household-level livestock losses as further support of our hypothesis that losses are driven by factors beyond the scope of the household's actions.

[10] However, when we instead employ the *absolute* number of livestock lost by households as outcome, pre-shock herd size does have a significant and positive effect on losses, indicating that wealthier herders before the shock lost more animals overall (results available upon request). Yet, the effect of the *dzud* was much worse for relatively poorer herders before the shock, whose herd size was diminished close to or even below the minimum herd size required to maintain a herding livelihood in Mongolia.

Table 2: Determinants of household-level livestock mortality in 2010 (Generalized linear model using the logit link)

| | Outcome: Household-level livestock mortality in 2010, in percent | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| *Dzud intensity* | | | | | | | | |
| Mortality (district) | 0.68*** | | | 0.69*** | 0.71*** | 0.67*** | 0.68*** | 0.70*** |
| | (0.069) | | | (0.069) | (0.070) | (0.069) | (0.069) | (0.069) |
| Mortality (sub-distr.) | | 0.42*** | | | | | | |
| | | (0.054) | | | | | | |
| Winter temperature (district) | | | 0.34*** | | | | | |
| | | | (0.091) | | | | | |
| Winter temperature squared | | | 0.13*** | | | | | |
| | | | (0.036) | | | | | |
| *Pre-shock herd characteristics* | | | | | | | | |
| Herd size in 2009 (in log) | 0.01 | 0.02* | 0.01 | | 0.01 | 0.01 | 0.02* | 0.01 |
| | (0.010) | (0.010) | (0.010) | | (0.011) | (0.010) | (0.010) | (0.010) |
| Herd size in 2009 btw 50 and 99 | | | | 0.03 | | | | |
| | | | | (0.044) | | | | |
| Herd size in 2009 btw 100 and 199 | | | | 0.07* | | | | |
| | | | | (0.040) | | | | |
| Herd size in 2009 greater 199 | | | | 0.08** | | | | |
| | | | | (0.038) | | | | |
| Share of goats in 2009 | | | | | 0.04 | | | |
| | | | | | (0.041) | | | |
| *Experience* | | | | | | | | |
| Parents of head were herders | -0.03 | -0.04 | -0.03 | -0.04 | -0.01 | -0.03 | -0.03 | -0.03 |
| | (0.038) | (0.040) | (0.039) | (0.039) | (0.044) | (0.039) | (0.039) | (0.039) |
| Head always lived in current district | -0.02 | -0.06** | -0.05** | -0.02 | -0.01 | -0.01 | -0.02 | -0.03 |
| | (0.021) | (0.022) | (0.022) | (0.021) | (0.024) | (0.023) | (0.021) | (0.022) |
| Head was full-time herder in 2009 | -0.07** | -0.07** | -0.07** | -0.08*** | -0.05 | -0.07** | -0.04 | -0.06** |
| | (0.029) | (0.029) | (0.029) | (0.029) | (0.033) | (0.029) | (0.030) | (0.029) |
| Spouse was full-time herder in 2009 | -0.03 | -0.03 | -0.03 | -0.03 | -0.03 | -0.02 | -0.02 | -0.02 |
| | (0.022) | (0.022) | (0.022) | (0.022) | (0.024) | (0.022) | (0.022) | (0.022) |
| Herding during the 2000-2002 dzuds | | | | | | | -0.07** | |
| | | | | | | | (0.028) | |
| *Shock coping in 2010* | | | | | | | | |
| Temporary migration | | | | | | | | 0.00 |
| | | | | | | | | (0.017) |
| Household sold livestock | | | | | | | | -0.03 |
| | | | | | | | | (0.020) |
| *Volatility and stocking density* | | | | | | | | |
| Volatility in livestock population (distr.) | 0.00 | 0.00 | 0.01*** | 0.00 | -0.00 | 0.00 | 0.00 | -0.00 |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) |
| Stocking density (district) | | | | | | 0.01 | | |
| | | | | | | (0.007) | | |
| *Household characteristics* | | | | | | | | |
| Age of head | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Female head | 0.10*** | 0.10*** | 0.10*** | 0.10*** | 0.10*** | 0.10*** | 0.11*** | 0.09*** |
| | (0.031) | (0.031) | (0.032) | (0.032) | (0.034) | (0.031) | (0.031) | (0.031) |
| Secondary or higher education | -0.03 | -0.03 | -0.03** | -0.03* | -0.03 | -0.03 | -0.03* | -0.03 |
| | (0.016) | (0.016) | (0.016) | (0.016) | (0.017) | (0.016) | (0.016) | (0.016) |
| Lived in rural area in 2009 | 0.02 | 0.02 | 0.01 | 0.01 | -0.01 | 0.02 | 0.02 | 0.02 |
| | (0.021) | (0.022) | (0.023) | (0.021) | (0.023) | (0.021) | (0.021) | (0.021) |
| District characteristics | YES | YES | YES | YES | YES | YES | YES | YES |
| Fixed Effects | Province | Province | Province | Province | Province | Province | Province | Province |
| Observations | 1,073 | 1,073 | 1,073 | 1,073 | 931 | 1,063 | 1,073 | 1,056 |

Model estimated as generalized linear model using the logit link. The table reports marginal effects obtained using the delta method and standard errors (clustered at the level of the enumeration area) in parentheses with * significant at 10%, ** significant at 5%, *** significant at 1%. In column 4, the excluded category is herd size in 2009 between 1 and 49 animals. Sources: Coping with Shocks in Mongolia Household Panel Survey, Mongolia Livestock Census, and ERA-Interim data.

Similarly, herding experience does not significantly affect household-level livestock mortality in 2010. Even if the head of household grew up in a herding household and, thus, most likely experienced previous *dzud* events, this did not provide him or her with additional knowledge or skills that could have helped minimizing shock exposure (table 2, column 1). Nor did herders residing in their native district benefit from better herder networks or more secure pasture use rights. We only find a significant effect of experience when directly controlling for whether the household was herding already during the triple *dzud* winters between 2000 and 2002 (column 7): Having experienced these previous *dzud* events reduces losses due to the 2010 *dzud* by 7 percentage points. Herders living in a district that faced higher volatility in livestock growth between 1991 and 2009 do not differ significantly in their livestock mortality from herders exposed to lower previous livestock volatility.

Similarly, the shock coping strategies chosen by the household – going on temporary migration during the *dzud* or purchasing animal fodder (column 8) – do not significantly affect livestock mortality in 2010. Most household-level characteristics do not have a significant effect on household-level livestock mortality either. Two exceptions are households headed by a woman and households in which the head was not a full-time herder in 2009, directly before the *dzud* (table 2, column 1); both characteristics are associated with higher household-level mortality. To explore the robustness of the latter finding, we restrict the sample to those households for which both the head and the spouse reported herding as their main income earning activity in 2009 (results available upon request). Results confirm our baseline findings.

Recall that all results presented so far rely on total herd size, treating animals of different species as equal, which is common in Mongolia. As additional robustness test, we transform the outcome variable into horse units,[11] the conversion rate commonly used in Mongolia. Table A1 in the Appendix displays estimates obtained for the subsample of 882 households that reported 2009 livestock holdings and 2010 livestock losses by species. Results are similar to the baseline findings.

Put together, these results confirm our hypothesis that livestock losses experienced by households are largely exogenously determined by weather conditions during the *dzud* and unaffected by household characteristics or coping behavior. Nevertheless, the *dzud* was not perfectly covariate either, given that district-level livestock mortality does not fully translate into household-level livestock mortality.

[11] One horse unit is equivalent to one cow, 0.67 camels, six sheep, or eight goats.

## 5. Post-shock asset growth: An empirical investigation

### *5.1. Households that abandoned herding after the 2009/10 extreme winter*

In the theoretical discussion above, we show that exposure to a large covariate shock can affect households beyond the direct and immediate loss of assets. As a first approach to evaluating empirically the persistence of shock effects, we focus on households that abandoned herding in the aftermath of the 2009/10 extreme winter. Given the harsh continental climate in Mongolia, farming is unfeasible in most areas and employment opportunities are virtually nonexistent in rural areas. Thus, most households dropping out of the herding economy in the aftermath of the shock move to district or provincial centers and earn income through other activities. In the sample studied in this paper, 13 percent of the households that owned livestock in 2009 abandoned herding after the *dzud*.[12]

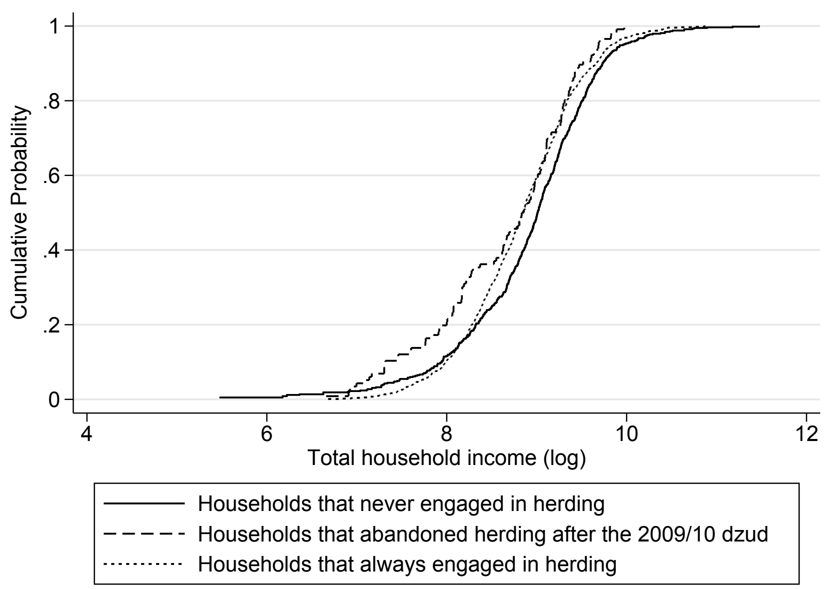
We first investigate the determinants of abandoning herding after the 2009/10 *dzud*. To do so, we estimate the probability of owning no livestock at the time of the first panel wave (2012/13) as a function of pre-shock livestock holdings, shock losses, as well as household, herd, and district characteristics prior to the shock with a probit regression. Results displayed in table 3 show that the livestock mortality experienced by the household in 2010 is the single most important predictor for dropping out of herding. An increase in livestock mortality by 10 percent increases the likelihood of abandoning herding by 1.4 percent (column 1). This finding is robust to measuring shock intensity with district-level livestock mortality (column 2) and district-level winter temperature (column 3). When both head and spouse were full-time herders prior to the shock, when the head always lived in the current district as well as a large pre-shock herd size have a significant, but economically small, mitigating effect on the likelihood of abandoning herding in the aftermath of the shock. On the contrary, having been a herder throughout the triple *dzuds* of 2000-2002 does not significantly affect post-shock outcomes (column 6). Results are robust to expanding the sample with the 29 households that reported zero livestock holdings in the first panel interview but had restarted herding when interviewed during the second or

[12] Recall that the sample is representative of the population in western Mongolia as of November 2010, when the Population and Housing Census was implemented. Hence, our database misses households that moved to other provinces or the capital Ulaanbaatar immediately following the *dzud*. Yet, neighboring provinces lack employment opportunities, while the distance between the survey area and Ulaanbaatar is more than 1,000 km. Hence, we do not consider it likely that such movements occurred quickly after the *dzud*.

third panel waves (results available upon request).

In 2012, households that abandoned herding after the extreme winter have lower income and fewer assets (measured by the current value of all assets) compared to households that stayed in herding and compared to non-herding households that never engaged in herding (figures 3 and 4).[13] In addition to the economic costs, abandoning herding also entails social costs for households. Herding households are held in high esteem in the society, as herding is perceived as element of true Mongolness (Murphy, 2011). Likewise, qualitative evidence suggests few households quit herding voluntarily, as this implies a loss in social status (ibid.).

Figure 3: Cumulative distribution of total household income, by herding status in 2012




Source: Coping with Shocks in Mongolia Household Panel Survey.

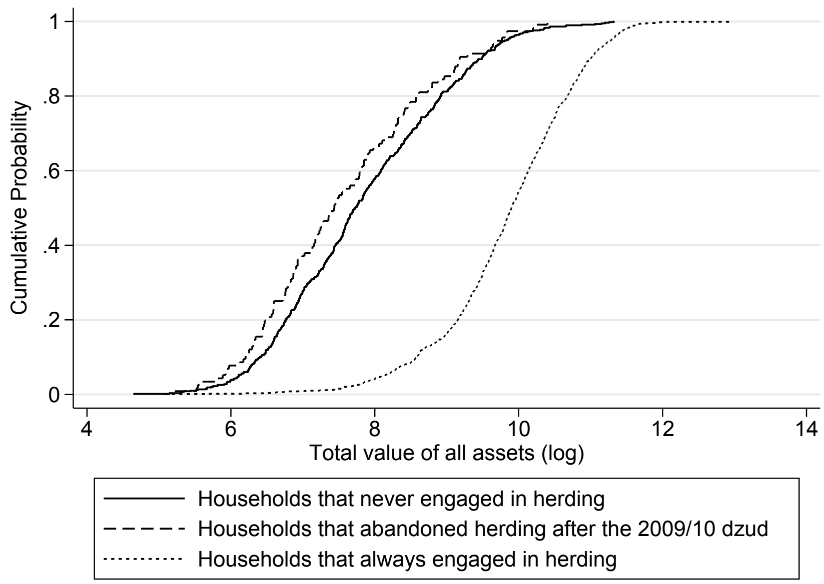
[13]If we compare the post-shock income and asset values of the households that dropped out of herding to those households that stayed in herding and had similar pre-shock livestock holdings and shock losses, the income and asset gap narrows, but remains. This seems to be driven by a higher risk of earning a very low income for former herders (results available upon request).

Table 3: Determinants of abandoning herding in the aftermath of the *dzud* (Probit)

| | Outcome: Household abandoned herding after the shock | | | | | | |
|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| *Dzud intensity* | | | | | | | |
| Livestock mortality (household) | 0.14*** | | | 0.12*** | 0.13*** | 0.14*** | 0.14*** |
| | (0.016) | | | (0.014) | (0.016) | (0.016) | (0.016) |
| Livestock mortality (district) | | 0.20*** | | | | | |
| | | (0.047) | | | | | |
| Winter temperature (district) | | | 0.26*** | | | | |
| | | | (0.056) | | | | |
| Winter temperature squared | | | 0.11*** | | | | |
| | | | (0.024) | | | | |
| *Pre-shock herd characteristics* | | | | | | | |
| Herd size in 2009 (in log) | -0.02*** | -0.02*** | -0.02*** | -0.02*** | -0.02*** | -0.02*** | -0.02*** |
| | (0.005) | (0.005) | (0.006) | (0.004) | (0.005) | (0.005) | (0.005) |
| Share of goats in 2009 | | | | -0.01 | | | |
| | | | | (0.014) | | | |
| *Experience* | | | | | | | |
| Parents of head were herders | -0.04*** | -0.05*** | -0.06*** | -0.03*** | -0.04*** | -0.04*** | -0.04*** |
| | (0.012) | (0.012) | (0.013) | (0.009) | (0.011) | (0.012) | (0.011) |
| Head always lived in current district | -0.04*** | -0.05*** | -0.05*** | -0.03*** | -0.03** | -0.04*** | -0.04*** |
| | (0.010) | (0.011) | (0.011) | (0.007) | (0.011) | (0.010) | (0.010) |
| Head was full-time herder in 2009 | -0.03*** | -0.05*** | -0.06*** | -0.01 | -0.03*** | -0.03** | -0.03*** |
| | (0.011) | (0.013) | (0.014) | (0.009) | (0.011) | (0.012) | (0.011) |
| Spouse was full-time herder in 2009 | -0.04*** | -0.05*** | -0.06*** | -0.03*** | -0.04*** | -0.04*** | -0.04*** |
| | (0.012) | (0.015) | (0.016) | (0.012) | (0.012) | (0.012) | (0.012) |
| Herding during the 2000-2002 *dzuds* | | | | | | -0.01 | |
| | | | | | | (0.012) | |
| *Shock coping in 2010* | | | | | | | |
| Temporary migration | | | | | | | 0.02* |
| | | | | | | | (0.009) |
| Household sold livestock | | | | | | | 0.00 |
| | | | | | | | (0.012) |
| *Volatility and stocking density* | | | | | | | |
| Volatility in livestock population (distr.) | -0.00 | -0.00 | -0.00 | -0.00* | -0.00 | -0.00 | -0.00 |
| | (0.002) | (0.002) | (0.003) | (0.002) | (0.002) | (0.002) | (0.002) |
| Stocking density (district) | | | | | 0.01** | | |
| | | | | | (0.004) | | |
| *Household characteristics* | | | | | | | |
| Age of head | 0.00 | 0.00 | 0.00 | -0.00 | 0.00 | 0.00 | 0.00 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Female head | -0.01 | 0.01 | 0.01 | 0.00 | -0.01 | -0.01 | -0.01 |
| | (0.013) | (0.016) | (0.016) | (0.009) | (0.012) | (0.013) | (0.013) |
| Secondary or higher education | -0.01 | -0.01 | -0.02 | -0.01 | -0.01 | -0.01 | -0.01 |
| | (0.011) | (0.012) | (0.012) | (0.009) | (0.011) | (0.011) | (0.011) |
| Lived in rural area in 2009 | 0.00 | 0.01 | 0.00 | -0.03*** | 0.00 | 0.00 | 0.00 |
| | (0.011) | (0.012) | (0.012) | (0.010) | (0.011) | (0.011) | (0.011) |
| District characteristics | YES | YES | YES | YES | YES | YES | YES |
| Fixed Effects | Province | Province | Province | Province | Province | Province | Province |
| Observations | 1,073 | 1,073 | 1,073 | 931 | 1,063 | 1,073 | 1,056 |

Model estimated with probit. The table reports marginal effects and standard errors (clustered at the level of the enumeration area) in parentheses with * significant at 10%, ** significant at 5%, *** significant at 1%. Sources: Coping with Shocks in Mongolia Household Panel Survey, Mongolia Livestock Census, and ERA-Interim data.

Figure 4: Cumulative distribution of the total value of all household assets, by herding status in 2012




Source: Coping with Shocks in Mongolia Household Panel Survey.

*5.2. Post-shock asset growth among households that stayed in herding*

Next, we test empirically to what extent the extreme winter of 2009/10 shaped households' post-shock asset growth. If the shock significantly lowers asset accumulation even years after its occurrence, households facing severe shock-induced livestock losses may find themselves on a different growth path compared to households experiencing few shock-induced losses. This would perpetuate shock effects, potentially trapping strongly-affected households in a low asset equilibrium. In the sample studied here, the herd size of the average herding household only reached pre-shock levels at the time of the third panel interview in 2014/15. Yet, about a quarter of the sample households had merely recovered 50 percent or less of their herd by 2014/15.

We estimate the following model of growth in herd size in the post-shock period for household $i$ in district $j$ at time $t$:

$$\begin{aligned} g_{ijt+1} = & \beta_1 dzudintensity_{ij,2010} + \beta_2 idiosyncraticshocks_{ijt} \\ & + \beta_3 herdcharacteristics_{ijt} + \beta_4 experience_{ij} + \beta_5 volatility_j \\ & + \beta_6 coping_{ij2010} + \beta_7 X_{ijt} + \eta_p + \lambda_t + \epsilon_{ijt} \end{aligned} \tag{6}$$

where the growth in herd size $g_{ijt+1}$ is defined as the change in the capital stock from the beginning to the end of the year,[14] $g_{ijt+1} = k_{ijt+1}/k_{it} - 1$. Given that the panel data contain three yearly observations on herd size in the post-shock period for each household, we consider growth rates over two time periods: wave 1-2 (2012/13-2013/14) and wave 2-3 (2013/14-2014/15), 2-5 years after the shock occurred. *Dzudintensity* is measured by the number of animals a household lost in 2010 (in logs).[15] Rejecting the null hypothesis of $\beta_1 = 0$ in favor of a negative coefficient would indicate shock persistence, i.e. the effect of the shock going beyond its immediate impact on livestock holdings in 2010.

To explore to what extent shock persistence is driven by the nature of the shock, we also control for households' exposure to $idiosyncraticshocks_{ijt}$. While such idiosyncratic shocks are unrelated to the extreme winter of 2009/10, they may still create additional consumption needs and, hence, influence asset growth. We capture exposure to idiosyncratic shocks with an indicator variable taking the value one if the household reported experiencing any idiosyncratic shock not related to livestock in the 12 months prior to each survey interview. Moreover, we account for unexpected livestock losses (due to theft, wild animals, diseases, weather conditions, and remittances given)[16] and livestock gains (due to remittances and gifts received) in the previous 12 months. Rejecting the null hypothesis of $\beta_1 = \beta_2$ in favor of $\beta_1 - \beta_2 > 0$ would indicate stronger effects on asset growth of the covariate winter disaster compared to idiosyncratic shocks.

[14]Recall that each panel wave was implemented over a 12-month time period, while each household was interviewed for the second and third waves exactly 12 and 24 months after the initial interview. Hence, to be more precise, the period of interest is not the calendar year, but the previous 12 months.

[15]The absolute number of animals lost, in logarithm, is used here as *dzud* intensity measure for the ease of interpreting coefficients. Specifying *dzud* intensity as proportion of the number of animals lost by the household in 2010 relative to the household's herd size in 2009 does not change the results (available upon request).

[16]The exclusion of losses due to livestock disease – which might be affected by the household's herding skills – does not change the results.

The vector $herdcharacteristics_{ijt}$ includes various predictors for the natural growth potential of the herd at the beginning of each year. Most importantly, this includes the beginning-of-year herd size. In the theoretical framework outlined above, we show that beginning-of-year herd size may be influenced by the extreme winter of 2009/10, pre-shock herd size, as well as idiosyncratic shocks. In order to partial out the effects of those factors and allow for a separate estimation of shock and stock effects, we first regress beginning-of-year herd size on *dzud* intensity measures, 2009 herd size, and measures of idiosyncratic shocks. The predicted beginning-of-year herd size obtained from this regression is then subtracted from the observed beginning-of-year herd size. This purged beginning-of-year herd size (in logs) is then used in estimating equation 6. In addition, we include the share of small ruminants (sheep and goat) that have the highest natural reproduction rates among the species common in Mongolia as well as the overall share of female animals in the herd. Moreover, we control for herd size in 2009 (in logs), before the extreme weather event, which determines from which level a household starts the post-shock recovery process. Again, we account for the *volatility* in livestock numbers in the district in the past two decades, as in equation 5.

Similar controls for $experience_{ij}$ as in equation 5 are included. We additionally control for the ownership of a spring shelter that provides protection for the herd during the breeding phase. The vector $coping_{ij2010}$ represents the same set of coping strategies applied by households in 2010 – selling livestock and conducting additional nomadic movements during the *dzud* – as used in equation 5 above. In addition, we include the average amount of food and livestock fodder (in tons) distributed in each district per herding household, as reported by the MRCS,[17] as well as knowledge of the sub-district governor to control for the household's social network. Moreover, we explore to what extent potential transfers from other, less affected households, might have helped mitigating the adverse shock effects on asset growth. Transfers and the functioning of informal insurance arrangements likely depend on the spread of losses as well as the overall number of people affected. Therefore, we control for the within-district variability of losses (measured by the standard deviation[18]) and the

[17]However, the distribution of emergency aid was influenced by weather-related cost and feasibility considerations and is thus not fully exogenous (see Groppo and Kraehnert, 2016). Potential effects should be interpreted as correlation only.

[18]We use district-level livestock losses from the livestock census as $\mu_{losses}$ in the calculation of the standard deviation of the within-district variance of losses. Using the within-district loss variance

share of households reporting zero livestock losses (calculated from the household panel data), as well as their interaction terms with household-level losses. These measures are calculated separately for the 2009/10 *dzud* and idiosyncratic shocks occurring during the past 12 months.

$X_{ijt}$ stands for a vector of household and district-level controls measured in time period $t$. Apart from the controls used in equation 5, we include household size expressed in adult equivalent scales to account for the household's manpower (Deaton, 1997). As, at the district level, the available infrastructure may affect livestock marketing opportunities, we additionally account for availability of cellphone networks and the number of transportation options between the district and the province center. Finally, we include both province fixed effects ($\eta_p$) and time fixed effects ($\lambda_t$). Summary statistics of the variables used in the asset growth regression are displayed in table 4.

Household specific herding skills – which may influence both beginning-of-year herd size and herd growth – are only partly observable and, thus, not fully controlled for in the model.[19] This might lead to biased estimates. Therefore, we decompose the error term into a zero mean i.i.d. part and a household-specific effect ($u_{it} = \alpha_i + \epsilon_{it}$) and estimate the model using a Hausman-Taylor panel estimator (Hausman and Taylor, 1981). This allows us to estimate the effect of time-invariant household-level variables while still controlling for unobservable household-specific herding skills. The Hausman-Taylor estimator is an instrumental variables estimator. Regressors are divided into time-varying and time-invariant as well as exogenous and endogenous variables, where endogeneity is defined as correlation with the time fixed effects. Instruments are then based on the mean of time-varying exogenous regressors (for time-invariant endogenous regressors) or values of the time-varying exogenous regressors at periods other than the current one (for time-varying endogenous regressors). This implies that we need at least as many time-varying exogenous regressors as time-invariant endogenous ones for the model to be identified. In the following, we specify all livestock-related variables (beginning-of-year and 2009 herd size, the share of female livestock, and the share of small ruminants) as endogenous.

or coefficient of variation or basing these measures solely on loss information from our survey leaves the results unchanged.

[19]Given that the panel data used in this study only cover five years and learning effects take time, we abstract from potential changes in herding skills over time.

Table 4: Summary statistics - Part B

| Variable | Mean | Std. Dev. | Min. | Max. | N |
|---|---|---|---|---|---|
| *Outcome* | | | | | |
| Livestock growth rate | 0.17 | 0.43 | -0.96 | 5.91 | 1,710 |
| Livestock recovery rate 2009-2014/15 | 1.13 | 0.96 | 0.01 | 20 | 855 |
| Number of livestock consumed | 22.20 | 9.05 | 0 | 68 | 1,710 |
| Number of livestock sold | 19.45 | 28.90 | 0 | 300 | 1,710 |
| Number of livestock purchased | 2.73 | 11.93 | 0 | 230 | 1,710 |
| Number of newborns | 78.45 | 61.43 | 0 | 638 | 1,160 |
| *Beginning-of-year herd characteristics* | | | | | |
| Herd size | 253.37 | 200.75 | 2 | 1613 | 1,710 |
| Share of small ruminants | 0.90 | 0.13 | 0 | 1 | 1,710 |
| Share of sheep | 0.38 | 0.19 | 0 | 1 | 1,710 |
| Share of female animals | 0.38 | 0.08 | 0.06 | 0.95 | 1,710 |
| *Current idiosyncratic shocks* | | | | | |
| Experienced non-livestock related idiosyncratic shock at t-1 | 0.21 | 0.37 | 0 | 1 | 1,710 |
| Unexpected livestock gains at t-1 (in percent) | 0.00 | 0.01 | 0 | 0.67 | 1,710 |
| Unexpected livestock losses at t-1 (in percent) | 0.04 | 0.07 | 0 | 1 | 1,710 |
| *Beginning-of-year household characteristics* | | | | | |
| Head and spouse are full-time herders | 0.72 | 0.40 | 0 | 1 | 1,710 |
| Household size in adult equivalents | 3.81 | 1.11 | 1 | 8 | 1,710 |
| Location is rural | 0.77 | 0.38 | 0 | 1 | 1,710 |
| Household owns spring shelter of good quality | 0.21 | 0.35 | 0 | 1 | 1,193 |
| Percent of households per district with zero LS losses | 0.36 | 0.20 | 0 | 1 | 1710 |
| Loss covariance (within-district SD) | 0.03 | 0.03 | 0.00 | 0.22 | 1,710 |
| Distance to district center (km) | 25.00 | 19.94 | 0 | 115 | 1,710 |
| *Beginning-of-year district characteristics* | | | | | |
| Availability of cellphone networks | 2.46 | 0.78 | 1 | 4 | 1,710 |
| No. of transportation options | 1.34 | 0.61 | 0 | 3 | 1,710 |
| Price index | 111.14 | 7.70 | 96.72 | 147.61 | 1,710 |

Note: Summary statistics are reported for the pooled sample, except the livestock recovery rate. Source: Coping with Shocks in Mongolia Household Panel Survey.

Results (table 5) show that the *dzud* has a significant effect on households' asset growth even several years after it hit the country. Households facing higher shock-induced livestock losses in 2010 have significantly lower growth rates in herd size between 2012 and 2015 compared to less-affected households (column 1). A 10 percent increase in household-level livestock losses decreases the growth rate by about 5.2 percent. Furthermore, the effects of the extreme winter on asset growth rates at the household level appear to be nonlinear, with the shock effect becoming larger in increasing losses (column 2). A 10 percent increase in losses reduces the growth rate by 4.3 percent at the $10^{th}$ percentile of the loss distribution, but by 13.4 percent at the $90^{th}$ percentile.

Table 5: Annual livestock growth rates 2012-2015 (Hausman-Taylor estimator)

| | Outcome: Livestock growth rates | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| *Dzud intensity* | | | | |
| Livestock mortality in 2010 (hh) (log)[a] | -0.52*** | 0.57*** | -0.53*** | -0.70*** |
| | (0.135) | (0.216) | (0.129) | (0.148) |
| Livestock mortality (log) squared | | -0.17*** | | |
| | | (0.032) | | |
| Mortality covariance in 2010 (district) | | | 0.42 | |
| | | | (1.087) | |
| Mortality covariance*livestock mortality (hh) | | | -0.40 | |
| | | | (1.212) | |
| % of HHs with zero dzud losses in 2010 (distr.) | | | | 0.63 |
| | | | | (0.952) |
| Zero dzud losses*livestock mortality (hh) | | | | 2.66*** |
| | | | | (0.517) |
| *Beginning-of-year herd characteristics* | | | | |
| Herd size (log)[b◇] | -1.59*** | -1.59*** | -1.58*** | -1.59*** |
| | (0.109) | (0.109) | (0.109) | (0.109) |
| Share of small ruminants[◇] | -1.01 | -1.01 | -0.97 | -1.01 |
| | (0.768) | (0.764) | (0.772) | (0.768) |
| Share of female livestock[◇] | -0.09 | -0.09 | -0.07 | -0.07 |
| | (0.316) | (0.315) | (0.319) | (0.316) |
| Herd size in 2009[◇] | 1.21*** | 1.38*** | 1.25*** | 1.33*** |
| | (0.247) | (0.275) | (0.243) | (0.257) |
| *Experience and gender* | | | | |
| Parents of head were herders | -0.09 | -0.15 | -0.09 | -0.13 |
| | (0.234) | (0.222) | (0.240) | (0.227) |
| Head always lived in current district | 0.03 | -0.02 | 0.03 | 0.09 |
| | (0.145) | (0.134) | (0.145) | (0.144) |
| Full-time herders | 0.13* | 0.12 | 0.13 | 0.12 |
| | (0.080) | (0.081) | (0.080) | (0.081) |
| Volatility in LS population (distr.) | 0.04** | 0.03* | 0.04** | 0.04** |
| | (0.018) | (0.019) | (0.018) | (0.018) |
| Female head | -0.21 | -0.21 | -0.19 | -0.24 |
| | (0.223) | (0.209) | (0.225) | (0.222) |
| *Current idiosyncratic shocks* | | | | |
| Experienced idiosyncratic shock at t-1 | 0.00 | 0.00 | -0.00 | 0.00 |
| | (0.033) | (0.033) | (0.034) | (0.033) |
| Unexpected LS gains at t-1 | -0.05 | -0.05 | -0.05 | -0.06 |
| | (0.047) | (0.046) | (0.047) | (0.047) |
| Unexpected LS losses at t-1[a] | -0.17*** | -0.18*** | -0.18*** | -0.18*** |
| | (0.017) | (0.018) | (0.017) | (0.018) |
| Loss covariance (district) | | | 0.07 | |
| | | | (0.698) | |
| Loss covariance*unexpected LS losses | | | 0.49 | |
| | | | (0.503) | |
| % of HHs with zero losses (distr.) | | | | 0.01 |
| | | | | (0.103) |
| Zero losses*unexpected LS losses | | | | 0.06 |
| | | | | (0.047) |
| Constant | -2.68** | -4.90*** | -5.33*** | -5.84*** |
| | (1.055) | (1.285) | (1.429) | (1.538) |
| Household characteristics | YES | YES | YES | YES |
| District characteristics | YES | YES | YES | YES |
| Province and time FE | YES | YES | YES | YES |
| Observations | 1,710 | 1,710 | 1,710 | 1,710 |
| Number of households | 855 | 855 | 855 | 855 |

Model estimated with the Hausman-Taylor estimator. Standard errors (clustered at the level of the enumeration area) in parentheses with * significant at 10%; ** significant at 5%; *** significant at 1%. If not otherwise specified, household, herd and district characteristics are measured at the beginning of the year. Sample restricted to households with positive livestock holdings in all three panel waves. The same household and district controls as in table 2 are used. [◇]Endogenous controls: Herd size (beginning-of-year and in 2009), share of female livestock, and the share of small ruminants. [a]In columns 3 and 4, household-level livestock mortality and unexpected livestock losses are demeaned for better interpretability of the interaction terms. [b]Beginning-of-year herd size has been purged of the effects of past shocks and the pre-shock herd size. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Table 6: Annual livestock growth rates 2012-2015 (Hausman-Taylor estimator) - Coping and emergency aid

| | Outcome: Livestock growth rates | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| *Dzud intensity* | | | | | |
| Livestock mortality in 2010 (hh) (log)[a] | -0.48*** | -0.44*** | -0.51*** | -0.47*** | -0.38*** |
| | (0.141) | (0.145) | (0.132) | (0.162) | (0.141) |
| *Beginning-of-year herd characteristics* | | | | | |
| Herd size (log)[b]◇ | -1.58*** | -1.58*** | -1.59*** | -1.69*** | -1.51*** |
| | (0.111) | (0.111) | (0.109) | (0.143) | (0.144) |
| Share of small ruminants◇ | -1.07 | -1.07 | -1.01 | -0.03 | -1.71* |
| | (0.771) | (0.771) | (0.769) | (1.406) | (1.013) |
| Share of female LS◇ | -0.09 | -0.08 | -0.09 | -0.04 | -0.07 |
| | (0.320) | (0.321) | (0.316) | (0.363) | (0.415) |
| Herd size in 2009[c]◇ | 1.15*** | 1.11*** | 1.17*** | 1.17*** | 1.07*** |
| | (0.279) | (0.276) | (0.244) | (0.313) | (0.397) |
| Spring shelter of good quality◇ | | | | 0.06* | |
| | | | | (0.037) | |
| *Experience and gender* | | | | | |
| Parents of head were herders | -0.12 | -0.27 | -0.09 | -0.23 | -0.19 |
| | (0.242) | (0.389) | (0.232) | (0.442) | (0.309) |
| Head always lived in current district | 0.09 | 0.25 | 0.04 | 0.03 | 0.09 |
| | (0.150) | (0.303) | (0.143) | (0.186) | (0.211) |
| Full-time herders | 0.14* | 0.15* | 0.13 | 0.23** | 0.14 |
| | (0.081) | (0.088) | (0.080) | (0.104) | (0.087) |
| Full recovery achieved after 2002 dzud | | | | | 1.51*** |
| | | | | | (0.563) |
| Volatility in LS population (distr.) | 0.04 | 0.04* | 0.04* | 0.02 | 0.04 |
| | (0.024) | (0.023) | (0.018) | (0.024) | (0.029) |
| Female head | -0.26 | -0.24 | -0.22 | -0.26 | -0.34 |
| | (0.224) | (0.242) | (0.222) | (0.212) | (0.249) |
| *Current idiosyncratic shocks* | | | | | |
| Experienced idiosyncratic shock at t-1 | 0.00 | 0.00 | 0.00 | -0.03 | 0.01 |
| | (0.033) | (0.033) | (0.033) | (0.035) | (0.039) |
| Unexpected LS gains at t-1 | -0.06 | -0.06 | -0.05 | -0.07 | -0.03 |
| | (0.048) | (0.049) | (0.047) | (0.088) | (0.046) |
| Unexpected LS losses at t-1 | -0.17*** | -0.18*** | -0.17*** | -0.18*** | -0.18*** |
| | (0.018) | (0.018) | (0.018) | (0.021) | (0.023) |
| *Shock coping in 2010* | | | | | |
| Temporary migration | -0.29 | | | | |
| | (1.250) | | | | |
| Temporary migration*LS mortality (hh) | 0.12 | | | | |
| | (0.227) | | | | |
| Livestock sold◇ | | 2.10 | | | |
| | | (3.312) | | | |
| Livestock sold*LS mortality (hh) | | -0.29 | | | |
| | | (0.762) | | | |
| Amount of aid[a] | | | 1.05 | | |
| | | | (1.706) | | |
| Amount of aid*LS mortality (hh) | | | -1.28 | | |
| | | | (1.564) | | |
| Constant | -4.65*** | -4.70*** | -4.71*** | -3.28* | -2.78* |
| | (1.547) | (1.618) | (1.499) | (1.816) | (1.531) |
| Household characteristics | YES | YES | YES | YES | YES |
| District characteristics | YES | YES | YES | YES | YES |
| Province and time FE | YES | YES | YES | YES | YES |
| Observations | 1,688 | 1,688 | 1,710 | 1,148 | 1,118 |
| Number of households | 844 | 844 | 855 | 574 | 559 |

Model estimated with the Hausman-Taylor estimator. Standard errors (clustered at the level of the enumeration area) in parentheses with * significant at 10%; ** significant at 5%; *** significant at 1%.
If not otherwise specified, household, herd and district characteristics are measured at the beginning of the year. Sample restricted to households with positive livestock holdings in all three panel waves. ◇Endogenous controls: Herd size (beginning-of-year and in 2009), share of female livestock, share of small ruminants, whether full recovery after the 2000-2002 dzuds was achieved, whether the household owns a spring shelter in good quality, and livestock sold directly after the shock. The same household and district controls as in table 2 are used. [a]Household-level livestock mortality and the amount of aid received are centered for better interpretability of the interaction terms in columns 1-3. [b]Beginning-of-year herd size has been purged of the effects of past shocks and the pre-shock herd size. [c]In column 5, pre-shock livestock holdings refer to the dzuds of 2000-2002. Sources: Coping with Shocks in Mongolia Household Panel Survey, Mongolia Livestock Census, and MRCS emergency aid data.

Households facing livestock losses as a result of an idiosyncratic shock during the past 12 months also exhibit significantly lower growth rates (table 5, column 1). Yet, the magnitude of this effect is significantly smaller – only about one third in size – than the reduction in growth rates due to the extreme winter of 2009/10. In contrast, exposure to non-livestock related idiosyncratic shocks or unexpected gains in livestock does not significantly affect growth in herd size.

In line with our expectations, the beginning-of-year herd size has a significant and negative impact on subsequent herd growth (table 5, column 1): Pastoralist households owning smaller herds in 2012 yield faster growth in herd size in the subsequent year than households owning larger herds in 2012. This result confirms the catch-up effect put forth by standard growth theory. Controlling for this catch-up effect leaves the negative effect of the extreme weather event unaltered: An interaction term between household-level livestock losses in 2010 and beginning-of-year herd size is insignificant, while the coefficients of both beginning-of-year herd size and 2010 livestock losses are unchanged compared to the baseline regression (results available upon request). Neither measures of herding experience nor measures of the reproductive potential of the herd significantly affect herd growth. However, households that experienced the 2000-2002 *dzuds*, did not abandon herding afterwards and achieved full recovery until 2009 exhibit significantly higher asset growth rates also after the 2009/10 *dzud* (table 6, column 5). Yet, even for this selection of households, the asset growth effect of the 2010 extreme winter remains unaltered compared to the full sample. Owning a spring shelter in a good or very good condition increases growth rates by 6 percent compared to owning a spring shelter in a poor condition or owning no spring shelter at all (column 4).

Lastly, neither shock coping strategies employed by the household (table 6, columns 1-2) nor emergency aid distributed in the aftermath of the shock (column 3) significantly affect post-shock growth rates. The interaction terms between shock intensity and coping strategies employed or external aid received are also not significant, implying that coping activities or aid did not mitigate the effect of the shock on subsequent growth. However, the potential for post-shock transfers in districts in which shock intensity was not uniform across households seems to play a role in mitigating the negative effect of the extreme winter on subsequent asset growth. While there is no direct effect of either shock covariance (table 5, column 3) or the share of *dzud*-affected households within the district (column 4) on asset growth, the latter significantly mitigates the negative *dzud* effect. There is a significant and positive effect of the interaction between the share of households reporting zero losses during the 2009/10 *dzud* in the district and household-level losses in 2010 on post-shock growth rates. An increase in the share of households with no losses within the district by 10 percentage points decreases the *dzud* effect on subsequent asset growth by 26 percentage points. Yet, there is no such effect for losses caused by idiosyncratic shocks during the past 12 months. Hence, transfers seem to take place only after large covariate shocks and mainly from households who did not experience any losses. Taken together, we consider these findings as evidence that shock persistence is influenced both by shock severity and, for covariate shocks, the degree of covariance.

Overall, the empirical analysis shows that a one-off shock in the form of extreme weather events can have persistent effects on asset growth going beyond direct level effects, observable even five years after the shock occurred. Shock persistence is driven by both shock severity and its covariate nature. Yet, few variables apart from shock exposure and initial herd size explain the variation in growth rates across households. To better understand how households rebuild their asset base, we disentangle herd size into livestock consumption, livestock sales, livestock purchases, and natural reproduction in section 6.

*Robustness tests*

The empirical analysis presented here is subject to econometric challenges. More specifically, the inclusion of beginning-of-year herd size as a regressor in estimating growth in herd size – even though standard in the growth literature – might be problematic. In particular, the Hausman-Taylor estimator assumes covariates to be strictly exogenous with respect to the individual and time-specific disturbance $\epsilon_{it}$, which also precludes feedback effects from the disturbance term to future values of the covariates. Yet, by construction, $k_{it+1}$ is also a function of $\epsilon_{it}$, so the strict exogeneity assumption fails. Thus, interpretation of the coefficient on the beginning-of-year herd size should be done with caution. Any potential bias introduced by this should however be small, given that the share of the total variance explained by the time-specific disturbance compared to the share explained by the individual heterogeneity is small (10 percent at most). Furthermore, when re-estimating the model with a household fixed effects specification, we obtain similar coefficients on the time-varying variables (results available upon request).

Importantly, results do not depend on the specific measure of *dzud* intensity employed. We first test the robustness of this finding by grouping households into quintiles according to the incurred losses in 2010 (the reference category being between 20 and 40 percent mortality, table A2, column 1). Again, households in the highest loss category exhibit significantly lower growth rates than households experiencing fewer losses. Findings are also robust to controlling for district fixed effects instead of province fixed effects (column 2). This result is reassuring, given that district fixed effects control most comprehensively for variation in shock intensity across districts. Furthermore, we employ alternative *dzud* intensity measures derived from different data sources. Results are robust to measuring *dzud* intensity with district-level livestock mortality, calculated from the Mongolia Livestock Census (column 3), and to measuring shock intensity with winter temperature (column 5).

All results presented so far rely on total herd size, treating animals of different species as equal. To test for potential herd composition effects, we re-estimate the model using the gross herd value, evaluated at current sales prices, as outcome. Results (available upon request) are very similar to the baseline findings, indicating that effects are not driven by differences in herd composition.

Recall that all results presented so far are derived from a sample of households with positive livestock holdings at each panel interview. To ensure the exclusion of households that abandoned herding after the 2010 extreme winter is not driving our results, we now use the compound annual asset growth rate between 2009 and each of the three panel waves instead of the observed annual growth rate. This compound growth rate $n$ years after the shock is defined as $(k_{i2009+n}/k_{i2009})^{1/n} - 1$. It is equal to -1 for households that abandoned herding. Results (available upon request) confirm baseline findings, regardless of whether the pre-shock herd size in 2009 or post-shock herd size in 2010 are used as baseline asset stock for the calculation of the compound annual growth rate.

As another robustness test, we define the outcome in a slightly different way – as recovery rate of a household's herd size at the time of the third panel interview (2014/15) to its pre-shock level in 2009, expressed in percent – and then test how recovery rates vary with losses incurred. Given that pre-shock herd size is directly accounted for when using the recovery rate as outcome variable, results can be regarded as a robustness test of the potentially confounding effects of differences in 2009 herd size. We regress the household-level recovery rate on intensity measures of the 2009/10 extreme winter, pre-shock herd size, as well as household, herd and district characteristics, and province fixed effects. The analysis builds on information from the third panel wave only. The cross-sectional estimation is carried out with

OLS. Results are presented in table A3 in the appendix. The *dzud* has a significant and negative effect on the recovery rate in herd size even five years after the extreme event, analogously to the findings in the asset growth regression. These results are robust to using district fixed effects instead of province fixed effects (column 2) and using an alternative shock intensity measure (2010 livestock mortality rate at the sub-district, column 4).[20]

## 6. Changes in herding behavior and natural reproduction

Finally, we explore potential mechanisms that might explain the observed changes in asset growth after the extreme weather event. Recall that the direction of the shock effect on household behavior remained ambiguous in the theoretical model. Do households exposed to high shock-induced livestock losses reduce off-take from their herd to stabilize their asset level? Or, on the contrary, do higher shock-losses create additional consumption needs the household seeks to satisfy by drawing down its livestock base even further? Furthermore, potentially persistent shock effects on the herd's natural reproduction rate might counteract asset preserving efforts by the household.

Analogously to the growth regression discussed above (equation 6), we separately regress four aspects of livestock offtake and reproduction that all matter for growth in herd size – the number of livestock consumed by the household, livestock sales, newborns, and livestock purchases – on measures of the spatial intensity of the 2009/10 extreme winter, the experience of idiosyncratic shocks, herd characteristics, herding experience, further household and district characteristics, and a price index:

$$\begin{aligned} D_{ijt+1} = &\beta_1 dzudintensity_{ij2010} + \beta_2 idiosyncraticshocks_{ijt} \\ &+ \beta_3 herdcharacteristics_{ijt} + \beta_4 experience_{ij} + \beta_5 volatility_j \\ &+ \beta_6 coping_{ij2010} + \beta_7 price_{t+1} + \beta_8 X_{ijt} + \eta_p + \lambda_t + \epsilon_{ijt}, for D = c, s, n, p \end{aligned} \tag{7}$$

The number of livestock consumed $c_{ijt+1}$, sold $s_{ijt+1}$, purchased $p_{ijt+1}$, and the

[20]In contrast to the results for growth rates, we now find that many household and herd characteristics have a significant effect on recovery rates. We suggest that this is most likely due to the fact that unobservable herding skills and knowledge are only proxied by the covariates in this cross-sectional model, but are not directly accounted for as in the Hausman-Taylor panel estimator. All significant household and herd characteristics have the expected signs.

number of newborns[21] $n_{ijt+1}$ are measured during the 12 months prior to each panel wave and are transformed into logarithm. Similar measures of the intensity of the 2009/10 winter as well as of the idiosyncratic shocks are employed as in equation 6 above. Beginning-of-period household, herd, and district characteristics are defined analogously to section 5.2. For the consumption regression, we use the share of sheep in the household's herd instead of the share of small ruminants (goats and sheep combined): While both goats and sheep play a similar role in livestock sales, sheep provide the preferred type of meat and are more important for household consumption. Furthermore, both the consumption and sales decision likely respond to food prices. Consequently, we include a price index, calculated as the average price level over the 12-months period for which livestock offtake is recorded. It is based on monthly price data from the district price questionnaire that was jointly collected with the household survey. The index is calculated as the simple average of the prices of all items contributing 2 percent or more to the consumption expenditures of an average household. Again, herding ability and experience are likely to influence households' herd management decisions, but are only partly observed. To minimize endogeneity concerns, we again employ the Hausman-Taylor panel estimator and specify all herd characteristics (beginning-of-year herd size, pre-shock herd size, share of small ruminants, and share of female livestock) as endogenous. Regressions are carried out based on data from all three panel waves.

[21]Recall that each panel wave was collected over a 12-month period. Hence, some households were interviewed before the breeding season was over and, thus, the total number of newborns is not accurately measured for these households. We therefore restrict the analyses of the natural reproduction to sample households for whom the livestock breeding season is complete at the time of the survey interview. We repeat the consumption and sales regression for this sub-sample of households and results are highly similar to the baseline regressions. This makes us confident that this sample restriction for the newborn regression does not introduce a selection bias.

Table 7: Livestock consumption (Hausman-Taylor estimator)

| | Outcome: Number of livestock consumed by the household (log) | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| *Dzud intensity* | | | | | |
| Livestock mortality in 2010 (hh) (log)[a] | -0.15*** | 0.15*** | | | -0.19*** |
| | (0.049) | (0.051) | | | (0.057) |
| Livestock mortality (log) squared | | -0.05*** | | | |
| | | (0.011) | | | |
| Livestock mortality in 2010 (district) (%) | | | -0.57*** | | |
| | | | (0.193) | | |
| Winter temperature (district) | | | | -0.24 | |
| | | | | (0.251) | |
| Winter temperature squared | | | | -0.05 | |
| | | | | (0.108) | |
| % of HHs with zero dzud losses in 2010 (distr.) | | | | | 0.17 |
| | | | | | (0.327) |
| Zero dzud losses*livestock mortality (hh) | | | | | 0.61*** |
| | | | | | (0.224) |
| *Beginning-of-year herd characteristics* | | | | | |
| Herd size (log)[b◇] | 0.10 | 0.11* | 0.10* | 0.10* | 0.09 |
| | (0.062) | (0.061) | (0.061) | (0.061) | (0.060) |
| Share of sheep[◇] | 0.01 | 0.01 | 0.02 | 0.02 | 0.04 |
| | (0.194) | (0.194) | (0.193) | (0.194) | (0.184) |
| Share of female livestock[◇] | -0.07 | -0.05 | -0.07 | -0.08 | -0.07 |
| | (0.223) | (0.224) | (0.222) | (0.223) | (0.222) |
| Herd size in 2009[◇] | 0.63*** | 0.63*** | 0.48*** | 0.50*** | 0.65*** |
| | (0.110) | (0.114) | (0.066) | (0.069) | (0.114) |
| *Selected beginning-of-year household and district characteristics* | | | | | |
| Parents of head were herders | 0.05 | 0.04 | 0.03 | 0.02 | 0.04 |
| | (0.086) | (0.081) | (0.082) | (0.083) | (0.087) |
| Head always lived in current distr. | 0.09* | 0.08* | 0.07 | 0.08 | 0.10** |
| | (0.053) | (0.049) | (0.049) | (0.053) | (0.052) |
| Full-time herders | 0.12*** | 0.11*** | 0.11*** | 0.11*** | 0.11*** |
| | (0.037) | (0.036) | (0.036) | (0.037) | (0.038) |
| Volatility in LS population (distr.) | 0.00 | 0.00 | 0.00 | -0.00 | 0.00 |
| | (0.008) | (0.008) | (0.007) | (0.007) | (0.008) |
| Female head | -0.12 | -0.12* | -0.14* | -0.15** | -0.13* |
| | (0.073) | (0.069) | (0.072) | (0.073) | (0.071) |
| Price index | -0.01 | -0.00 | -0.00 | -0.01 | -0.01 |
| | (0.004) | (0.004) | (0.004) | (0.004) | (0.004) |
| Distance | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| *Current idiosyncratic shocks* | | | | | |
| Experienced idiosyncratic shock at t-1 | -0.04 | -0.04 | -0.04 | -0.04 | -0.04 |
| | (0.032) | (0.032) | (0.032) | (0.033) | (0.033) |
| Unexpected LS gains at t-1 | 0.06** | 0.06** | 0.06** | 0.06** | 0.06** |
| | (0.026) | (0.027) | (0.026) | (0.026) | (0.026) |
| Unexpected LS losses at t-1[a] | 0.00 | 0.01 | 0.01 | 0.00 | -0.00 |
| | (0.016) | (0.016) | (0.016) | (0.016) | (0.016) |
| % of HHs with zero losses (distr.) | | | | | -0.03 |
| | | | | | (0.110) |
| Zero losses*unexpected LS losses | | | | | 0.04 |
| | | | | | (0.041) |
| Constant | 0.52 | -0.21 | 0.74 | 0.42 | -0.31 |
| | (0.628) | (0.710) | (0.594) | (0.623) | (0.808) |
| Household characteristics | YES | YES | YES | YES | YES |
| District characteristics | YES | YES | YES | YES | YES |
| Province and time FE | YES | YES | YES | YES | YES |
| Observations | 1,710 | 1,710 | 1,710 | 1,710 | 1,710 |
| Number of households | 855 | 855 | 855 | 855 | 855 |

Model estimated with the Hausman-Taylor estimator. Standard errors (clustered at the level of the enumeration area) in parentheses with * significant at 10%; ** significant at 5%; *** significant at 1%.
If not otherwise specified, household, herd and district characteristics are measured at the beginning of the year. Sample restricted to households with positive livestock holdings in all three panel waves. The same household and district controls as in table 2 are used. [◇]Endogenous controls: Herd size (beginning-of-year and in 2009), share of female livestock, and the share of sheep. [a]In column 5, household-level livestock mortality and unexpected livestock losses are centered for better interpretability of the interaction terms. [b]Beginning-of-year herd size has been purged of the effects of past shocks and the pre-shock herd size. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Table 8: Livestock sales (Hausman-Taylor estimator)

| | Outcome: Number of livestock sold (log) | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| *Dzud intensity* | | | | | |
| Livestock mortality in 2010 (hh) (log)[a] | -0.55*** | -0.01 | | | -0.57*** |
| | (0.158) | (0.159) | | | (0.180) |
| Livestock mortality (log) squared | | -0.08** | | | |
| | | (0.039) | | | |
| Livestock mortality in 2010 (district) (%) | | | -0.78 | | |
| | | | (0.604) | | |
| Winter temperature (district) | | | | -0.76 | |
| | | | | (0.664) | |
| Winter temperature squared | | | | -0.12 | |
| | | | | (0.270) | |
| % of HHs with zero dzud losses (distr.) | | | | | 0.73 |
| | | | | | (0.948) |
| Zero dzud losses*livestock mortality (hh) | | | | | 1.20* |
| | | | | | (0.623) |
| *Beginning-of-year herd characteristics* | | | | | |
| Herd size (log)[b◇] | 0.50** | 0.51** | 0.51** | 0.50** | 0.53*** |
| | (0.207) | (0.209) | (0.206) | (0.205) | (0.204) |
| Share of small ruminants[◇] | 0.02 | 0.03 | -0.01 | 0.04 | -0.08 |
| | (0.684) | (0.689) | (0.684) | (0.684) | (0.668) |
| Share of female livestock[◇] | -0.67 | -0.63 | -0.69 | -0.69 | -0.72 |
| | (0.571) | (0.569) | (0.573) | (0.571) | (0.570) |
| Herd size in 2009[◇] | 1.77*** | 1.81*** | 1.26*** | 1.32*** | 1.70*** |
| | (0.352) | (0.380) | (0.218) | (0.225) | (0.359) |
| *Selected beginning-of-year household and district characteristics* | | | | | |
| Parents of head were herders | -0.22 | -0.24 | -0.34 | -0.36 | -0.19 |
| | (0.200) | (0.214) | (0.216) | (0.219) | (0.200) |
| Head always lived in current distr. | 0.08 | 0.07 | 0.07 | 0.05 | 0.09 |
| | (0.125) | (0.121) | (0.123) | (0.128) | (0.122) |
| Full-time herders | 0.11 | 0.10 | 0.09 | 0.06 | 0.11 |
| | (0.108) | (0.106) | (0.108) | (0.110) | (0.105) |
| Volatility in LS population (distr.) | 0.01 | 0.01 | -0.00 | -0.01 | 0.01 |
| | (0.019) | (0.019) | (0.020) | (0.020) | (0.021) |
| Female head | 0.33** | 0.33** | 0.25 | 0.22 | 0.30* |
| | (0.162) | (0.157) | (0.171) | (0.177) | (0.155) |
| Price index | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | (0.009) | (0.009) | (0.011) | (0.011) | (0.009) |
| Distance | 0.00 | 0.00 | 0.00* | 0.00 | 0.00 |
| | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) |
| *Current idiosyncratic shocks* | | | | | |
| Experienced idiosyncratic shock at t-1 | -0.04 | -0.04 | -0.05 | -0.05 | -0.06 |
| | (0.079) | (0.078) | (0.075) | (0.076) | (0.079) |
| Unexpected LS gains at t-1 | 0.03 | 0.03 | 0.04 | 0.06 | 0.03 |
| | (0.102) | (0.102) | (0.102) | (0.102) | (0.101) |
| Unexpected LS losses at t-1 | 0.09** | 0.09** | 0.10** | 0.09** | 0.11** |
| | (0.046) | (0.047) | (0.045) | (0.045) | (0.047) |
| % of HHs with zero losses (distr.) | | | | | -0.18 |
| | | | | | (0.249) |
| Zero losses*unexpected LS losses | | | | | -0.31** |
| | | | | | (0.139) |
| Constant | -5.85*** | -7.28*** | -5.59*** | -6.24*** | -7.78*** |
| | (1.664) | (2.143) | (1.737) | (1.925) | (2.218) |
| Household characteristics | YES | YES | YES | YES | YES |
| District characteristics | YES | YES | YES | YES | YES |
| Province and time FE | YES | YES | YES | YES | YES |
| Observations | 1,710 | 1,710 | 1,710 | 1,710 | 1,710 |
| Number of households | 855 | 855 | 855 | 855 | 855 |

Model estimated with the Hausman-Taylor estimator. Standard errors (clustered at the level of the enumeration area) in parentheses with * significant at 10%; ** significant at 5%; *** significant at 1%.
If not otherwise specified, household, herd and district characteristics are measured at the beginning of the year. Sample restricted to households with positive livestock holdings in all three panel waves. The same household and district controls as in table 2 are used. [◇]Endogenous controls: Herd size (beginning-of-year and in 2009), share of female livestock, and the share small ruminants. [a]In column 5, household-level livestock mortality and unexpected livestock losses are centered for better interpretability of the interaction terms. [b]Beginning-of-year herd size has been purged of the effects of past shocks and the pre-shock herd size. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Results displayed in tables 7 and 8 show that the extreme weather event had a significant negative effect on active offtake from the herd (both livestock consumption and sales). A 10 percent increase in the losses incurred due to the *dzud* leads to a 1.5 percent reduction in livestock consumption and a 5.5 percent reduction in livestock sales (column 1). The negative relation between shock intensity and consumption as well as sales from the herd even several years after the extreme event occurred indicates that severely affected households pursue an asset conservation strategy. On the contrary, idiosyncratic shocks experienced in the past 12 months do not evoke such a strong reaction. Unexpected livestock gains lead to a small increase in livestock consumption (0.6 percent for a 10 percent increase), while there is no significant effect of unexpected losses due to idiosyncratic shocks on consumption. However, livestock sales rise in response to unexpected losses, which likely reflects the need for additional cash-income or consumption triggered by an idiosyncratic shock.

Natural reproduction, as measured by the number of newborn, is also persistently and strongly affected by the extreme winter. A 10 percent increase in shock-induced losses decreases the number of newborns by 6.9 percent (table 9, column 1). This could suggest that mortality during the *dzud* was higher among female breeding stock or that this extreme event weakened animals for several years, thus impeding their reproductive capacity. Further, the effect of the extreme winter of 2009/10 is again stronger than the reduction in newborns in response to current shocks (0.3 percent for a 10 percent increase). The active asset preservation undertaken by the household in the form of reduced offtake from the herd is, thus, counteracted by the reduction in the natural reproduction of the herd even several years after the shock occurred, resulting in an overall negative net growth effect.

Table 9: Natural reproduction (Hausman-Taylor estimator)

| | Outcome: Number of newborns (log) | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| *Dzud intensity* | | | | | |
| Livestock mortality in 2010 (hh) (log)[a] | -0.69*** | 0.19 | | | -0.84*** |
| | (0.139) | (0.186) | | | (0.148) |
| Livestock mortality (log) squared | | -0.14*** | | | |
| | | (0.027) | | | |
| Livestock mortality in 2010 (district) (%) | | | -1.62** | | |
| | | | (0.672) | | |
| Winter temperature (district) | | | | -1.51** | |
| | | | | (0.736) | |
| Winter temperature squared | | | | -0.56** | |
| | | | | (0.277) | |
| % of HHs with zero dzud losses (distr.) | | | | | 1.13 |
| | | | | | (0.827) |
| Zero dzud losses*livestock mortality (hh) | | | | | 2.03*** |
| | | | | | (0.521) |
| *Beginning-of-year herd characteristics* | | | | | |
| Herd size (log)[b◇] | -0.26*** | -0.26*** | -0.26*** | -0.26*** | -0.27*** |
| | (0.085) | (0.085) | (0.085) | (0.085) | (0.085) |
| Share of small ruminants[◇] | 0.22 | 0.23 | 0.22 | 0.22 | 0.22 |
| | (0.738) | (0.735) | (0.737) | (0.736) | (0.739) |
| Share of female livestock[◇] | -0.16 | -0.15 | -0.16 | -0.16 | -0.15 |
| | (0.306) | (0.306) | (0.306) | (0.306) | (0.306) |
| Herd size in 2009[◇] | 2.08*** | 2.21*** | 1.35*** | 1.41*** | 2.18*** |
| | (0.247) | (0.257) | (0.137) | (0.142) | (0.246) |
| *Selected beginning-of-year household and district characteristics* | | | | | |
| Parents of head were herders | 0.03 | -0.03 | -0.18 | -0.17 | -0.01 |
| | (0.247) | (0.240) | (0.190) | (0.195) | (0.246) |
| Head always lived in current distr. | 0.13 | 0.05 | 0.06 | 0.04 | 0.18 |
| | (0.150) | (0.141) | (0.131) | (0.146) | (0.155) |
| Full-time herders | 0.04 | 0.03 | 0.04 | 0.04 | 0.03 |
| | (0.051) | (0.049) | (0.051) | (0.052) | (0.052) |
| Volatility in LS population (distr.) | 0.01 | 0.01 | 0.01 | -0.01 | 0.01 |
| | (0.026) | (0.026) | (0.032) | (0.031) | (0.027) |
| Female head | -0.05 | -0.10 | -0.15 | -0.18 | -0.10 |
| | (0.209) | (0.196) | (0.204) | (0.209) | (0.207) |
| Price index | -0.00 | -0.00 | -0.00 | -0.00 | -0.00 |
| | (0.008) | (0.008) | (0.008) | (0.008) | (0.008) |
| Distance | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) |
| *Current idiosyncratic shocks* | | | | | |
| Experienced idiosyncratic shock at t-1 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | (0.038) | (0.039) | (0.038) | (0.038) | (0.039) |
| Unexpected LS gains at t-1 | -0.11** | -0.11** | -0.11** | -0.11** | -0.12** |
| | (0.047) | (0.046) | (0.046) | (0.047) | (0.047) |
| Unexpected LS losses at t-1[a] | -0.03 | -0.03* | -0.03 | -0.03* | -0.03** |
| | (0.017) | (0.017) | (0.017) | (0.017) | (0.017) |
| % of HHs with zero losses (distr.) | | | | | -0.06 |
| | | | | | (0.158) |
| Zero losses*unexpected LS losses | | | | | 0.07 |
| | | | | | (0.061) |
| Constant | -3.89** | -5.68*** | -2.21 | -3.81** | -7.30*** |
| | (1.540) | (1.720) | (1.551) | (1.749) | (1.915) |
| Household characteristics | YES | YES | YES | YES | YES |
| District characteristics | YES | YES | YES | YES | YES |
| Province and time FE | YES | YES | YES | YES | YES |
| Observations | 1,160 | 1,160 | 1,160 | 1,160 | 1,160 |
| Number of households | 580 | 580 | 580 | 580 | 580 |

Model estimated with the Hausman-Taylor estimator. Standard errors (clustered at the level of the enumeration area) in parentheses with * significant at 10%; ** significant at 5%; *** significant at 1%.
If not otherwise specified, household, herd and district characteristics are measured at the beginning of the year. Sample restricted to households with positive livestock holdings and for whose livestock the breeding season is complete in all three panel waves. The same household and district controls as in table 2 are used. [◇]Endogenous controls: Herd size (beginning-of-year and in 2009), share of female livestock, and the share small ruminants. [a]In column (5), household-level livestock mortality and unexpected livestock losses have been centered for better interpretability of the interaction terms. [b]Beginning-of-year herd size has been purged of the effects of past shocks and the pre-shock herd size. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Table 10: Livestock purchases (Hausman-Taylor estimator)

| | Outcome: Number of livestock purchased (log) | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| *Dzud intensity* | | | | | |
| Livestock mortality in 2010 (hh) (log)[a] | -0.21* | 0.14 | | | -0.25** |
| | (0.109) | (0.102) | | | (0.127) |
| Livestock mortality (log) squared | | -0.06** | | | |
| | | (0.024) | | | |
| Livestock mortality in 2010 (district) (%) | | | -0.05 | | |
| | | | (0.333) | | |
| Winter temperature (district) | | | | -0.57 | |
| | | | | (0.368) | |
| Winter temperature squared | | | | -0.21 | |
| | | | | (0.130) | |
| % of HHs with zero dzud losses (distr.) | | | | | 0.44 |
| | | | | | (0.567) |
| Zero dzud losses*livestock mortality (hh) | | | | | 0.94** |
| | | | | | (0.400) |
| *Beginning-of-year herd characteristics* | | | | | |
| Herd size (log)[b◇] | -0.51*** | -0.51*** | -0.49*** | -0.50*** | -0.49*** |
| | (0.115) | (0.113) | (0.114) | (0.113) | (0.114) |
| Share of small ruminants[◇] | 0.14 | 0.14 | 0.10 | 0.10 | 0.05 |
| | (0.750) | (0.752) | (0.753) | (0.752) | (0.744) |
| Share of female livestock[◇] | 0.32 | 0.35 | 0.32 | 0.32 | 0.36 |
| | (0.505) | (0.502) | (0.507) | (0.507) | (0.500) |
| Herd size in 2009[◇] | 0.47* | 0.50* | 0.25 | 0.27* | 0.47* |
| | (0.242) | (0.260) | (0.153) | (0.158) | (0.257) |
| *Selected beginning-of-year household and district characteristics* | | | | | |
| Parents of head were herders | -0.33* | -0.35** | -0.37** | -0.36** | -0.33* |
| | (0.173) | (0.175) | (0.168) | (0.170) | (0.171) |
| Head always lived in current distr. | 0.03 | 0.02 | 0.04 | 0.02 | 0.05 |
| | (0.085) | (0.086) | (0.079) | (0.082) | (0.081) |
| Full-time herders | 0.00 | 0.00 | -0.00 | -0.00 | -0.00 |
| | (0.076) | (0.076) | (0.075) | (0.076) | (0.077) |
| Volatility in LS population (distr.) | 0.02 | 0.02 | 0.01 | 0.01 | 0.02 |
| | (0.012) | (0.012) | (0.012) | (0.011) | (0.012) |
| Female head | -0.06 | -0.06 | -0.10 | -0.10 | -0.07 |
| | (0.101) | (0.099) | (0.100) | (0.100) | (0.099) |
| Price index | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) |
| Distance | -0.00 | -0.00 | 0.00 | -0.00 | -0.00 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| *Current idiosyncratic shocks* | | | | | |
| Experienced idiosyncratic shock at t-1 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| | (0.065) | (0.065) | (0.062) | (0.063) | (0.064) |
| Unexpected LS gains at t-1 | -0.04 | -0.05 | -0.04 | -0.04 | -0.05 |
| | (0.088) | (0.086) | (0.085) | (0.086) | (0.088) |
| Unexpected LS losses at t-1[a] | -0.06** | -0.06** | -0.06* | -0.06* | -0.06* |
| | (0.031) | (0.031) | (0.031) | (0.031) | (0.035) |
| % of HHs with zero losses (distr.) | | | | | -0.01 |
| | | | | | (0.152) |
| Zero losses*unexpected LS losses | | | | | -0.05 |
| | | | | | (0.099) |
| Constant | -1.21 | -2.22 | -1.07 | -1.43 | -2.23 |
| | (1.239) | (1.479) | (1.264) | (1.380) | (1.615) |
| Household characteristics | YES | YES | YES | YES | YES |
| District characteristics | YES | YES | YES | YES | YES |
| Province and time FE | YES | YES | YES | YES | YES |
| Observations | 1,710 | 1,710 | 1,710 | 1,710 | 1,710 |
| Number of households | 855 | 855 | 855 | 855 | 855 |

Model estimated with the Hausman-Taylor estimator. Standard errors (clustered at the level of the enumeration area) in parentheses with * significant at 10%; ** significant at 5%; *** significant at 1%.
If not otherwise specified, household, herd and district characteristics are measured at the beginning of the year. Sample restricted to households with positive livestock holdings in all three panel waves. The same household and district controls as in table 2 are used. [◇]Endogenous controls: Herd size (beginning-of-year and in 2009), Share of female LS, and the Share small ruminants. [a]In column 5, household-level livestock mortality and unexpected livestock losses are centered for better interpretability of the interaction terms. [b]Beginning-of-year herd size has been purged of the effects of past shocks and the pre-shock herd size. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Lastly, we explore if households resort to purchasing livestock as a means of regulating the size of their herd. Overall, less than 20 percent of sample households purchased livestock and, even for households that do so, average livestock sales are more than twice as large as livestock purchases. As such, buying livestock does not seem to play a primary role in stimulating herd growth. Results displayed in table 10 show that there is a significant negative effect of the extreme winter on livestock purchases by the household, even several years after the event occurred. A 10 percent increase in number of livestock lost at the household level due to the 2009/10 *dzud* decreases the number of livestock purchased by 2.1 percent. Yet, the magnitude of the shock effect on livestock purchases is much smaller compared to its effect on livestock sales and reproduction. When comparing the effect size of livestock losses caused by the extreme winter and by idiosyncratic shocks on purchases, we find the effect size of losses induced by the extreme winter being more than three times as large. With respect to other control variables, herding experience does not affect livestock consumption, sales, purchases, or natural reproduction. Interestingly, the distance to the next district center has no significant effect on livestock sales, suggesting that remoteness does not pose an obstacle to livestock transactions.[22] Alternatively, markets in district centers may be underdeveloped and not a relevant outlet for sales.

Finally, again there are no effects of the shock coping strategy chosen by the household, nor the amount of external emergency aid received on offtake and natural reproduction (results available upon request). On the other hand, the share of households within the district that did not experience any losses during the *dzud* significantly mitigates the negative *dzud* effect on livestock offtake and reproduction (tables 7-10, column 5). Interestingly, there is no direct effect of the share of households experiencing no losses in 2010 on offtake. We take this as indicative evidence that the overall availability of livestock in local markets, which is expected to be lower if many households within a district experienced *dzud* losses, does not seem to be the driving factor behind the reduced livestock purchases or consumption. Put together, it seems that it is not the household's individual strategies chosen as immediate response to the extreme weather event that help the household recover, but rather the possibility of transfers from neighboring households.

To ensure that results do not depend on the specific shock measure used, we repeat all regressions with alternative measures of shock intensity (tables 7-10). More

[22]This result also holds if distance is transformed into categorical variables, using varying thresholds.

specifically, we separately employ livestock mortality at the district (column 3) and winter temperature (column 4). All baseline findings are confirmed. Herd management decisions might also differ across households that fully rely on livestock for their livelihood and those that have alternative income sources available. Therefore, we interact household-level losses experienced in 2010 with an indicator variable that takes the value one if herding is the household's sole income source and find that the loss effect does not differ with herder status (results available upon request).

## 7. Conclusion

In this paper, we analyze to what extent a one-off extreme weather event can have persistent effects on household-level asset growth. Our focus is on an unusually harsh winter that caused massive livestock losses. The empirical context provides an interesting study setting, as the occurrence and severity of this extreme event was unanticipated by households. Furthermore, the effects of the shock are directly and immediately felt by households that primarily rely on herding for their livelihood. A regression analysis of the determinants of individual shock outcomes confirms that the immediate effects of the extreme weather event in the form of direct livestock losses are largely exogenous. The percentage of livestock lost is hardly influenced by household characteristics, post-shock coping strategies applied, or other factors under the control of the household.

Our analyses show that the extreme weather event had a significant, large, and negative effect on growth rates in herd size even several years after the shock occurred. In addition, the severity of the extreme event is a strong predictor for dropping out of the herding economy. The income and asset value of these former herders in the non-herding economy is, on average, below that of households that stayed in herding and of non-herding households that never engaged in herding, suggesting the existence of a poverty trap. Furthermore, findings indicate significantly weaker growth effects of smaller idiosyncratic shocks.

Overall, the presented results indicate that the effects of a large shock, such as the extreme weather event analyzed here, are persistent. The extreme event shapes household-level asset growth beyond immediate livestock losses. This does not necessarily imply that severely shock-affected households are trapped in poverty and will never escape (although we cannot exclude permanent effects). Growth rates are still positive for most households that continue herding in the aftermath of the extreme event, but lower compared to those households less affected by the shock.

Hence, recovery takes longer. Thus, the negative effects of the shock are entrenched further into the future. Even if households try to stabilize their asset levels by reducing consumption and sales from the herd, the reproduction potential of the herd is severely impaired even several years after the shock occurred. In addition, neither coping strategies applied by the household, nor food aid and livestock fodder distributed in the aftermath of the shock significantly mitigate these persistent shock effects on asset growth at the household level. Yet, being surrounded by households that did not experience any shock losses can significantly mitigate the negative shock impact. Thus, households are generally unable to fully counteract the shock effects on asset growth rates through their own herd management behavior. Successfully rebuilding their asset base depends on transfers from other households. Overall, the detrimental effects of extreme weather events are a result of both their severity and their covariate nature.

Given the expected increase in the frequency and intensity of extreme weather events in the future, these findings have several policy implications. Shock-affected households reduce their consumption of livestock even several years after the shock occurred. This might negatively influence their food security, in particular the intake of micro-nutrients (Lehmann-Uschner and Kraehnert, 2017). As such, policies should be expanded beyond immediate disaster relief and support households throughout the long recovery process after a shock so they do not have to cut down consumption to maintain their livelihood. Furthermore, given the persistence of these shock effects, policies should also focus on strengthening households' adaptation strategies as well as help reducing households' vulnerability to these extreme events.

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**Supplemental material**

Table A1: Determinants of household-level livestock mortality in 2010 in horse units (Generalized linear model using the logit link)

| | Outcome: Household-level livestock mortality in 2010 in horse units, in percent | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| *Dzud intensity* | | | | | | | | |
| Mortality (district) | 0.72*** | | | 0.57*** | 0.75*** | 0.75*** | 0.72*** | 0.71*** |
| | (0.079) | | | (0.081) | (0.079) | (0.079) | (0.079) | (0.079) |
| Mortality (sub-distr.) | | 0.50*** | | | | | | |
| | | (0.073) | | | | | | |
| Winter temperature (district) | | | 0.54*** | | | | | |
| | | | (0.108) | | | | | |
| Winter temperature squared | | | 0.23*** | | | | | |
| | | | (0.046) | | | | | |
| *Pre-shock herd characteristics* | | | | | | | | |
| Herd size in 2009 in horse units (in log) | -0.14*** | -0.13*** | -0.12*** | | -0.12*** | -0.12*** | -0.14*** | -0.14*** |
| | (0.011) | (0.011) | (0.011) | | (0.011) | (0.011) | (0.011) | (0.011) |
| Herd size in 2009 btw 50 and 99 | | | | 0.03 | | | | |
| | | | | (0.056) | | | | |
| Herd size in 2009 btw 100 and 199 | | | | 0.04 | | | | |
| | | | | (0.049) | | | | |
| Herd size in 2009 greater 199 | | | | 0.08* | | | | |
| | | | | (0.049) | | | | |
| Share of goats in 2009 | | | | | -0.34*** | -0.34*** | | |
| | | | | | (0.052) | (0.052) | | |
| *Experience* | | | | | | | | |
| Parents of head were herders | -0.03 | -0.03 | -0.04 | -0.08 | -0.05 | -0.05 | -0.03 | -0.03 |
| | (0.052) | (0.050) | (0.052) | (0.055) | (0.051) | (0.051) | (0.052) | (0.052) |
| Head always lived in current district | -0.03 | -0.06** | -0.04 | -0.05 | -0.03 | -0.01 | -0.03 | -0.02 |
| | (0.028) | (0.028) | (0.028) | (0.032) | (0.026) | (0.027) | (0.028) | (0.028) |
| Head was full-time herder in 2009 | 0.02 | 0.01 | 0.01 | -0.06 | 0.01 | 0.01 | 0.01 | 0.01 |
| | (0.032) | (0.032) | (0.030) | (0.039) | (0.030) | (0.030) | (0.035) | (0.032) |
| Spouse was full-time herder in 2009 | -0.01 | -0.01 | -0.02 | -0.05 | -0.02 | -0.02 | -0.01 | -0.01 |
| | (0.026) | (0.026) | (0.025) | (0.029) | (0.025) | (0.024) | (0.026) | (0.026) |
| Herding during the 2000-2002 dzuds | | | | | | | 0.02 | |
| | | | | | | | (0.040) | |
| *Shock coping in 2010* | | | | | | | | |
| Temporary migration | | | | | | | | -0.01 |
| | | | | | | | | (0.022) |
| Household sold livestock | | | | | | | | 0.03 |
| | | | | | | | | (0.025) |
| *Volatility and stocking density* | | | | | | | | |
| Volatility in livestock population (distr.) | -0.00 | 0.00 | 0.01** | 0.00 | 0.00 | 0.00 | -0.00 | -0.00 |
| | (0.004) | (0.004) | (0.004) | (0.004) | (0.004) | (0.004) | (0.004) | (0.004) |
| Stocking density (district) | | | | | | 0.01 | | |
| | | | | | | (0.008) | | |
| *Household characteristics* | | | | | | | | |
| Age of head | 0.00*** | 0.00*** | 0.00*** | 0.00** | 0.00** | 0.00* | 0.00*** | 0.00*** |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Female head | 0.00 | -0.00 | 0.02 | 0.07 | 0.01 | 0.02 | -0.00 | 0.00 |
| | (0.046) | (0.045) | (0.040) | (0.044) | (0.041) | (0.041) | (0.046) | (0.046) |
| Secondary or higher education | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | (0.020) | (0.020) | (0.020) | (0.022) | (0.020) | (0.020) | (0.020) | (0.020) |
| Lived in rural area in 2009 | 0.05** | 0.05** | 0.03 | 0.06** | 0.03 | 0.03 | 0.05* | 0.05* |
| | (0.024) | (0.024) | (0.024) | (0.026) | (0.024) | (0.024) | (0.024) | (0.024) |
| District characteristics | YES | YES | YES | YES | YES | YES | YES | YES |
| Fixed Effects | Province | Province | Province | Province | Province | Province | Province | Province |
| Observations | 882 | 882 | 882 | 882 | 882 | 874 | 882 | 882 |

Model estimated as generalized linear model using the logit link. The table reports marginal effects obtained using the delta method and standard errors (clustered at the level of the enumeration area) in parentheses with * significant at 10%, ** significant at 5%, *** significant at 1%. In column 4, the excluded category is herd size in 2009 between 1 and 49 animals. One horse unit is equivalent to one cow, 0.67 camels, six sheep, or eight goats. Source: Coping with Shocks in Mongolia Household Panel Survey, and Mongolia Livestock Census.

Table A2: Annual livestock growth rates 2012-2015 (Hausman-Taylor estimator) - Alternative shock measures

| | Outcome: Livestock growth rates | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| *Dzud intensity* | | | | | |
| Livestock mortality in 2010 (hh) (log) | | -0.51*** | | | |
| | | (0.142) | | | |
| Mortality <20% | -0.05 | | | | |
| | (0.129) | | | | |
| Mortality 40-60% | -0.14 | | | | |
| | (0.103) | | | | |
| Mortality 60-80% | -0.53*** | | | | |
| | (0.118) | | | | |
| Mortality >80% | -0.99*** | | | | |
| | (0.247) | | | | |
| Livestock mortality in 2010 (district) (%) | | | -1.30** | | |
| | | | (0.596) | | |
| Livestock mortality in 2010 (sub-district) (%) | | | | -0.01 | |
| | | | | (0.447) | |
| Winter temperature (district) | | | | | -1.54** |
| | | | | | (0.653) |
| Winter temperature squared | | | | | -0.61** |
| | | | | | (0.261) |
| *Beginning-of-year herd characteristics* | | | | | |
| Herd size (log)[a]◇ | -1.59*** | -1.58*** | -1.59*** | -1.59*** | -1.59*** |
| | (0.109) | (0.111) | (0.109) | (0.109) | (0.109) |
| Share of small ruminants◇ | -1.00 | -1.02 | -1.00 | -1.00 | -1.01 |
| | (0.767) | (0.778) | (0.767) | (0.767) | (0.766) |
| Share of female LS◇ | -0.09 | -0.05 | -0.09 | -0.09 | -0.09 |
| | (0.315) | (0.320) | (0.315) | (0.316) | (0.316) |
| Herd size in 2009◇ | 0.64*** | 1.22*** | 0.75*** | 0.76*** | 0.80*** |
| | (0.141) | (0.270) | (0.156) | (0.156) | (0.165) |
| *Experience and gender* | | | | | |
| Parents of head were herders | -0.19 | 0.03 | -0.21 | -0.23 | -0.19 |
| | (0.213) | (0.237) | (0.210) | (0.211) | (0.213) |
| Head always lived in current distr. | 0.01 | -0.10 | -0.00 | 0.05 | -0.00 |
| | (0.127) | (0.153) | (0.127) | (0.131) | (0.134) |
| Full-time herders | 0.14* | 0.13 | 0.13 | 0.13 | 0.13* |
| | (0.078) | (0.081) | (0.078) | (0.078) | (0.078) |
| Volatility in LS population (distr.) | 0.02 | 0.03 | 0.03 | 0.01 | 0.01 |
| | (0.019) | (0.068) | (0.023) | (0.021) | (0.021) |
| Female head | -0.27 | -0.21 | -0.28 | -0.30 | -0.29 |
| | (0.206) | (0.225) | (0.220) | (0.219) | (0.220) |
| *Current idiosyncratic shocks* | | | | | |
| Experienced idiosyncratic shock at t-1 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 |
| | (0.033) | (0.034) | (0.033) | (0.033) | (0.033) |
| Unexpected LS gains at t-1 | -0.05 | -0.06 | -0.05 | -0.05 | -0.05 |
| | (0.045) | (0.048) | (0.045) | (0.046) | (0.046) |
| Unexpected LS losses at t-1 | -0.17*** | -0.17*** | -0.17*** | -0.17*** | -0.18*** |
| | (0.017) | (0.018) | (0.018) | (0.018) | (0.018) |
| Constant | -1.60* | -3.54** | -1.95** | -2.25** | -3.31*** |
| | (0.882) | (1.423) | (0.951) | (0.976) | (1.184) |
| Household characteristics | YES | YES | YES | YES | YES |
| District characteristics | YES | NO | YES | YES | YES |
| Fixed Effects | Province | District | Province | Province | Province |
| Time FE | YES | YES | YES | YES | YES |
| Observations | 1,710 | 1,710 | 1,710 | 1,710 | 1,710 |
| Number of households | 855 | 855 | 855 | 855 | 855 |

Model estimated with the Hausman-Taylor estimator. Standard errors (clustered at the level of the enumeration area) in parentheses with * significant at 10%; ** significant at 5%; *** significant at 1%.
If not otherwise specified, household, herd and district characteristics are measured at the beginning of the year. Sample restricted to households with positive livestock holdings in all three panel waves. The excluded reference category in column 5 is losses between 20 and 40%. The same household and district controls as in table 2 are used. ◇Endogenous controls: Herd size (beginning-of-year and in 2009), share of female livestock, and the share of small ruminants. [a]Beginning-of-year herd size has been purged of the effects of past shocks and the pre-shock herd size. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Table A3: Livestock recovery to pre-shock levels (OLS)

| | Outcome: Livestock recovery rate 2009-2014/15 | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| *Dzud intensity* | | | | | | |
| Livestock mortality in 2010 (hh) (log) | -0.15*** | -0.14*** | | | | -0.10*** |
| | (0.041) | (0.043) | | | | (0.027) |
| Livestock mortality in 2010 (district) (%) | | | -0.54 | | | |
| | | | (0.410) | | | |
| Livestock mortality in 2010 (sub-district) (%) | | | | -0.48** | | |
| | | | | (0.220) | | |
| Winter temperature (district) | | | | | -0.33 | |
| | | | | | (0.336) | |
| Winter temperature squared | | | | | -0.24* | |
| | | | | | (0.121) | |
| *Herd characteristics* | | | | | | |
| Share of female livestock | -0.90** | -1.00*** | -0.92** | -0.98** | -1.02** | -0.31 |
| | (0.433) | (0.378) | (0.464) | (0.436) | (0.453) | (0.252) |
| Share of small ruminants | 1.11*** | 0.84*** | 1.04*** | 1.05*** | 1.08*** | 0.85*** |
| | (0.235) | (0.205) | (0.245) | (0.235) | (0.232) | (0.152) |
| Herd size in 2009 | -0.41*** | -0.41*** | -0.57*** | -0.58*** | -0.59*** | -0.29*** |
| | (0.103) | (0.081) | (0.117) | (0.113) | (0.114) | (0.054) |
| *Experience and gender* | | | | | | |
| Parents of head were herders | 0.22* | 0.30** | 0.18* | 0.17* | 0.21** | 0.13 |
| | (0.125) | (0.127) | (0.103) | (0.105) | (0.102) | (0.111) |
| Head always lived in current district | -0.01 | -0.07 | -0.05 | -0.03 | -0.03 | 0.05 |
| | (0.094) | (0.105) | (0.093) | (0.092) | (0.094) | (0.076) |
| Full-time herders | 0.30*** | 0.35*** | 0.30*** | 0.31*** | 0.33*** | 0.23*** |
| | (0.078) | (0.080) | (0.077) | (0.077) | (0.080) | (0.066) |
| Female head | -0.20** | -0.07 | -0.20** | -0.19** | -0.19** | -0.21*** |
| | (0.092) | (0.097) | (0.095) | (0.095) | (0.095) | (0.080) |
| Volatility in LS population (distr.) | -0.01 | | -0.01 | -0.01 | -0.02 | 0.01 |
| | (0.013) | | (0.017) | (0.015) | (0.014) | (0.008) |
| *Current idiosyncratic shocks* | | | | | | |
| Experienced idiosyncratic shock at t-1 | -0.01 | -0.03 | -0.04 | -0.04 | -0.03 | 0.06 |
| | (0.088) | (0.087) | (0.088) | (0.086) | (0.088) | (0.065) |
| Unexpected LS gains at t-1 | 0.06 | -0.00 | 0.05 | 0.06 | 0.04 | 0.02 |
| | (0.112) | (0.142) | (0.113) | (0.112) | (0.113) | (0.084) |
| Unexpected LS losses at t-1 | 0.10*** | 0.10*** | 0.11*** | 0.11*** | 0.12*** | 0.08*** |
| | (0.023) | (0.022) | (0.025) | (0.024) | (0.025) | (0.021) |
| *Shock coping in 2010* | | | | | | |
| Temporary migration | | | | | | 0.19*** |
| | | | | | | (0.069) |
| Sold livestock | | | | | | 0.06 |
| | | | | | | (0.067) |
| *Household and district characteristics* | | | | | | |
| Education | 0.16*** | 0.14** | 0.18*** | 0.17*** | 0.19*** | 0.13** |
| | (0.057) | (0.057) | (0.057) | (0.057) | (0.056) | (0.053) |
| Location is rural | 0.35*** | 0.32*** | 0.37*** | 0.35*** | 0.40*** | 0.30*** |
| | (0.073) | (0.092) | (0.073) | (0.076) | (0.073) | (0.064) |
| Cellphone networks | -0.05 | | -0.03 | -0.04 | -0.01 | -0.06** |
| | (0.034) | | (0.034) | (0.034) | (0.036) | (0.028) |
| Number of transportation options | 0.04 | | 0.05 | 0.04 | 0.03 | 0.06 |
| | (0.044) | | (0.042) | (0.042) | (0.042) | (0.041) |
| Constant | 2.82*** | 2.85*** | 3.33*** | 3.35*** | 3.30*** | 2.16*** |
| | (0.535) | (0.490) | (0.531) | (0.544) | (0.700) | (0.301) |
| Household characteristics | YES | YES | YES | YES | YES | YES |
| District characteristics | YES | NO | YES | YES | YES | YES |
| Fixed Effects | Province | District | Province | Province | Province | Province |
| R-squared | 0.242 | 0.346 | 0.229 | 0.229 | 0.235 | 0.295 |
| Observations | 871 | 871 | 871 | 871 | 871 | 860 |

Cross-sectional analysis based on wave 3. Standard errors (clustered at the level of the enumeration area) in parentheses with * significant at 10%; ** significant at 5%; *** significant at 1%.
If not otherwise specified, household, herd and district characteristics are measured at the beginning of the year. Sample restricted to households with positive livestock holdings in all three panel waves. The same household and district controls as in table 2 are used. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.