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The impact of extreme weather events on child health: Evidence from Mongolia

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Abstract

This paper investigates the impact of a devastating weather shock on child anthropometrics, using data from Mongolia. We employ a diff-in-diff strategy to single out the effect of an extremely harsh winter in 2010, which caused the death of about 20 percent of national livestock. Results indicate that cohorts of children exposed to the 2010 winter and who lived in districts in which the shock was particularly harsh are significantly shorter two years after the shock. The negative effect of the shock is strongest for children from herding households. Moreover, we explore the role of mitigation channels to cushion the impact of the weather shock. In households where the head has more experience in herding, children suffer less from the consequences of the shock. Similarly, households having access to alternative sources of income are better able to protect their children from the effect of the shock. Finally, both the amount of emergency aid delivered per district and the presence of an international organization in a given district relieve the negative impact of the shock. Our findings are robust to different measures of shock intensity and to endogenous migration concerns.

Key words: aid, anthropometrics, children, health, Mongolia, weather shocks

JEL: I15, J13, O12

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1. Introduction

As a consequence of climate change and global warming, it is very likely that extreme weather events will occur more frequently and with a higher intensity (IPCC 2007). Developing countries will be most affected by this trend, both due to their geographic location and geophysical endowments and due to fewer public means that may be invested in mitigation and adaptation measures (Stern 2007). As a result, households in developing countries will bear the brunt of the impact of extreme weather events. In developing countries, where insurance markets are incomplete or non-existent, households often have difficulties to smooth their income and consumption when facing shocks (e.g., Townsend 1994; Udry 1994; Zimmerman & Carter 2003). This renders children in particular vulnerable to the consequences of shocks. A growing number of empirical studies provide evidence of the negative effects of shocks on child anthropometrics (Akresh, Bhalotra, et al. 2012; Akresh, Lucchetti, et al. 2012; Minoiu & Shemyakina 2012). In turn, children's anthropometric outcomes are considered an important predictor for cognitive skills, schooling outcomes and hence long-term income-earning capabilities (Maccini & Yang 2009; Strauss & Thomas 2007). Therefore, understanding how shocks influence children's anthropometric outcomes and what strategies are effective in mitigating these negative consequences has important policy implications.

In this paper, we analyze the impact of one extreme weather shock on child anthropometric outcomes in Mongolia. Specifically, we focus on the particularly harsh winter of 2009/2010, which caused the death of an estimated 8.8 million animals, about 20 percent of the national livestock at that time (United Nations 2010). The phenomenon of catastrophic livestock mortality caused by winter conditions is referred to as *dzud* in Mongolian. The 2010 dzud was triggered by a combination of unfavorable weather conditions, including a drought in summer 2009, several temperature swings above zero during the winter, long spells of extreme cold, excess snow fall, and long overall duration of the winter. In January 2010, the Government of Mongolia declared national disaster, calling for international support. In livestock-based economies such as Mongolia, where almost half the labor force engages in herding (NSO et al. 2004), weather shocks are reported as the major cause of poverty (World Bank 2006).

This paper addresses two research questions. First, we explore the impact of the 2010 dzud on children's height, using a diff-in-diff approach. Second, we analyze the effectiveness of

mitigation channels in cushioning the negative impact of the dzud. Specifically, our analysis focusses on access to health infrastructure, household wealth, and emergency aid distributed during the dzud.

Our estimation approach exploits exogenous variation in the intensity of the 2010 dzud across space and birth cohorts, which allows us to draw causal inferences. The outcome variable of interest is children's height-for-age z-scores, which is considered a good indicator for children's long-term nutritional status. The survey data used in this paper were collected by the authors in collaboration with the National Statistical Office of Mongolia (NSO) in western Mongolia in 2012 and 2013. In addition, we draw on historic livestock data to derive a district-level index of dzud intensity.

Results reveal that the 2010 dzud significantly slowed down the growth trajectory of affected children, which is still observable two years after the shock occurred. Results are robust to including controls for mother characteristics, household characteristics and various fixed effects, as well as when using alternative definitions of dzud intensity. The negative effect of the dzud is strongest for children from herding households, who were more immediately affected by the dzud. With respect to the role of mitigation channels, access to medical facilities does not appear to mitigate the consequences of the dzud. Also, wealthier herders were not able to protect their children from the negative impact of the dzud in a better way than poorer herders. However, the provision of food aid appears to mitigate the negative consequences of the dzud. Both the amount of emergency aid delivered per district and the presence of an international organization in a given district relieves the negative impact of the shock. Similarly, households that have close ties to the local governor are better able to protect their children from the consequences of the shock. These preliminary results are encouraging, pointing towards an area where policy interventions may prove beneficial.

Our contribution to the existing literature is twofold. First, we provide strong and robust results for one particularly severe weather shock which is very likely to occur again in the future. The dataset used was particularly designed for this endeavor and allows us to draw causal inferences. Second, our analysis assesses the role of factors that may attenuate the impact of the dzud on children's outcomes, which is seldom done in existing research.

The paper proceeds as follows. The next section reviews some recent studies on the link between shocks and children's anthropometric outcomes. Section 3 outlines the context of Mongolia. Section 4 introduces the household survey data as well as the livestock census data

used to construct a shock intensity measure. The estimation strategy is outline in Section 5, followed by a discussion of results and robustness tests in Section 6. The last section summarizes the results and outlines policy implications.

2. Review of the literature on child anthropometrics

There is a small but growing area of empirical research that analyzes the impact of shocks on child health. A first group of studies explore the effects of weather shocks on child anthropometrics. For instance, a study by Tiwari et al. (2013) investigates the impact of weather variability on the anthropometric outcomes of children in rural Nepal. The authors specifically disentangle the income effect and the disease effect – in particular diarrhea – of excess rainfall. Their analysis builds on three cross-sectional waves of Nepal Demographic and Health Surveys (DHS) from 2001, 2006, and 2011. Rainfall variability is defined as deviation from the historical average, based on precipitation data collected by weather stations across Nepal. Results indicate that an increase in rainfall from historical rainfall patterns significantly increases the weight-for-age z-score for young children of age 0 to 3 years. Tiwari et al. interpret this finding as a positive income effect in a rural setting where rain-fed farming techniques prevail. Proxies for the distance to sources of drinking water and health facilities have no significant effect in mitigating the disease effects of the rainfall shock. Excess rainfall also has a significantly positive effect on children's height-for-age z-scores, although this effect only holds for children who experienced a positive rainfall shock during their second year of life.

Using a similar approach, Rabassa et al. (2012) investigate the impact of weather variability on child health in rural Nigeria, using DHS data from 2003 and 2008. As in the study by Tiwari et al. (2013), the authors construct a measure of weather in the last rainy season and in the current rainy season by calculating the deviation from the local average during the past 20 years. Rabassa et al. find that excess rainfall in the current season has a significantly negative effect on children's weight-for-age z-scores, which is attributed to a negative disease effect. In contrast, excess rainfall in the last season significantly increases children's weight, indicating a positive income effect. Excess rainfall has a similarly positive effect on the height-for-age z-scores for children exposed to the positive shock when below age 3. The authors find no evidence for cumulative effects of shocks in older children. Instead, only the weather (both rainfall and temperature) in the last season significantly influences height-for-age z-scores.

Another recent group studies examines the link between child health and violent conflict as one specific example of a negative shock. For instance, Minoiu and Shemyakina (2012) explore the impact of the civil war in Côte d'Ivoire between 2002 and 2007 on child health. They pool two cross-sectional waves of Household Living Standard Surveys from before and after the war. Conflict intensity is proxied both at the regional level, building on conflict event data from the ACLED database, and at the household level. The latter is drawn from a module of the household questionnaire that captures various aspects of victimization, such as displacement, health-related stress and loss of productive assets. Employing a diff-in-diff estimation strategy, Minoiu and Shemyakina find that children born in regions with high conflict intensity have lower height-for-age z-scores than children born in regions with less conflict intensity. Moreover, children of victimized households living in conflict-affected regions and who were born during the war suffered the most severe consequences.

Akresh et al. (2012) analyze the impact of the Eritrean-Ethiopian border war (1998-2000) on the anthropometric outcomes of Eritrean children, using Eritrean DHS data of 2002. The authors distinguish between cohorts of children born before, during, and after the war. Various measures of children's war exposure are used, including an indicator variable taking the value one if a child was living in one of the three border regions with Ethiopia at the beginning of the war, the number of months a child was alive during the war, and the proportion of internally displaced persons in each of the war regions. Akresh et al. find that the exposure to war significantly reduced height-for-age z-scores among children born before and during the war. The negative effect of the war on children's height is found to be of similar magnitude for girls and boys.

Another example is a study on the long-term effects of the Nigerian Biafra war of 1967-1970 on the height of adult women (Akresh, Bhalotra, et al. 2012). The database used for this analysis consists again of two cross-sectional waves of Nigerian DHS data from 2003 and 2008. The authors employ a difference-in-difference approach, using war-exposed ethnicity and the number of months exposed to the war as treatment. Results indicate that women of war-exposed ethnicity who experienced the war between age 0 and 16 are significantly shorter in adulthood compared to unexposed women of the same cohort. The negative effect of the war is largest for women who experienced war during adolescence.

Common to all cited studies is that a major event – be it violence or a weather shock – have a significant impact on anthropometric outcomes. Yet, most studies are limited to establishing that such relationship exists. For instance, little is known about the impact of shock coping

strategies applied by households to mitigate the impact of the shock. This shortcoming is largely driven by the fact that most existing studies draw on DHS data that use a standardized questionnaire, with little information recorded on the socio-economic characteristics of respondents. This paper aims at shedding light at these issues by drawing on a unique dataset that was particularly designed to understand the impact of shocks on households and households' behavior to cope with such shocks in Mongolia.

3. Herding and weather shocks in Mongolia

Livestock activities are an important source of income for most Mongolians living outside the capital city of Ulan Bator. In 2011, about 29.6 percent of Mongolian households owned livestock and 21.7 percent were herders, with livestock activities being their main source of living (National Statistical Office of Mongolia 2011, 2013). For households owning livestock, the average herd size was 213 in 2013 (National Statistical Office of Mongolia 2013). Most herders in the countryside are nomadic or semi-nomadic, seasonally rotating between campsites to ensure optimal grazing conditions for their herd. The number of herders and of livestock increased considerably since the early 1990s, leading in many areas to overgrazing, particularly around provincial and district centers. The sudden collapse of the public social safety net in the transition period had major implications for herders – and particularly with respect to coping with dzud (Murphy 2011).

In Mongolia, severe winters have been occurring with an average frequency of every eight years since the beginning of meteorological recording in the 1950s (Siurua & Swift 2002). While dzuds are a recurrent phenomenon in Mongolia, the intensity of the 2010 dzud was exceptional. The climatic conditions contributing to the 2010 dzud started with a drought in summer 2009 (IFRC 2010). In October 2009, heavy snowfall started and then melted. With a sudden drop in temperature, the melted snow water iced over, thereby inhibiting animals from reaching grass. In December 2009, another sudden drop of temperature occurred, which further weakened the livestock. The Government of Mongolia declared national disaster in January 2010, appealing for assistance from the international community (United Nations Mongolia Country Team 2010). By March 2010, 5.8 million livestock had perished. In April 2010, 60 percent of the country was still under a thick snow cover, thus preventing livestock from grazing. With spring temperatures starting in May 2010, flash flooding set in and livestock mortality increased to 8.5 million. By June 2010, the total number of perished livestock was estimated at 8.8 million.

After the occurrence of three consecutive dzuds occurring between 1999 and 2002, a large number of impoverished herders moved permanently to urban centers. Qualitative ethnographic research by Siurua and Swift (2002) based on a small sample of households concludes that Mongolian herders seek to protect their assets, most importantly their livestock, even by compromising welfare during the winter.

4. Data

4.1 Household Survey Data

Our analysis builds on the *Coping with Shocks in Mongolia Household Survey*, which is collected by the authors in western Mongolia in collaboration with the National Statistical Office of Mongolia (NSO). The survey is implemented in the three aimags (provinces) of Uvs, Zavkhan, and Govi-Altai (Fig. 1). This area represents all major ecological zones prevalent in Mongolia, including grass steppe, desert, mountainous regions, and forest areas. The sample comprises some 1,750 households, of which about 1,100 are herders, and 7,200 individuals. The survey is a panel with three yearly waves, with data collection ongoing between 2012 and 2015. The analysis presented here relies on the first wave.

The survey is based on a multi-stage sample design, which ensures that the sample is representative of the population in western Mongolia. The Population and Housing Census of 2010 was used as sampling frame. In the first sampling step, the three aimags were subdivided into nine mutually exclusive strata of aimag centers (urban areas), soum (district) centers and rural areas (the latter two are considered as rural areas). In the second step, Primary Sampling Units (PSU) were randomly drawn in each stratum, resulting in a total number of 221 PSU. We used enumeration areas as defined for the 2010 census as PSU. In a third sampling step, inside each PSU households were selected again randomly, with fixed cluster size of 8 households per PSU. The implemented sampling strategy allows us to achieve statistically significant results ($p < 0.05$) with a standard error of 2.29 for the entire survey and a standard error of 3.24 for urban areas and 3.23 for rural areas. Each interviewed household represents about 20 households in urban areas and 40 households in rural areas. All estimations presented in the following account for survey design effects.¹

¹ Results presented in this draft were derived without household weights and should be considered as preliminary.

The household survey was collected continuously throughout the year, with interviews conducted between June 2012 and May 2013. On average, 145 households were interviewed every month. The data are also representative across seasons. To account for possible seasonal effects and enumerators' learning effects (recording child anthropometrics with greater precision as time progresses), we control for month of interview fixed effects in our estimations.

The household questionnaire is designed to particularly explore how households cope with weather shocks. The questionnaire includes retrospective questions on the *dzud* occurring in 2010, a broad range of assets, formal and informal insurance, transfers received, and social networks, in addition to the standard household-level and individual-level information typically captured by household surveys (such as household demographics, education, health, consumption expenditures, and income-earning activities). In addition, a community questionnaire was administered in each of the 49 districts in which sample households are residing. The community questionnaire records population characteristics, infrastructure and service facilities, economic activities, the intensity of the 2010 *dzud*, and assistance provided to households during the *dzud*.

A questionnaire module on child anthropometrics was filled out for all children below the age of 6 who were present at the time of the survey interview.² The dataset comprises anthropometric measures – height, weight, and middle-arm circumference – of 851 children. These children were born between July 2006 and February 2013. The survey enumerators used the standard UNICEF toolkit, including length/height boards and electronic scales, to record child anthropometrics. Prior to the survey, the enumerators received intensive training on specific measurement and recording techniques. The questionnaire asks for children's date of birth at the beginning of the household interview (in the module on household membership) and again in the module on child anthropometrics. Having information on each child twice allows us to detect possible reporting errors or data entry errors in the date of birth, which may be a potential source of error in any analysis of child anthropometrics.

Our outcome variable of interest is children's height. More precisely, we use height-for-age z-scores, which indicate the deviation of a sample child's observed height from the median

² Enumerators were asked to revisit sample households in which children were absent during the interview in district centers and aimag centers. Due to high transportation costs, it was not feasible to revisit households in rural areas. This allowed obtaining anthropometric measures of 152 children. Due to this process, a few children had turned 6 when their anthropometric measures were recorded.

height of an international reference population of children, divided by the standard deviation of the international reference population. A height-for-age z-score of zero would indicate that a child has the expected height for a healthy child of his or her age. A z-score below zero would indicate that a child is shorter than healthy children of exactly the same age are on average, thus indicating malnutrition. Following common procedures in the child anthropometrics literature, we use the Child Growth Standards compiled by the WHO (2006) as the international reference dataset.³ We exclude from our Mongolian sample 19 children with implausible z-scores out of the interval (-6, 6), as suggested by WHO (2009). This leaves us with a sample of 829 children with non-missing data. Fig. 2 plots the distribution of height-for-age z-scores for the sample of Mongolian children and the international reference dataset. The distribution of height-for-age z-scores of Mongolian children has a bell-shaped form, which roughly resembles a normal distribution. Yet, the z-score distribution of Mongolian children is to the left of the distribution of the international reference dataset, thus indicating worse nutritional status for the average child in our Mongolian survey.

4.2 Constructing a measure of shock intensity

We exploit the extraordinarily rich historic livestock data available for Mongolia to define an intensity measure of the 2010 dzud across space.⁴ Since the 1950s, the NSO has been implementing an annual livestock census. In mid-December of every year, enumerators in collaboration with local authorities estimate the number of livestock in each bag (sub-district),⁵ which is then aggregated to the district level. The livestock census collects information on the total stock and the losses of adult animals by year. The information is recorded for each of the five major species prevalent in Mongolia (camel, cattle, horse, sheep, goat). The district-level data are available electronically since 1970.

³ The WHO Child Growth Standards data consists of a sample of healthy children from Brazil, Ghana, India, Norway, Oman, and the US whose mothers followed recommended practices in child care and child nutrition (WHO Multicentre Growth Reference Study Group 2006). The height of young children was found to be very similar for children across countries and ethnicities. Therefore, the dataset is considered to represent child growth under optimal environmental conditions and is used for assessing child growth anywhere in the world.

⁴ Alternatively, one could derive a measure of dzud intensity based on weather data. Yet, the 2009/2010 dzud was caused by a combination of unfavorable weather conditions occurring over a relatively long time span. Accumulating various sub-measures of weather conditions into one common index is not trivial. For this reason, we opted for using aggregate livestock statistics to construct a dzud intensity index. Skees and Enkh-Amgalan (2002) use a similar line of argument in their study on the potential of introducing an insurance against dzud-related livestock losses for Mongolian herders.

⁵ A bag is a third level administrative subdivision, which is often a virtual classification. As of 2014, there are currently 1720 bags.

One shortcoming of the livestock census data for our purpose of analysis is that mortality rates are not disaggregated by loss category. Instead, the census subsumes any losses caused by disease, accidents, animal depredation, and disaster (due to dzud, heavy rain, fire, and lightning) into one single number. Ideally, we would only consider livestock losses caused by dzud in our analysis. Yet, both NSO reports and descriptive statistics suggest that it is dzud losses which explain the large fluctuations in livestock mortality over time. The average annual mortality rate of adult animals is 3.1 percent for non-dzud years in the period 1970-2008. During years considered to be dzud years, the livestock mortality increased to 9.4 percent.⁶ Livestock losses due to dzud are very strongly correlated with overall livestock losses, which makes it a good measure for our analysis.

Based on the livestock census data, we derive a standardized measure of the intensity of the 2010 dzud in district k (for a total number of 49 districts) as follows:

$$dzud\ intensity_{k,2010} = \frac{(livestock\ mortality_{k,2010} - livestock\ mortality_{k,1970-2008})}{standard\ deviation\ of\ livestock\ mortality_{k,1970-2008}} \quad (1)$$

where we relate the livestock mortality occurring in 2010 to the long-term local patterns in livestock mortality between 1970-2008 in the same district.⁷ Our dzud intensity measure thus accounts for both spatial and temporal variation in dzud-related losses. Negative values of the dzud intensity index would indicate lower than average livestock mortality in 2010, positive values would indicate higher than average mortality rates. The dzud intensity index varies between 1.7 and 13.2 and the mean value is 5.2. In short, loss rates in 2010 are above the long-term average in every single survey district. Figure 3 shows the spatial variation in the dzud intensity index for the 49 districts included in our survey area in western Mongolia. This considerable spatial variation mirrors the fact that dzud is a highly localized phenomenon, which is reinforced or meliorated by local climatic conditions, terrain features, and other characteristics of the local ecozone.

Figure 4 illustrates annual livestock losses per district for the years 2007-2012 in Western Mongolia. Clearly, the dzud in 2010 stands out as a single infamous event. The graph for

⁶ Reading et al. (2006) report a list of dzud years over the last 60 years. Accordingly, after 1970, a dzud was registered in the winter of 1976/1977, 1986/1987, 1992/1993, 1996/1997, 1999/2000, and 2000/2001. We further consider 2001/2002 and 2010 as dzud years, which resulted in average livestock loss rates of 19.5 and 33.6 percent, respectively.

⁷ Our measure disregards the fact that dzud-related livestock mortality occurred even in late 2009. As a robustness test, we include the average livestock mortality over 2009 and 2010 in eq. 1. Results are very similar, as will be discussed in section 6.3 below.

2010 also shows that the dzud was particularly intense in a small number of districts. To account for this nonlinear distribution of the dzud intensity across districts in the multivariate analysis below, we further transform the continuous dzud intensity measure into an indicator variable. We define the variable *most affected district* to take the value one if a district has a dzud intensity value above the 85th percentile of the distribution. In the following, we thus compare districts in which the dzud was catastrophic to districts in which it was moderate. It is important to stress that the total effect of the dzud (compared to non-affected districts) would be even larger. In other words, our analysis provides a lower-bound estimate of the damage caused by the 2010 dzud.

5. Estimation strategy

Our empirical strategy exploits exogenous variation in the intensity of the 2010 dzud across space. Moreover, given that the mass mortality of livestock occurred within a contained time period, from about November 2009 to June 2010, there is also exogenous variation in the exposure to the shock across birth cohorts.

Our empirical strategy is summarized in Fig. 5, which shows height-for-age z-scores for sample children born between 2006 and 2013 in districts that were most affected and less affected by the 2010 dzud. Children who were born during the dzud and who live in most severely affected districts have lower height-for-age z-scores than children born during the dzud and living in less affected districts. A similar pattern – residing in most affected districts being associated with lower height-for-age z-scores – is also found for the oldest children in the sample, who experienced the dzud as small children. The negative effect of the dzud appears to persist for some time: Children born shortly after the dzud in most severely affected districts have lower height-for-age z-scores than children of the same age born in less affected districts. This pattern suggests that the dzud even had negative impacts on pregnant women and their unborn babies. Our control group consists of children who were conceived after the dzud (that is, children who were born after March 2011).

In line with the literature discussed in Section 2, we estimate the impact of the dzud on child anthropometrics using a difference-in-difference approach:

$$HAZ_{ikt} = \beta_1 X_i + \beta_2 exposed\ cohort_i + \beta_3 (exposed\ cohort_i * most\ affected\ district_k) + \alpha_k + \delta_t + \lambda_{kt} + \gamma_m + \varepsilon_{ikt} \quad (2)$$

with HAZ_{ikt} representing the height-for-age z-score of child i born in district k at time period t . X_i are vectors of controls of the child, the mother, the head of household, and the household as such. $Exposed\ cohort_i$ is an indicator variable taking the value one if the child experienced the dzud while alive or while in utero. This variable hence identifies children who were born before April 2011. $Exposed\ cohort_i * most\ affected\ district_k$ represents an interaction between experiencing the dzud as small child or unborn baby and living in a district most severely affected by the dzud (as defined in Section 4.2). Additionally, we include various fixed effects to control for other potential factors that may influence child outcomes but are not related to the dzud. Most importantly, α_k stands for district fixed effects, which controls for any pre-existing differences in child health across districts before the dzud. δ_t are year of birth fixed effects. λ_{kt} are district-specific linear time trends that capture potential divergence or convergence in child anthropometrics over time across districts; γ_m are fixed effects for the month of interview; and ε_{ikt} is a random idiosyncratic error term.

As child-level controls, we include the sex of the child and ethnicity (Durvud, Bayad, Khalk, other). As regards mother characteristics, we account for her age and education (illiterate, primary, lower secondary, upper secondary, university). Controls for the characteristics of the head of household are whether the head is female, whether he or she is married, age, education and religion (Buddhist, none, other). Household characteristics include whether the household's location is rural, the total number of members, the proportion of members in the age range 0-5, 6-14, and 15-64 years, as well as indicators of households' long-term assets.⁸ Table 1 displays summary statistics of the full list of variables used in the regressions.

We estimate eq. 2 using OLS. Our focus is on the estimated coefficient β_3 , which measures the causal impact of the 2010 dzud for children residing in most severely affected districts who were alive or in utero when the dzud occurred. Our main analysis draws on children from herding households.⁹ However, to obtain more insights on the mechanisms through which the dzud affects child health, we also estimate eq. 2 for the sample of children from non-herding households and for the whole sample of children.

⁸ Using principal component analysis, an asset index is constructed from 30 different dummy variables indicating ownership of durables bought one year or longer before the survey interview. The durables considered include home appliances, furniture, electronic goods, and means of transportation. The asset index is transformed into quintiles.

⁹ To avoid issues of endogeneity, we focus on households who were herders in 2009, before the dzud. A small number of households lost a significant share of their livestock and dropped out of the herding economy following the dzud. The children of those households may have been more severely affected by the dzud than other children. Focusing on the sample of households who were herders at the time of the survey collection would result in biased estimates.

Next, we explore in more detail three possible channels which may mitigate the effects of the dzud on children's height. In this analysis, we only consider the sub-sample of children from herding households. To estimate the impact of the three mitigation channels, we extend eq. 2 by a triple interaction term:

$$HAZ_{ikt} = \beta_1 X_i + \beta_2 exposed\ cohort_i + \beta_3 (exposed\ cohort_i * most\ affected\ district_k) + \beta_4 channel_{ik} + \beta_5 (exposed\ cohort_i * most\ affected\ district_k * channel_{ik}) + \alpha_k + \delta_t + \lambda_{kt} + \gamma_m + \varepsilon_{ikt} \quad (3)$$

where $channel_{ik}$ represents measures for each of the three mitigation channels, which are either household-level or district-level variables. Our interest lies in the estimated coefficient β_5 , which captures the effect of a mitigation channel on children's height-for-age z-scores for children living in a most severely affected district and who belong to a cohort exposed to the dzud.

The first channel is experience in herding. The underlying hypothesis is that more experienced household heads were more able to defend their livestock from the weather shock, and thus suffered lower livestock losses. Therefore, living in a household with a relatively more experienced head might have reduced the negative impact of the dzud on exposed children. We proxy head's experience in herding through his or her age.

The second channel is income diversification at the household level. We test if households who obtain a regular income from non-herding activities are better able to smooth consumption during the dzud and hence protect their children from its negative consequences, compared to households which rely solely on income from herding. First, we use the number of household members working in non-herding activities, such as public sector employment and self-employment. Second, we count the number of monthly and bi-monthly transfers a household receives, such as state pension, disability pension, maternity benefits, and student allowances. One potential weakness is that both variables refer to the time of the survey interview, while ideally this information was available for 2009 (just before the dzud). However, non-herding work and transfer income relate to skills and characteristics of household members that are likely to remain stable in the short term. Hence, we are confident that our proxies for household income diversification measured in 2012/2013 are strongly correlated with income diversification in 2009.

The third channel is access to health facilities. For pregnant women and young children in particular, access to medical services and nutritional supplements during a period of extremely cold temperatures and stress on households' resources may be important. Two

alternative variables are used to proxy for access to health facilities: First, we construct a district-level indicator variable which takes the value one if a maternity house exists in a district. Second, we use information on the number of different health facilities available in each district center (nurse, doctor, pharmacy, health center, maternity house, hospital). This district-level variable ranges between 3 and 6. As a proxy for availability of health facilities, we construct a dummy variable which is equal to one if the district had the maximum number of health facilities.

Next, we explore the role of emergency aid provided to households during the dzud. As outlined above, the dzud in the winter of 2009/2010 was declared a national catastrophe. The Mongolian Government issued a call for assistance to the international community for support in providing animal fodder, fuel, food, warm clothing and blankets, as well as medical equipment (United Nations Mongolia Country Team 2010). We employ two alternative measures to proxy for access to aid during the 2010 dzud. First, we draw on district-level data on the total amount (in tons) of food items and animal fodder distributed to households during the dzud. The data was compiled by the Mongolian Red Cross Society and comprises aid provided by the central government, provincial governments, and NGOs, including the Red Cross. The amount of distributed food aid and animal fodder ranges between 0 and 82 tons across the 49 survey districts, with the average being 26.1 tons. By employing a district-level measure of the amount of food aid distributed (instead of a household-level measure), we avoid issues of endogeneity. The latter may exist if food aid was targeted to worst affected households. Second, we construct an indicator variable taking the value one if at least one international organization was active in a given district.¹⁰ This is hence a very crude measure of access to external support.

6. Results and discussion

6.1 Descriptive statistics

Table 2 provides an illustration of the incidence of malnutrition in the survey area of western Mongolia, based on the *Coping with Shocks in Mongolia Household Survey*. The mean

¹⁰ Strictly speaking, this variable refers to 2012, when the community questionnaires were completed. Yet, anecdotal evidence suggests that international organizations tend to engage in a specific area at least with a medium time horizon. Amongst other factors, this is due to the remoteness from Ulan Bator, the extremely thin population density, and high costs involved in transportation. Hence, we assume that international organizations active in a given district in 2012 were also active in the same district in 2009.

height-for-age z-score is -1.05 for the whole sample of children. Overall, about 24.9 percent of children are moderately stunted, i.e. their height-for-age z-scores are more than 2 standard deviations below the median of the international reference dataset. About 10.6 percent of children are severely stunted, with z-scores more than 3 standard deviations below the median.

Our figures fit well with the results of two recent national child surveys conducted in Mongolia. The National Nutrition Survey (Public Health Institute, et al. 2006) implemented in 2004 found the average height-for-age z-score to be -0.97 for Mongolian children of age 6 to 59 months. In the Western region, malnutrition was found to be above the national average, with 28.7 percent of children moderately stunted and 11.8 percent of children severely stunted. In the Multiple Indicator Cluster Survey of 2010 (National Statistics Office & UNICEF 2011), 16 percent of Mongolian children of age 0-59 months were found to be moderately stunted. Again, the prevalence of stunting was higher in the Western region, where 25 percent of children were found to be stunted. To conclude, finding very similar levels of malnutrition as do two recent surveys with larger sample size underlines the quality of the *Coping with Shocks in Mongolia* data. The comparison with other child surveys also indicates that our survey region had worse child outcomes compared to other regions of Mongolia.

Table 2 also shows correlations between child anthropometrics and selected socio-economic characteristics. For instance, the proportion of stunted children is higher in Govi-Altai and Uvs than in Zavkhan. The height-for-age z-scores of older children deviate more from the international reference dataset than the z-scores of newborn babies, which is a common finding in the child anthropometrics literature. Boys have slightly lower height-for-age z-scores than girls, but t-tests on the difference in means indicate that this difference is not statistically significant. Children from herding households have significantly lower z-scores than children from non-herding households. The incidence of child malnutrition is significantly lower in households which are wealthy in assets and in households in which the head is literate. In our estimations below, we control for a rich set of child and household characteristics, which may otherwise confound the effects of the dzud.

Moreover, Table 2 shows that 580 out of the 829 of sample children (70 percent) were exposed to the dzud. For the dzud-exposed cohort, the height-for-age z-scores are significantly lower compared to children conceived after the dzud. Also, the height-for-age z-scores of children residing in districts most severely affected by the dzud is slightly lower

compared to children living in less affected districts (although this difference is not statistically significant). Yet, even in districts less affected by the dzud, the average anthropometric outcome of the Mongolian sample children is below the average of the international reference population, thus indicating worse overall nutritional status.

6.2 The impact of the dzud

Results from OLS regressions on the determinants of height-for-age z-scores are displayed in table 3. Estimates are shown for the sample of children from herding households (column 1), for children from non-herding households (column 2), and for the full sample (column 3).

We find evidence for a strong negative impact of the climate shock on the height of children from herding households (table 3, column 1). Children who were exposed to the 2010 dzud as infants or as unborn babies and who lived in a most severely affected district have height-for-age z-scores 1.26 standard deviations lower compared to children of the same age but who lived in less affected districts. The point estimate of the interaction term is significant at the 10 percent level. This result is robust to excluding socio-economic controls (Appendix, table A1). For instance, the magnitude of the point estimate is only slightly smaller (-1.21) in specifications that do not control for the socio-economic characteristics of the child, the child's mother, the head of the household, and the household as such (column 1).

The magnitude of the effect of the 2010 dzud on children in Mongolia is large in comparison with empirical findings on the impact of other types of shocks on child anthropometrics. For instance, the height-for-age z-scores of children are reduced by 0.46 standard deviations if they lived in regions affected by the Ivorian civil war (Minoiu & Shemyakina 2012) and by 0.45 standard deviations for children living in regions affected by the Eritrean-Ethiopian war (Akresh, Lucchetti, et al. 2012).

Next, we repeat the estimation for the sample of children from non-herding households (table 3, column 2) and for the full sample of children (column 3). Interestingly, the dzud has no significant effect on the height of children from non-herding households. This finding suggests that it is not the exposure to harsh weather conditions per se that causes health problems in children. Rather, it appears that the mechanism through which the dzud affects children is the loss of livestock. One may speculate that herders face economic stress during the period of dzud, when they see their source of living threatened. Recent research has established that stress during pregnancy reduces the birth weight of newborns (e.g., Beydoun

& Saftlas 2008; Camacho 2008; Mansour & Rees 2012). Alternatively, our results could possibly indicate asset-smoothing behavior of herding households who may have sacrificed their consumption in the short term in order to maintain their stock of animals in the medium term.

All statistically significant socio-economic controls have the expected signs (Appendix, table A1): Children living in households with an educated head are significantly taller than their peers. Interestingly, the education of the child's mother does not have a statistically significant effect on child anthropometrics. Children of wealthier households are significantly taller.

6.3 The effects of mitigation channels

Next, we present results from OLS regressions that explore the impact of three channels that may cushion the negative impact of the dzud, using triple interactions (table 4). Note that this analysis is only conducted for children from herding households.

We first explore the influence of herding experience (table 4, column 1). The interaction term considering our proxy for experience, the age of the household head, has a positive and statistically significant coefficient, indicating that children in households with more experienced herders indeed were overall less affected by the shock.

Second, we test if households with diversified income sources are better able to cushion the effects of the dzud (table 4, column 2-3). Our first measure of income diversification is a variable measuring the number of household members engaged in non-herding activities. The triple interaction term considering this proxy is not statistically significant, indicating that income from non-herding activities did not play a relevant role in taming the negative impact of the dzud (table 4, column 2). Next, we consider the number of income transfers that the household receives regularly, i.e. either once a month or every two months (table 4, column 3). The estimated coefficient on the triple interaction term considering this mitigation channel is positive and statistically significant, indicating that households resorted to income transfers in order to preserve children's health during the 2010 dzud. The table also shows that the non-interacted term measuring the number of income transfers regularly received by the

households is negative and statistically significant, suggesting that households that receive a higher number of transfers are relatively disadvantaged.¹¹

We then explore the impact of availability of health facilities (table 4, column 4-5). The first proxy – a district-level dummy variable indicating whether the district has the maximum number of health facilities – has no statistically significant effect in mitigating the negative effects of the shock. Neither do we find any significant evidence that the presence of a maternity house in a district cushions the impact of the dzud. These findings suggest that the local health infrastructure does not matter during a crisis.

Last, we assess the role of emergency aid. Our first proxy for emergency aid is the tons of food and animal fodder distributed per district (table 4, column 6). Interestingly, the triple interaction term has a positive sign and is significant at the 1 percent level, thus indicating that emergency aid indeed mitigates the negative impact of the dzud. Each additional ton of emergency aid delivered in a child's district increases the height-for-age z-scores by 0.061 standard deviations for children of exposed cohorts living in most affected districts. Given that the average amount of aid delivered per district is 26 tons, the total positive effect of emergency aid on children's height is relatively large. We find statistically significant results also on the second proxy of aid, an indicator variable taking the value one if an international organization is active in a given district (column 7). In particular, the presence of an international organization almost offsets the negative effect of the dzud for children of exposed cohorts and living in most affected districts.

6.4 Robustness tests

We conduct various tests on the robustness of our results. First, we employ alternative definitions of dzud intensity. In our main regressions (tables 3-4) we considered the dzud intensity index calculated for year 2010, and defined most affected districts as those districts with an index above the 85th percentile of the distribution. In the first of our robustness tests (Appendix table A2, column 1), we change this threshold to the 75th percentile. In column 2, we maintain the threshold fixed at the 85th percentile and compute the indicator for most affected districts considering an average of the dzud intensity index in years 2009 and 2010 (this way, we account for the fact that dzud-related livestock losses started in late 2009).

¹¹ Indeed, the most frequently received income transfers by the households in our survey sample are the Human Development Fund (for elderly, disabled, students), the state social pension, the students' allowances, and the disability pensions.

Using these indicators, we obtain similar estimates as those reported in our main regressions. Results are also statistically significant when using the continuous dzud intensity index as defined in eq. 1, although by definition the estimated coefficient is of smaller magnitude (table A2, column 3).

As a second set of robustness tests, we conduct placebo dzud tests. In these tests, we used dzud intensity for the years 2008 and 2012 when deriving indicator variables for most affected districts (table A2, columns 4 and 5, respectively). None of the placebo proxies is statistically different from zero. This evidence confirms that our analysis captures effects that are specific to the dzud in winter 2009/2010.

Third, we tackle the issue of endogenous dzud-related migration, which is seldom done in the existing literature.¹² For this test, we exploit information on the location of individuals in 2009, just before the 2009-2010 dzud. By considering parental location in 2009, we are able to identify children's location at the same time. The data allows us to identify children's location in 2009 for a total of 814 children. For 14 of them (1.7%), location in 2009 was different from location at the time of the survey. For these children, hence, we measure the weather shock referring to their district of residence in 2009. This way, we avoid errors in the assignment of the dzud intensity index due to endogenous dzud-related migration. As table A4 shows, our main results are all maintained, also when taking into account endogenous migration.

7. Conclusions

In this paper, we explore the impact of the particularly harsh winter of 2009/2010 (locally referred to as *dzud*) on child health in Mongolia. Even by Mongolian standards, where extreme weather events are not uncommon, the 2010 dzud caused catastrophic damage, resulting in the death of more than 8 million livestock. With global warming, it is likely that such types of events will occur with greater frequency in the future.

We employ data on child anthropometrics stemming from a household survey that was particularly designed for this research topic. Our analysis exploits exogenous variation in the intensity of the 2010 dzud across time and space and thus identifies causal effects of the dzud.

¹² An exception is the study by Akresh et al. (2012).

We employ a diff-in-diff approach to detect the effects of the dzud on children's height-for-age z-scores. Further, we investigate the role of four channels in mitigating the negative effects of the shock, using diff-in-diff-in-diff estimations.

Results reveal that the 2010 dzud significantly slowed down the growth trajectory of affected children, with effects which are still observable two years after the shock occurred. Of all affected cohorts of children, the negative effect of the weather event had the largest magnitude for children from herding households. However, in households where the head had a higher experience in herding, children suffered relatively less. Our results also suggest that alternative income sources in the form of transfers play a relevant role in reducing the negative consequences of the dzud. Differently, access to medical facilities does not appear to mitigate the consequences of the dzud. Instead, there is strong evidence that access to emergency aid mitigates the negative consequences of the dzud. Both the amount of emergency aid delivered per district and the presence of an international organization in a given district relieves the negative impact of the shock. These preliminary results are encouraging, pointing towards an area where policy interventions may prove beneficial.

8. References

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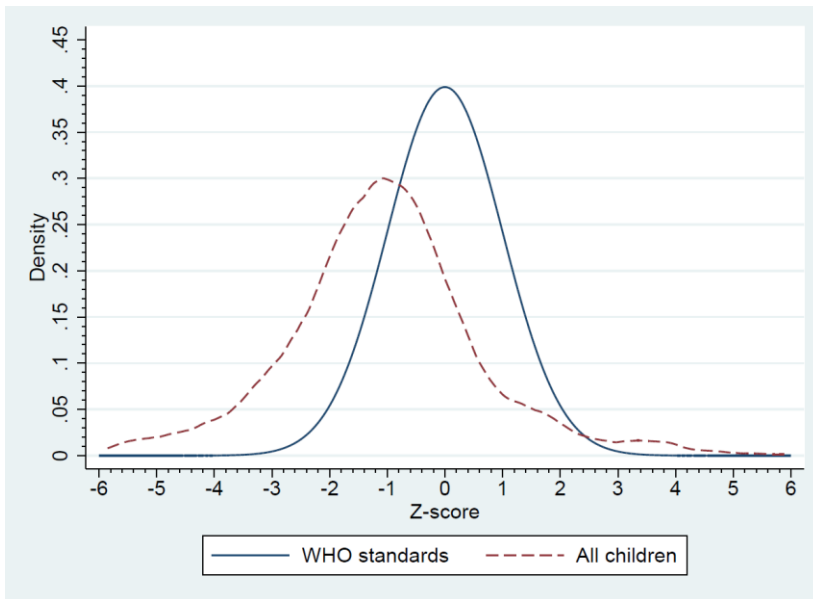
Figures and Tables

Fig. 1: Map of Mongolia, showing the location of the survey area



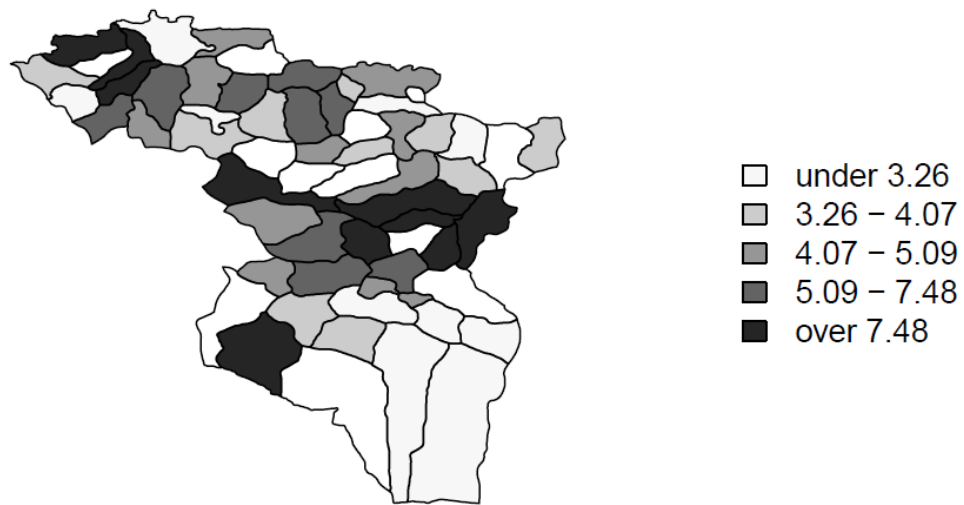
Note: Map shows aimags (provinces) of Mongolia. Aimags shaded in grey indicate the survey area.

Fig. 2: Distribution of height-for-age z-scores in Mongolian sample and international reference dataset



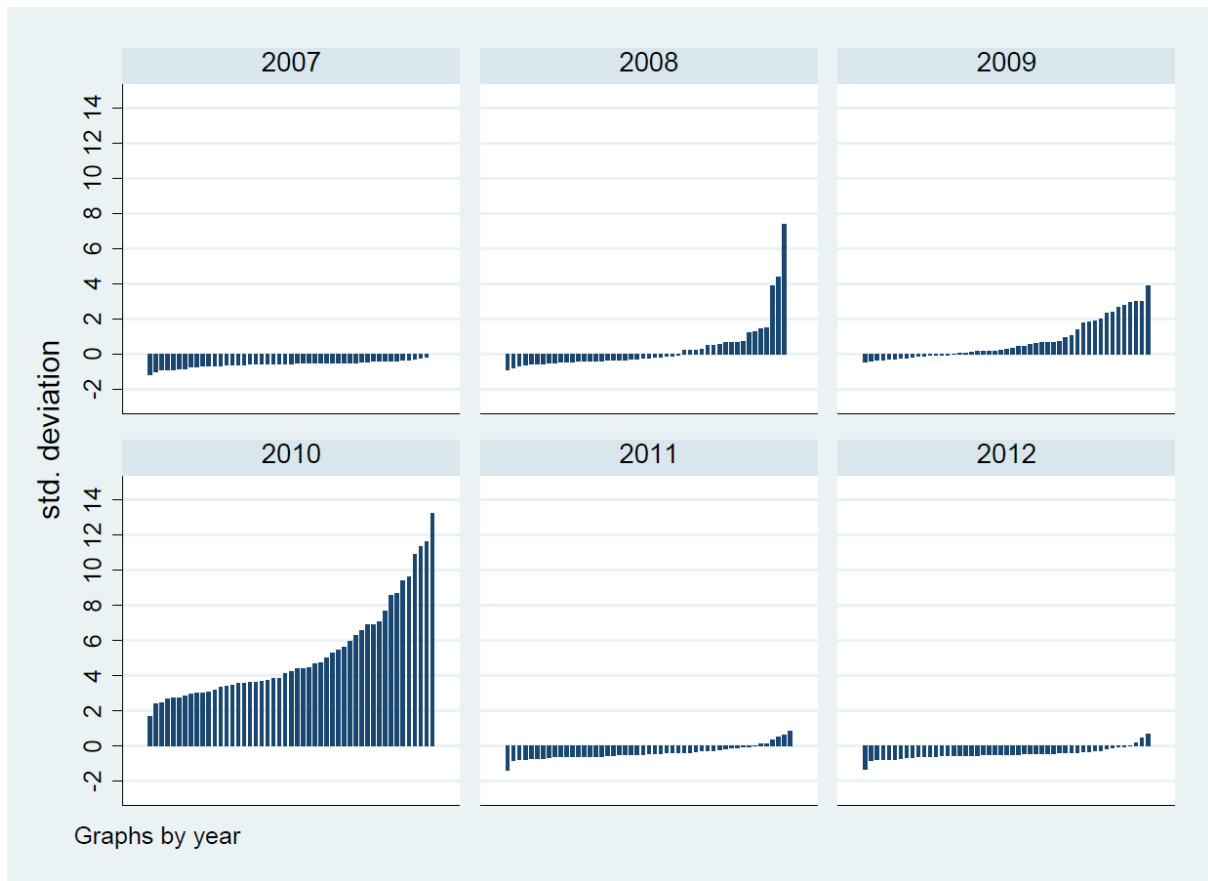
Source: Coping with Shocks in Mongolia Household Survey and WHO Child Growth Standards dataset.

Fig. 3: Spatial variation in the dzud-intensity index across survey districts



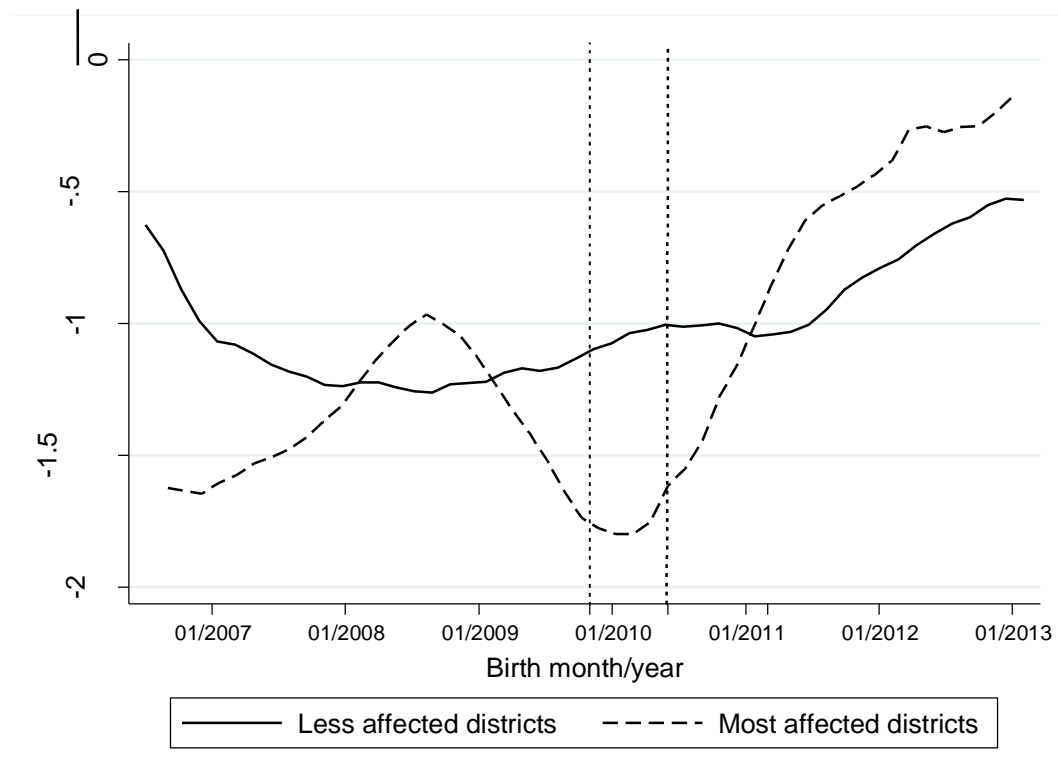
Note: Dzud intensity index calculated based on equation 1. Only district included in the household survey are shown. Source: Livestock Census 1970-2010.

Fig. 4: Distribution of dzud intensity between 2007 and 2012 across survey districts



Note: Dzud intensity index calculated based on equation 1. Each bar represents one district. Source: Livestock Census 1970-2010.

Fig. 5: Children’s height-for-age z-scores over time in districts that were most affected and less affected by the 2010 dzud



Note: Dzud intensity index calculated based on equation 1. Most affected districts are defined as districts with a dzud intensity index above the 85th percentile of the distribution. The vertical dotted lines indicate the start (November 2009) and the end (June 2010) of the dzud. The vertical solid line indicates the time threshold used to define dzud-exposed cohorts (exposed alive or in utero). Source: Coping with Shocks in Mongolia Household Survey and Livestock Census 1970-2010.

Table 1: Summary statistics

	Mean	SD	Min	Max	N in subgroup
<i>Dependent variable</i>					
Height-for-age z-score	-1.04	1.67	-5.85	5.88	829
<i>Mitigation channels (herders 2009 only)</i>					
District has max number of health facilities	0.35	0.48	0	1	481
Maternity house in district	0.77	0.42	0	1	481
Amount aid in district	28.05	23.16	0	82.26	481
IO in district	0.58	0.49	0	1	481
N. regular transfer sources	1.53	0.69	0	4	481
N. members in non-herding activities	0.46	0.76	0	3	481
<i>Child controls</i>					
Female	0.50	0.50	0	1	829
Khalkh	0.62	0.48	0	1	829
Durvud	0.20	0.40	0	1	829
Bayad	0.13	0.34	0	1	829
Other ethnicity	0.04	0.21	0	1	829
<i>Mother controls</i>					
Age	30.64	6.05	17	58	821
Primary & illiterate	0.01	0.10	0	1	821
Primary & literate	0.15	0.35	0	1	821
Lower secondary	0.23	0.42	0	1	821
Upper secondary	0.35	0.48	0	1	821
University	0.26	0.44	0	1	821
<i>Head of household controls</i>					
Age	34.97	9.22	21	76	829
Primary & illiterate	0.03	0.16	0	1	829
Primary & literate	0.26	0.44	0	1	829
Lower secondary	0.27	0.44	0	1	829
Upper secondary	0.33	0.47	0	1	829
University	0.11	0.32	0	1	829
Female	0.05	0.21	0	1	829
Married	0.94	0.24	0	1	829
No religion	0.31	0.46	0	1	829
Buddhist	0.66	0.47	0	1	829
Other religion	0.02	0.15	0	1	829

Table 1: Summary statistics (continued)

	Mean	SD	Min	Max	N in subgroup
<i>Household controls</i>					
Size	4.74	1.31	2	11	829
Proportion 0-5	0.35	0.14	0	0.67	829
Proportion 6-14	0.14	0.16	0	0.67	829
Proportion adults	0.50	0.13	0	0.86	829
Proportion elder	0.01	0.04	0	0.67	829
Asset index	0.05	2.19	-3.36	6.24	829
Rural	0.38	0.49	0	1	829

Notes: The asset index is computed using a principal component analysis of 30 dummy variables indicating ownership of assets bought more than 12 months before the interview.

Sources: Coping with Shocks in Mongolia Household Survey; Mongolian Red Cross.

Table 2: Nutritional status by socio-economic characteristics

	Mean height-for-age z-scores	Standard deviation of height-for-age z-scores	Percentage of stunted children ^a	Percentage of severely stunted children	N
All	-1.04	1.67	24.8	10.6	829
Govi-Altai	-1.20	1.63	28.0	12.6	214
Uvs	-1.08	1.72	26.8	11.7	343
Zavkhan	-0.87	1.62	19.8	7.7	272
0-5	-0.13	1.75	17.2	6.3	64
6-11	-0.73	1.97	18.3	14.1	71
12-23	-0.97	1.99	30.1	12.5	136
24-35	-1.09	1.55	24.4	9.9	131
36-47	-1.32	1.53	28.3	11.2	152
48-59	-1.13	1.42	24.8	7.1	141
>=60	-1.28	1.40	23.1	12.7	134
Male	-1.07	1.65	26.6	10.1	414
Female	-1.02	1.69	23.1	11.1	415
<i>Difference</i>	<i>-0.06</i>		<i>3.50</i>	<i>-1.00</i>	
Non-herding households in 2009	-0.94	1.80	25.3	11.8	348
Herding households in 2009	-1.12	1.57	24.5	9.8	481
<i>Difference</i>	<i>0.18</i>		<i>0.80</i>	<i>2.00</i>	
Head literate	-1.02	1.67	24.4	10.4	807
Head illiterate	-1.80	1.40	40.1	18.2	22
<i>Difference</i>	<i>0.77**</i>		<i>-15.7</i>	<i>-7.8</i>	
Soum or aimag centres	-0.96	1.79	26.1	11.1	514
Rural	-1.19	1.45	22.9	9.8	315
<i>Difference</i>	<i>0.23</i>		<i>3.2</i>	<i>1.3</i>	
Exposed	-1.20	1.47	25.2	9.8	580
Non exposed	-0.69	2.01	24.1	12.4	249
<i>Difference</i>	<i>-0.51***</i>		<i>1.1</i>	<i>-2.6</i>	
Most affected districts ^b	-1.08	1.91	27.8	14.8	209
Other districts	-1.03	1.58	23.9	9.2	620
<i>Difference</i>	<i>-0.05</i>		<i>3.9</i>	<i>5.6[§]</i>	

Notes: a. Children with height-for-age z-scores below -2 SD and below -3 SD are considered stunted and severely stunted, respectively. b. Most affected districts are defined as districts with a dzud intensity index above the 85th percentile of the distribution. § significant at the 11 percent level, * significant at 10 percent level, ** significant at 5 percent level, and *** significant at 1 percent level.

Source: Coping with Shocks in Mongolia Household Survey. Sources: Coping with Shocks in Mongolia Household Survey and NSO Livestock Census 1970-2010.

Table 3: The impact of the dzud, OLS

Dependent variable: Height-for-age z-score	Full sample	Herding households 2009	Non-herding households 2009
	(1)	(2)	(3)
<i>Child controls</i>			
(Exposed) x (Most affected district)	-0.325 [0.538]	-1.256* [0.741]	0.473 [0.736]
Exposed	-0.043 [0.348]	-0.025 [0.351]	0.100 [0.799]
Female	0.182* [0.106]	-0.030 [0.145]	0.448** [0.198]
Durvud	-0.520 [0.411]	0.167 [0.470]	-0.652 [0.607]
Bayad	-0.574 [0.420]	0.257 [0.615]	-0.831 [0.566]
Other ethnicity	-0.458 [0.439]	-0.100 [0.524]	-0.306 [0.685]
<i>Mother's controls</i>			
Age	0.011 [0.012]	0.036*** [0.013]	-0.007 [0.021]
Primary	0.222 [0.354]	-0.182 [0.446]	1.393 [1.258]
Lower secondary	0.135 [0.293]	-0.130 [0.417]	0.689 [1.151]
Upper secondary	0.114 [0.307]	-0.170 [0.431]	0.792 [1.123]
University	0.434 [0.341]	0.345 [0.498]	1.174 [1.145]
<i>Head of household controls</i>			
Age	0.014 [0.010]	0.028* [0.015]	0.013 [0.015]
Primary	0.840** [0.390]	1.255*** [0.449]	0.978 [0.866]
Lower secondary	0.693* [0.400]	0.890** [0.430]	0.973 [0.886]
Upper secondary	1.078*** [0.405]	1.209** [0.475]	1.620* [0.922]
University	1.062** [0.460]	1.441** [0.575]	1.380 [0.950]
Female	0.626 [0.617]	-0.004 [0.956]	0.464 [0.735]
Married	0.572 [0.526]	0.017 [0.860]	0.912 [0.601]
Buddhist	0.021 [0.149]	-0.114 [0.188]	0.046 [0.289]
Other religion	0.345 [0.371]	-0.196 [0.615]	0.511 [0.470]

Table 3: The impact of the dzud, OLS (continued)

Dependent variable: Height-for-age z-score	Full sample	Herding households 2009	Non-herding households 2009
	(1)	(2)	(3)
<i>Household controls</i>			
Size	0.000 [0.065]	0.014 [0.080]	-0.065 [0.118]
Proportion 0-5	-1.252 [1.958]	3.042 [2.418]	-4.670 [3.401]
Proportion 6-14	-2.221 [1.928]	0.957 [2.234]	-4.535 [3.323]
Proportion adults	-1.065 [1.774]	2.857 [2.073]	-5.011* [2.885]
Asset index (2nd quintile)	0.154 [0.218]	0.128 [0.226]	-0.366 [0.612]
Asset index (3rd quintile)	0.408 [0.282]	0.702** [0.301]	-0.348 [0.636]
Asset index (4th quintile)	0.498* [0.298]	0.586 [0.369]	-0.363 [0.630]
Asset index (5th quintile)	0.090 [0.339]	0.215 [0.457]	-0.843 [0.605]
Rural	-0.108 [0.254]	-0.024 [0.336]	0.278 [0.685]
Observations	821	824	826
R-squared	0.274	0.403	0.313
Interview month FE	YES	YES	YES
Soum FE	YES	YES	YES
Birth year FE	YES	YES	YES
Soum-specific trend	YES	YES	YES
N subpopulation	-	476	345

Notes: Most affected districts are defined as districts with a dzud intensity index above the 85th percentile of the distribution. * significant at 10 percent level, ** significant at 5 percent level, and *** significant at 1 percent level. Robust standard errors in brackets.

Table 4: The effects of mitigation channels

Dependent variable: Height-for-age z-score	Experience in herding	Income diversification		Access to health infrastructure		Access to emergency aid	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
<i>Shock and mitigation channels</i>							
(Exposed) x (Most affected district)	-3.395*** [1.090]	-1.413* [0.763]	-2.085** [0.872]	-1.075 [1.113]	-1.252 [1.432]	-2.741*** [0.885]	-3.969*** [0.589]
(Exposed) x (Most affected district) x (HH head age)	0.068*** [0.023]						
(Exposed) x (Most affected district) x (N. HH members in non-herding activities)		0.388 [0.296]					
N. HH members in non-herding activities		-0.120 [0.206]					
(Exposed) x (Most affected district) x (N. transfers received by HH)			0.577* [0.300]				
N. transfers received by HH			-0.453*** [0.125]				
(Exposed) x (Most affected district) x (Max n. facilities)				-0.332 [1.370]			
(Exposed) x (Most affected district) x (Maternity house)					-0.006 [1.618]		
(Exposed) x (Most affected district) x (Amount aid in district)						0.061*** [0.020]	
(Exposed) x (Most affected district) x (IO in district)							3.954*** [1.035]
Exposed	-0.030 [0.365]	-0.020 [0.352]	-0.152 [0.356]	-0.022 [0.351]	-0.025 [0.351]	-0.033 [0.359]	-0.069 [0.343]
Child, mother and HH controls	YES	YES	YES	YES	YES	YES	YES
Observations	824	824	824	824	824	824	824
R-squared	0.413	0.406	0.419	0.403	0.403	0.413	0.419
Interview month FE	YES	YES	YES	YES	YES	YES	YES
Soum FE	YES	YES	YES	YES	YES	YES	YES
Birth year FE	YES	YES	YES	YES	YES	YES	YES
Soum-specific trend	YES	YES	YES	YES	YES	YES	YES
N subpopulation	476	476	476	476	476	476	476

Notes: Sample only includes children from herding households. Most affected districts are defined as districts with a dzud intensity index above the 85th percentile of the distribution. * significant at 10 percent level, ** significant at 5 percent level, and *** significant at 1 percent level. Robust standard errors in brackets. The same set of child controls, mother controls, head of household controls, and household controls as in table 3 is included.

Appendix

Table A1: The impact of the dzud (OLS) with step-wise inclusion of control variables

Dependent variable: Height-for-age z-score	Herding households 2009		
	(1)	(2)	(3)
<i>Child controls</i>			
(Exposed) x (Most affected district)	-1.210*	-1.199*	-1.256*
	[0.696]	[0.691]	[0.741]
Exposed	-0.303	-0.319	-0.025
	[0.334]	[0.338]	[0.351]
Female		0.026	-0.030
		[0.151]	[0.145]
Durvud		0.774*	0.167
		[0.396]	[0.470]
Bayad		1.123**	0.257
		[0.508]	[0.615]
Other ethnicity		0.281	-0.100
		[0.453]	[0.524]
<i>Mother's controls</i>			
Age			0.036***
			[0.013]
Primary			-0.182
			[0.446]
Lower secondary			-0.130
			[0.417]
Upper secondary			-0.170
			[0.431]
University			0.345
			[0.498]
<i>Head of household controls</i>			
Age			0.028*
			[0.015]
Primary			1.255***
			[0.449]
Lower secondary			0.890**
			[0.430]
Upper secondary			1.209**
			[0.475]
University			1.441**
			[0.575]
Female			-0.004
			[0.956]
Married			0.017
			[0.860]
Buddhist			-0.114
			[0.188]
Other religion			-0.196
			[0.615]

Table A1: The impact of the dzud (OLS) with step-wise inclusion of control variables (continued)

Dependent variable: Height-for-age z-score	Herding households 2009		
	(1)	(2)	(3)
<i>Household controls</i>			
Size			0.014 [0.080]
Proportion 0-5			3.042 [2.418]
Proportion 6-14			0.957 [2.234]
Proportion adults			2.857 [2.073]
Asset index (2nd quintile)			0.128 [0.226]
Asset index (3rd quintile)			0.702** [0.301]
Asset index (4th quintile)			0.586 [0.369]
Asset index (5th quintile)			0.215 [0.457]
Rural			-0.024 [0.336]
Observations	829	829	829
R-squared	0.311	0.316	0.403
Interview month FE	YES	YES	YES
Soum FE	YES	YES	YES
Birth year FE	YES	YES	YES
Soum-specific trend	YES	YES	YES
N subpopulation	476	476	476

Notes: Sample only includes children from herding households. Most affected districts are defined as districts with a dzud intensity index above the 85th percentile of the distribution. * significant at 10 percent level, ** significant at 5 percent level, and *** significant at 1 percent level. Robust standard errors in brackets.

Table A2: Robustness tests (definition of dzud intensity and placebo)

Dependent variable: Height-for-age z-score	Herding households 2009				
				Placebo tests	
	Most affected district defined as districts with losses above the 75th percentile	Most affected districts based on 85th percentile of livestock mortality in 2009 and 2010	Continuous dzud intensity index	Most affected districts based on 85th percentile of livestock mortality in 2008	Most affected districts based on 85th percentile of livestock mortality in 2012
	(1)	(2)	(3)	(4)	(5)
(Exposed) x (Most affected district, 75th)	-1.364** [0.612]				
(Exposed) x (Most affected district, shock 2009 & 2010)		-1.585** [0.692]			
(Exposed) x (Continuous dzud index)			-0.226** [0.105]		
(Exposed) x (Most affected district, shock 2008)				-0.318 [0.681]	
(Exposed) x (Most affected district, shock 2012)					-0.567 [0.731]
Exposed	0.164 [0.361]	0.016 [0.353]	1.010 [0.620]	-0.132 [0.364]	-0.107 [0.389]
Child, mother and HH controls	YES	YES	YES	YES	YES
Observations	824	824	824	824	824
R-squared	0.406	0.406	0.405	0.397	0.398
Interview month FE	YES	YES	YES	YES	YES
Soum FE	YES	YES	YES	YES	YES
Birth year FE	YES	YES	YES	YES	YES
Soum-specific trend	YES	YES	YES	YES	YES
N subpopulation	476	476	476	476	476

Notes: Sample only includes children from herding households. * significant at 10 percent level, ** significant at 5 percent level, and *** significant at 1 percent level. Robust standard errors in brackets. The same set of child controls, mother controls, head of household controls, and household controls as in table 3 is included.

Table A3: Robustness tests (endogenous migration)

Dependent variable: Height-for-age z-score	Baseline model			Experience in herding	Income diversification		Access to emergency aid	
	(1)	(2)	(3)		(4)	(5)	(6)	(7)
<i>Shock and mitigation channels</i>								
(Exposed) x (Most affected district, 85th)	-1.288 [§] [0.807]			-3.037*** [1.067]	-1.994** [0.939]	-1.394 [0.846]	-2.838*** [0.959]	-4.234*** [0.783]
(Exposed) x (Most affected district, 75th)		-1.242* [0.690]						
(Exposed) x (Continuous dzud index)			-0.215* [0.113]					
(Exposed) x (Most affected district, 85th) x (HH head age)				0.056** [0.023]				
(Exposed) x (Most affected district, 85th) x (N. transfers received by HH)					0.506* [0.302]			
N. transfers received by HH					-0.455*** [0.128]			
(Exposed) x (Most affected district, 85th) x (N. HH members in non- herding activities)						0.246 [0.296]		
N. HH members in non-herding activities						-0.103 [0.193]		
(Exposed) x (Most affected district, 85th) x (Amount aid in district)							0.062*** [0.020]	
(Exposed) x (Most affected district, 85th) x (IO in district)								4.521*** [1.240]
Exposed	-0.083 [0.346]	-0.008 [0.358]	0.848 [0.634]	-0.084 [0.354]	-0.219 [0.344]	-0.072 [0.346]	-0.080 [0.355]	-0.164 [0.334]
Child, mother and HH controls	YES	YES	YES	YES	YES	YES	YES	YES
Observations	814	814	814	814	814	814	814	814
R-squared	0.409	0.410	0.410	0.416	0.424	0.410	0.419	0.430
Interview month FE	YES	YES	YES	YES	YES	YES	YES	YES
Soum FE	YES	YES	YES	YES	YES	YES	YES	YES
Birth year FE	YES	YES	YES	YES	YES	YES	YES	YES
Soum-specific trend	YES	YES	YES	YES	YES	YES	YES	YES
N subpopulation	471	471	471	471	471	471	471	471

Notes: Sample only includes children from herding households. § significant at the 11 percent level, * significant at 10 percent level, ** significant at 5 percent level, and *** significant at 1 percent level. Robust standard errors in brackets. The same set of child controls, mother controls, head of household controls, and household controls as in table 3 is included.