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Extreme weather events and child height: Evidence from Mongolia

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Abstract

We provide new evidence on the impact of one severe weather shock on child height in Mongolia. Our focus is on the extremely harsh winter – locally referred to as *dzud* – of 2009/10, which caused more than 23 percent of the national livestock to perish. This resulted in a food insecurity situation for many Mongolian households. Our analysis identifies causal effects by exploiting exogenous variation in the intensity of the shock across time and space. Results reveal that the shock significantly slowed the growth trajectory of exposed children from herding households. This negative effect is still observable three years after the shock and, hence, likely to persist. Moreover, we explore the role of socio-economic characteristics and mitigation channels to cushion the impact of the weather shock. Wealthier households and households led by a more experienced head are better able to protect their children from the negative consequences of the 2009/10 winter shock. There are also gender-specific effects, with boys more strongly affected than girls. There is indicative evidence showing that the provision of emergency aid mitigates the negative consequences of the dzud. Moreover, child height has a significant and positive association with households' receipt of informal help. Our findings are robust to alternative measures of shock intensity.

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

JEL: I15, J13, O12

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1. Introduction

Shocks experienced during childhood can have long-term effects on individual human capital. In developing countries, where insurance markets are incomplete or non-existent, households often have difficulties smoothing their consumption when facing income shocks (e.g., Townsend 1994; Udry 1994; Zimmerman and Carter 2003). Children are particularly vulnerable to shocks, given that the foundations of human capital are laid during early childhood (Cunha and Heckman 2007). Understanding how shocks impair children's anthropometric outcomes and what strategies are effective in mitigating shocks has important policy implications.

In this paper, we provide new evidence on the impact of one severe weather shock on child height in Mongolia. Our focus is on the extremely harsh winter of 2009/10, which was characterized by extremely cold temperatures, excessive snow, and a very long duration. The winter caused 10.3 million livestock to perish; more than 23 percent of the national stock. The phenomenon of high livestock mortality due to extreme winter conditions is referred to as *dzud* in Mongolian. The 2009/10 dzud resulted in a situation of food insecurity for many households and caused a wave of distress migration of impoverished herders to urban centers. In January 2010, the Mongolian government declared a natural disaster, seeking international assistance in emergency relief (United Nations Mongolia Country Team 2010). We explore the effects of the 2009/10 winter on children who experienced the shock in utero or as infants of up to 4 years and examine their anthropometric outcomes three years after the shock.

A large body of empirical studies analyzes the effects of shocks during pregnancy and early childhood on child development and health trajectories later in life.[1] According to the 'fetal origins' hypothesis (Hales and Barker 1992), the fetus adapts to unfavorable nutrition in utero, which leads to permanent changes in physical structure, physiology, and metabolism in adulthood. A number of biomedical and epidemiological studies find supportive evidence for the fetal origins hypothesis. Yet, these studies often cannot attribute causal relationships due to the difficulty of defining proper control groups (Almond and Currie 2011). Recently,

[1] See Strauss and Thomas (1998, 2008), Currie (2009), and Martorell (1997) for a review of the literature.

economists investigated the impact of shocks on child anthropometric outcomes, using identification strategies that allow drawing causal inferences.[2]

One group of economic studies focusses on the impact of rainfall shocks in empirical contexts where households strongly depend on rainfed agriculture. For example, Hoddinott and Kinsey (2001) investigate the impact of a drought in the mid-1990s on child anthropometrics using panel data from rural Zimbabwe. Hoddinott and Kinsey find that children exposed to the drought when aged 1-2 years face significantly lower growth velocity compared to children of the same age measured in years with average rainfall. In contrast, the drought does not affect the growth of children who were exposed to the shock when older than two years. Using the same data, Alderman, Hoddinott and Kinsey (2006) show that children exposed to either the Zimbabwean civil war or droughts in the early 1980s when younger than three years and are significantly shorter as preschoolers. When employing these two shocks as instruments for preschool height, Alderman et al. further find a significant positive relationship between height at preschool age and height at adolescence. Dercon and Porter (2014) examine the long-term effects of the infamous 1984 famine in Ethiopia on the height of young adults, using a measure of household-level drought exposure as self-reported by households. Dercon and Porter find that children who were exposed to the famine at 2-3 years of age are significantly shorter as young adults than individuals of the same cohort who were unaffected by the drought.

A more recent approach is to model the intensity of rainfall shocks with aggregate-level rainfall data. For example, Tiwari et al. (2013) document that an increase in rainfall from historical rainfall patterns – a positive rainfall shock – significantly increases the weight of young children in rural Nepal. In a study of rural Nigeria, Rabassa et al. (2014) find that excess rainfall in the current season has a significantly negative effect on children's weight. In contrast, excess rainfall in the previous season significantly increases children's weight, which is interpreted as a positive income effect.

Another recent group of studies examines the link between child anthropometrics and violent conflict as one specific example of a negative shock. For instance, Minoiu and Shemyakina (2014) analyze the impact of the civil war in Côte d'Ivoire between 2002 and 2007 on child anthropometrics, using multiple cross-sectional surveys from before, during, and after the

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[2] An early example is the study by Stein et al. (1975).

war. They find that children living in regions with high conflict intensity have significantly lower height-for-age z-scores than children of the same age but residing 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. Bundervoet, Verwimp and Akresh (2009) explore the impact of the Burundian civil war on child anthropometric outcomes. They find that one additional month of war exposure significantly reduces the height of children in rural Burundi. Akbulut-Yuksel (2009) analyzes the long-term effects of experiencing physical destruction caused by Allied bombings in Germany during WWII during childhood on height and other human capital outcomes in adulthood. Results show that individuals who experienced high levels of destruction, as children, are about 1 cm shorter than their peers. A significantly negative effect of conflict exposure on anthropometric outcomes has also been documented for the Eritrean-Ethiopian border war of 1998-2000 (Akresh et al. 2012b), the Rwandan civil war (Akresh et al. 2011), the Nigerian Biafra war (Akresh et al. 2012a), and the al-Aqsa Intifada (Mansour and Rees 2012).

Our contribution to the existing literature is threefold. First, we provide new evidence on the negative consequences of one particular type of weather shock – an extremely severe winter characterized by long spells of extreme cold and excess snow fall. The results of our analysis may be relevant for other regions characterized by a continental climate that exhibit large seasonal variation in temperature, such as Russia, inland China, or the Himalayas. In contrast, most of the existing literature on the impact of weather shocks on child outcomes cited above focuses on drought and rainfall shocks in tropical or dry climate zones.

Second, our analysis assesses the role of factors that may attenuate the impact of the 2009/10 dzud on children's outcomes, which is seldom found in existing research.[3] Our analysis sheds light on socio-economic factors, health infrastructure, and access to emergency aid. Moreover, we provide new evidence on the role of coping strategies applied by households during the shock. We are able to do so by drawing on unique household survey data that contains rich retrospective information on the household-level dzud experience, food aid received, and household behavior during the shock. Thus, our analysis bridges and contributes to related fields of research on household strategies to cope with shocks (e.g., Cameron and Worswick

[3] Two exceptions are the study by Minoiu and Shemyakina (2014), which provides a detailed analysis of the household-level experiences of the Ivorian civil war, and the study by Dercon and Porter (2014), which accounts for food aid provided during the Ethiopian famine.

2003; Carter et al. 2007; Carter and Maluccio 2003; Takasaki et al. 2004) and on the effects of food aid (e.g., Quisumbing 2003; Yamano et al. 2005). In contrast, many existing studies on the impact of shocks on child anthropometrics use Demographic and Health Surveys (DHS) (Akresh et al. 2012a; Akresh et al. 2012b; Rabassa et al. 2014; Tiwari et al. 2013). The limitation of DHS data is that a standardized questionnaire is employed, which records few information on the socio-economic characteristics of households and their exposure to shocks.

Third, the winter of 2009/10 is considered in Mongolia "the worst [winter] in nearly half a century" (United Nations Mongolia Country Team 2010, p. 7). Yet, to the best of our knowledge, our study is the first to identify the causal effects of the 2009/10 dzud on individuals.[4] This is particularly surprising, given that harsh winters are quite likely to occur again (Batima et al. 2005; Dagvadorj et al. 2009). Thus, the insights from our study may be applied to policies responding to future dzuds.

From a methodological perspective, the winter of 2009/10 exhibits characteristics that allow identifying the causal impact of the shock on child outcomes. On the one hand, the intensity of the shock varied strongly within the survey region. On the other hand, its abrupt start, severity, extremely long duration, and disastrous effect on livestock came unexpectedly to households. Thus, we argue that the shock is exogenous to child outcomes.

Our estimation approach is a difference-in-differences strategy that exploits large exogenous variation in the intensity of the 2009/10 dzud across space and birth cohorts. This quasi-experimental setting allows us to draw causal inferences of the impact of the 2009/10 dzud on children's height. More specifically, 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 (Behrmann et al. 2004). 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. The sample, drawn from a stratified design, includes some 800 children who are representative of the population of the region. The data includes precise information on individuals' location of residence at the beginning of the shock, which allows us to rule out effects of endogenous shock-related migration. In addition, we draw on historic livestock data to derive a district-level index of dzud intensity. With 47 districts included in the regression

[4] There are, however, a few insightful studies on the 2009/10 dzud in Mongolia that draw on anthropological fieldwork methods (Murphy 2011), qualitative methods, including focus groups and key informant interviews (Fernández-Gimenez et al. 2012a), and secondary sources, such as reports from state agencies and NGOs (Sternberg 2010).

sample, our shock measure is finer and, thus, more accurate than measures in most of the above-cited studies on the impact of shocks.

Results reveal that the 2009/10 dzud significantly slowed down the growth trajectory of exposed children from herding households. This negative effect is still observable three years after the shock occurred and, hence, likely to persist. Wealthier households and households led by a more experienced head are better able to protect their children from the negative consequences of the dzud. There is also evidence for gender-specific effects, with boys more strongly affected by the dzud than girls. The medical infrastructure in a district does not alleviate the consequences of the dzud. Rather, it appears that the children of accessibility constrained households, measured by snow depth during the dzud, faced poorer health outcomes. The provision of emergency aid appears to mitigate the negative consequences of the dzud. However, this finding should be considered as indicative evidence only, as there are selection effects at play. Receiving informal help during the shock also leads to significantly better child outcomes. Results are robust to including controls for child, mother, and household characteristics, fixed effects for year of birth and district, and district-specific time trends. Moreover, all main results hold when using alternative measures of dzud intensity.

The paper proceeds as follows. The next section describes the situation of herders in Mongolia and summarizes the causes and consequences of the 2009/10 dzud. Section 3 introduces the household survey data as well as the historic livestock census data used to construct the shock intensity measure. The estimation strategy is outline in Section 4. This is followed by a discussion of results and robustness tests in Section 5. The last section summarizes the results and discusses policy implications.

2. Herding and Weather Shocks in Mongolia

Livestock activities are an important source of income for Mongolians living outside the capital city of Ulaanbaatar. In 2011, about 29.6 percent of Mongolian households owned livestock and 21.7 percent were herders, for whom pastoral activities represent the main source of living (NSO 2011, 2013). The total number of livestock was 45.1 million in 2013, with herders having an average herd size of 213 animals (NSO 2013). Herders typically hold a mix of camel, cattle, horses, sheep and goats. In addition to providing meat, milk and dairy products to herding households, animals are an income source, through the sale of meat, milk, wool, and skins. Most herders are nomadic or semi-nomadic, seasonally rotating between campsites to ensure optimal grazing conditions for their herd. Land is a common property resource in Mongolia and, in principle, herders move and set up their campsites independently. Yet, despite the extremely low population density of 1.76 persons per square kilometer, there is overgrazing in some areas, particularly around provincial and district centers. Moreover, a complex system of use rights on campsites, animal shelters and wells practically restricts the free movement of herders (Murphy 2011). As a result, most herders follow similar seasonal migration patterns every year.

Weather risk and shocks are an inherent part of the pastoral livelihood. In particular, the extreme continental climate of Mongolia makes herders vulnerable to dzuds.[5] Dzuds are reported as one major cause of rural poverty and distress migration to urban centers (World Bank 2006, 2009). While dzuds have occurred in the past, we argue that for two reasons the 2009/10 dzud was an exogenous shock to Mongolian herders.

First, the context of herding in Mongolia changed dramatically after the 1990s transition period. During the socialist era, most livestock activities were organized in collective production units characterized by a very high division of labor, while households were only permitted to own a limited number of private livestock. The state provided all veterinary care, took care of pasture management, organized the production of winter animal fodder, and delivered post-disaster relief following dzuds (Schmidt 1995). With the beginning of the transition period in the early 1990s, cooperatives were privatized based on a voucher system with individuals obtaining asset shares and livestock of the former cooperatives. During the period of economic collapse unemployment rose dramatically, particularly among former civil servants. The number of private herders increased sharply in the 1990s as "few other livelihood options existed" outside herding (Bedunah and Schmidt 2004, p. 168). Yet, with the sudden collapse of the public social safety net, the responsibility for risk prevention and shock coping shifted to private herders (Murphy 2011). Many of those 'new herders' had little experience in herding and in particular in coping with dzuds.

[5] Herders distinguish between various types of *dzud*, depending on the underlying weather conditions (Murphy 2011, p. 32-33). For example, a *white dzud* occurs in winters with excessive snowfall that prevents animals from grazing. In contrast, a *black dzud* is characterized by too little precipitation in winter, often preceded by a drought in the previous summer. An *iron dzud* happens when winter temperatures fluctuate significantly and cause the snow to melt and then ice over. A *cold dzud* occurs if temperatures are excessively low, thus increasing the calorie intake animals that require to maintain their body temperature. During *combined dzud*, several of the aforementioned weather conditions occur in a single winter. Lastly, a *hoof dzud* is the result of overgrazing or degradation of pastures due to trampling, which is caused by poor pasture management.

Second, the intensity of the 2009/10 dzud was exceptional. Figure 1 provides an overview of the development of the livestock sector in Mongolia between 1960 and 2011. The figure shows that the extent of livestock mortality caused by the 2009/10 dzud, a single winter season, was unprecedented. More than 10.3 million livestock perished in 2010, corresponding to about 23.9 percent of the national herd. Herders had been exposed to dzuds also in relatively recent years. Indeed, there were three consecutive dzuds in the winters of 1999/00, 2000/01 and 2001/02, which also caused relatively high mortality when aggregating the losses over these three years. Yet, the mortality in each of these winters did not exceed 5 million losses and was hence not comparable in magnitude to the 2009/10 dzud. Reports from international organizations also emphasize that the 2009/10 dzud had a much more severe impact on livestock and households compared to previous dzuds (see, for instance, United Nations Mongolia Country Team 2010). Moreover, it was the long duration of unfavorable weather conditions between 1999 and 2002, with cold winters and droughts in summertime that weakened livestock over many months, that caused animals to die of exhaustion. In contrast, the 2009/10 dzud caused massive livestock death within a relative short time period, as will be outlined in the following paragraph. Thus, we assume that households did not anticipate the magnitude of livestock losses caused by the 2009/10 dzud.

Unfavorable weather conditions started with a drought in summer 2009 that prevented animals from building up fat reserves and impeded the production of hay as animal fodder during the winter months.[6] The winter started unusually early, with heavy snowfall occurring in October 2009, which soon melted. With a sudden drop in temperature, the melted snow water iced over, thereby preventing animals from reaching grass. From November 2009 onwards, livestock started perishing. In December 2009 there was another sudden drop in temperature, which further weakened the livestock. Record low temperatures continued in January 2010, with day-time temperatures below minus 40° Celsius for several days in a row in some areas. During this time period, animals could not leave the shelters for grazing and herders started depleting their fodder reserves. The government of Mongolia declared a national disaster in January 2010 and appealed to the international community to assist by providing animal fodder, fuel, food, warm clothing, blankets, and medical equipment. By March 2010, 5.8 million livestock had perished. Unusually heavy snowfall continued throughout the spring months, with 60 percent of the land still covered with snow at the end

[6] This paragraph is based on reports from the European Commission (2010), IFRC and MRCS (2010), and the United Nations Mongolia Country Team (2010).

of April, thus preventing livestock from grazing. The snow cover also blocked many roads and posed obstacles for rural households trying to reach markets and health facilities. Once the weather warmed, starting in May 2010, the thick layer of snow melted, resulting in flash flooding that further isolated rural communities and increased livestock losses.

The socio-economic effects of the dzud were disastrous for many herders. It is estimated that some 9,900 herding households (about 5.8 percent of all herding households) lost their entire herd and, hence, their consumption, income and asset base (National Statistical Office of Mongolia 2010, p. 92). These households dropped out of the herding economy; many moving as distressed migrants to provincial capitals or Ulaanbaatar in search of employment. A further 33,000 households lost half of their herd (United Nations Mongolia Country Team 2010, p. 8), which pushed them below the herd size considered the minimum necessary for sustaining a pastoralist livelihood in the long term. The excessive livestock mortality also caused “trauma, fatigue and stress” among herders (ibid, p. 15). In addition, children, the elderly, pregnant women, and lactating mothers were considered to be most vulnerable to the dzud, especially if they lived in remote areas and could not reach health facilities.

A rapid assessment of the dzud situation conducted by the International Federation of Red Cross and Red Crescent Societies (IFRC) and the Mongolian Red Cross Society (MRCS) in January 2010 concluded that, “the food security of the most affected herder families is seriously threatened” (IFRC and MRCS 2010, p. 3). According to this report, there was a risk of chronic malnutrition among children due to both diminished overall food intake and poor dietary diversity. Many affected households were running out of fuel for heating, animal fodder and food stocks. An in-depth case study of four communities conducted by Fernández-Gimenez et al. (2012b) found that the intake of milk and meat products continued to be low in the summer of 2010, given that large numbers of cows had perished during the dzud. Also, herders purposefully reduced the amount of milk taken to encourage livestock recovery.

The government of Mongolia through its National Emergency Management Agency (NEMA) and in cooperation with bilateral and multilateral donor agencies and NGOs provided emergency assistance to affected households. One of the key actors delivering food aid during the dzud was MRCS.[7] By March 2010, MRCS distributed emergency aid to 1,200 severely

[7] In this paragraph, we describe emergency relief activities carried out by MRCS, which published detailed and transparent information on the criteria for targeting districts and households. For most other organizations that delivered food aid during the dzud, such information is not available. However, Fernández-Giménez et al. (2012a) report that in their survey area in the

affected households in 66 districts. Households received food and non-food items to meet their immediate needs for a period of three months. This operation was implemented using the Red Cross Federation's Disaster Relief Emergency Fund (DREF) (IFRC 2010a). Given the seriousness of the situation, commitments for aid distribution were then extended and by July 2010 emergency aid had been distributed in a further 89 districts that were classified by NEMA as those experiencing highest livestock mortality (IFRC 2010b). Within these districts, MRCS targeted 1,800 households that lost all livestock and that were socially vulnerable (that is, single parents, individuals with disabilities, elderly living alone, and families with more than three children under 16 years of age). Each beneficiary household received a relief package consisting of three months of staple foods: 75 kg of wheat flour, 15 kg of rice, 3 kg of sugar, 3 liters of cooking oil, 3 kg of salt, and 3 blocks of tea (IFRC 2010bp. 4). Additionally, beneficiaries received both a warm coat and a pair of working boots for each adult and child. By October 2010, 1,100 households among those who had already received DREF aid were provided with further support in the form of cash grants, amounting to 325,000 Mongolian Tugrug per household; about 240 US dollars. Grants were mostly used to purchase animals (IFRC 2010b, 2011).

3. Data

3.1 Household Survey Data

Our analysis builds on the *Coping with Shocks in Mongolia Household Panel Survey*, which is collected by the German Institute for Economic Research 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 in western Mongolia (Fig. 2) and covers 49 out of 61 *soums* (districts) in these three provinces.[8] The survey area represents all major ecological zones prevalent in Mongolia, including grass steppe, desert, mountainous regions, and forest areas. The sample comprises 1,768 households, of which about 1,100 are herders, and 7,200 individuals. The survey is a panel with three yearly waves, with data collection

provinces of Arkhangai and Bayankhongor, most aid organizations delivering food aid during the dzud used selection criteria to target households.

[8] An *aimag* (province) is the top level of Mongolia's administrative structure. Each aimag is subdivided into several *soums* (districts), which have an average size of 4,200 square kilometers. Soums are further subdivided in *bags* (sub-districts). As of 2014, there are 21 aimags, 329 soums, and 1,720 bags in Mongolia.

ongoing between 2012 and 2015. The cross-sectional analysis presented here relies on the first wave.

The survey is based on a multi-stage design, which ensures that the sample is representative of the population in western Mongolia. The Population and Housing Census of 2010 is the sampling frame. In the first sampling step, the three provinces were subdivided into nine mutually exclusive strata of province centers (urban areas), district centers and rural areas (the latter two are considered as rural). In the second step, Primary Sampling Units (PSU) were randomly drawn from 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 eight households were randomly selected. 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 standard errors of 3.24 and 3.23 for urban and rural areas, respectively. Each interviewed household represents about 20 households in urban areas and 40 households in rural areas. All results presented in the following account for survey design effects, including the clustering of standard errors at the PSU level.

The household survey was collected continuously throughout the year, with interviews for the first wave taking place 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 (i.e., recording child anthropometrics with greater precision as time progresses), we control for month of interview fixed effects in our estimations.

The household questionnaire is especially designed to explore how households cope with weather shocks. It includes retrospective questions on the 2009/10 dzud, as well as questions about their assets, strategies in herding, formal and informal insurance, transfers received, social networks, and migration history in addition to the standard household-level and individual-level information typically captured in household surveys (such as household demographics, education, health, consumption expenditures, and income-earning activities). In addition, a community questionnaire was administered in each sample district. This questionnaire records population characteristics, infrastructure and service facilities, economic activities in the district, the intensity of the 2009/10 dzud, and assistance provided to households during the dzud.

A questionnaire module on child anthropometrics was filled out for all children, aged 0 to 6 years, present during the survey interview.[9] The dataset comprises anthropometric measures – height, weight, and middle-arm circumference – of 850 children. These children were born between July 2006 and February 2013, and were thus aged between 0 and 81 months at the time of the interview, with a median age of 36 months.[10] 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.

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 height of an international reference population of children of the same age and sex, divided by the standard deviation of the international reference population. A height-for-age z-score of zero indicates that a child has the expected height for a healthy child of his or her age and sex. A z-score significantly below zero indicates that a child is shorter than healthy children of exactly the same age and sex 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.[11] We exclude the 21 children from our Mongolian sample who have implausible z-scores (-6, 6), as suggested by WHO (2009). In order to rule out concerns of endogenous dzud-related migration, we use each child's district of residence in 2009. Out of a total of 829 children with non-missing anthropometric data, 44 (5.3%) were in a different location in 2009 compared to 2012. We drop the 14 children who, in 2009, were somewhere not covered by our survey. Moreover, we drop 13 children from the sample who have missing information either in the location of residence in 2009 or in other variables of interest. This leaves us with a sample of

[9] Enumerators were asked to revisit sample households if the children were absent during the interview in district and provincial centers. This procedure allowed us to obtain anthropometric measures of 152 additional children. Yet, a few children had turned 6 when their anthropometric measures were recorded. Due to high transportation costs, it was not possible to revisit households in rural areas.

[10] Children's age in months was computed as the difference between a child's date of measurement and his or her date of birth, which is reported in the survey module on child anthropometrics. The age so obtained was found to be consistent with that reported in the household roster, so that we can rule out reporting or data entry errors in the date of birth.

[11] The WHO Child Growth Standards dataset consists of a sample of healthy breastfed 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. The dataset is considered to represent child growth under optimal environmental conditions and is used for assessing child growth anywhere in the world.

802 children, belonging to 596 households and living in 47 different districts in 2009, just before the dzud began unfolding.

Figure 3 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 that 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 poorer nutrition for the average child in our Mongolian survey.

One limitation of the data at hand is that the fertility history of sample women was not collected. The analysis presented in the following is thus based on the sample of children who survived the dzud. It is likely that there was mortality selection, with unborn babies from the most strongly affected households either not being carried to term or passing away as infants. In fact, in March 2010, the Mongolian Ministry of Health reported infant and under-five mortality rates in dzud-affected provinces to be 42 percent and 38 percent above the national average (United Nations Mongolia Country Team 2010, p. 25). These children might have displayed worse anthropometric outcomes later in life compared to the average sample child. Our results may hence be regarded as a lower bound estimate of the total effects of the 2009/10 dzud on children.[12]

3.2 Constructing a Measure of Shock Intensity

We exploit the extraordinarily rich historic livestock data available for Mongolia to define an intensity measure of the 2009/10 dzud across space.[13] Since the 1950s, the NSO implements an annual livestock census in mid-December. The enumerators, working with local authorities, count the number of livestock in each *bag* (sub-district), which is then aggregated

[12] Potential downward bias due to mortality selection is a common challenge in the literature on child health (see Dercon and Porter 2014 for a discussion). While nationally representative Multiple Indicator Cluster Surveys (which include modules on child health and fertility) are implemented in Mongolia on a regular basis, such data is not made available to researchers. Hence, unfortunately, we cannot consult alternative data sources to examine the magnitude of the mortality bias. Similarly, we lack a comprehensive database to assess whether households postponed births during the dzud.

[13] Alternatively, one could derive a measure of dzud intensity based on weather data. Yet, the 2009/10 dzud was caused by a combination of unfavorable weather conditions occurring over a relatively long time span, as outlined in Section 2. Aggregating various sub-measures of climate conditions into one common index is not trivial. For this reason, we opted for using district-level livestock data to construct a dzud intensity index. Our choice is supported by the design of the index-based insurance covering dzud-related livestock losses for Mongolian herders, which was introduced in 2006. For a similar reason, the threshold for insurance payouts is also defined in terms of district-level livestock losses – and not based on weather data (Skees and Enkh-Amgalan 2002). As a robustness test, we calculate a dzud intensity measure based on snow depth and obtain similar results (see Section 5.6).

to the district level. The livestock census collects information on the total stock and losses of adult animals. District-level data, for each of the five major species in Mongolia, is available electronically, starting with 1970.

One potential shortcoming of the livestock census data is that mortality rates are not disaggregated by loss category. Instead, the census subsumes any losses caused by disease, accidents, animal depredation, and disaster (dzud, heavy rain, fire, and lightning) into a single number. Ideally, we would prefer to only consider livestock losses caused by dzud. Yet, both NSO reports and descriptive statistics suggest that it is dzud losses that explain most variation in livestock mortality over time.

Based on the livestock census data, we derive a standardized measure of the intensity of the dzud in survey district *k* as follows:[14]

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

where we relate the livestock mortality occurring in 2010 to the long-term local patterns in livestock mortality between 1970 and 2008 in the same district.[15] Negative values of the dzud intensity index indicate lower than average livestock mortality in 2010, while positive values indicate higher than average mortality rates. The index varies between 1.7 and 13.2 with a mean value of 5.2. In short, loss rates in 2010 are above the long-term average in every district surveyed. Figure 4 shows the spatial variation in the dzud intensity index for the 47 districts included in our survey area in western Mongolia. This considerable spatial variation mirrors the fact that dzuds are highly localized.

Figure 5 illustrates the district-level dzud intensity index over 2007-2012 in western Mongolia. Clearly, the year 2010 stands out as especially intense. The graph for 2010 also shows that the dzud was particularly intense in a small number of districts. To account for this nonlinear distribution of the 2009/10 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

[14] Demont (2013) uses a similar equation for deriving a measure of rainfall shocks in India.

[15] 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 5.6 below.

compare districts in which the 2009/10 dzud was catastrophic to districts in which it was moderate.[16] It is important to stress that the total effect of the dzud (compared to non-affected districts in other regions of Mongolia) would be even larger. In other words, our analysis provides a lower-bound estimate of the total damage caused by the 2009/10 dzud.

4. Estimation Strategy

Our empirical strategy exploits two distinct features of the 2009/10 dzud, which make it a highly suitable case for studying the impact of shocks: First, there was significant variation in dzud intensity across space, as outlined in the previous section. Second, the mass mortality of livestock occurred within a contained time period. Drawing on the sequence of events outlined in Section 2, we assume that the dzud started in November 2009 and ended in June 2010.[17] Therefore, there is also exogenous variation in the exposure to the shock across birth cohorts. We exploit this exogenous temporal and spatial variation in child exposure to the dzud by adopting a difference-in-differences approach.

The literature on child health provides strong evidence that unborn babies and infants are most vulnerable to nutritional shocks (e.g., Behrmann et al. 2004; Cunha and Heckman 2007; Martorell 1997). Therefore, we define the cohort of children who experienced the dzud in utero or as infants up to 4 years as the treatment group. These are children born between July 2006 and March 2011, who were between 15 and 81 months at the time of the survey. Our control group consists of children who were conceived after the dzud (that is, children who were born after March 2011). Children of the control group were between 0 and 29 months of age when their anthropometric measures were collected. Figure A1 in the Appendix provides an overview of the timeline of the dzud, as well as the definition of exposed cohorts. The empirical strategy is summarized in Fig. 6, which shows height-for-age z-scores for sample children born between 2006 and 2013 in the districts that were most affected and less affected by the 2010 dzud. The vertical dotted lines indicate the start and the end of the dzud. Children born during the dzud and who lived in the most severely affected districts have significantly

[16] In fact, the 2009/10 dzud was more severe in our survey region (where 34.2 percent of livestock died) compared to other regions of Mongolia (where 20.5 percent of livestock died).

[17] This definition of the dzud period is rather conservative as most likely households suffered from the negative consequences of the shock for a longer period of time. Therefore, in our robustness section we also consider two alternative dzud periods that extend the duration of the dzud by two and six months, respectively (see Section 5.6).

lower height-for-age z-scores than children born during the dzud but who lived in less affected districts.

In line with the literature discussed in Section 1, we estimate the impact of the dzud on child anthropometrics using the following baseline model:

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

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 for characteristics 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. *Exposed cohort*$_i$ * *most affected district*$_k$ represents the 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 3.2). 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, $\propto_k$ stands for district fixed effects, which control for any pre-existing differences in child outcomes across districts before the dzud. δ_t are year of birth fixed effects, accounting for the fact that worse nutritional status is typically observed among older children given that nutritional deficits accumulate with age (Akresh et al. 2012b, p. 334). The term λ_{kt} represents a district-specific linear time trend that captures 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 clustered at the PSU level.

As child-level controls, we include the gender of the child and ethnicity (Khalk, Durvud, other). As regards mother characteristics, we account for her age and education (primary, secondary, tertiary). Controls for the characteristics of the head of household are age, whether the head is female, education, and religion (Buddhist). Household characteristics include household size, the number of children in the age range 0-5 years, household assets (in quintiles),[18] pre-dzud livestock ownership (in terciles),[19] and whether the household's

[18] Using principal component analysis, an asset index is constructed from 30 durables that were bought one year or more before the survey interview. The durables considered include home appliances, furniture, electronic goods, and means of transportation. The continuous asset index is then transformed into dummy variables indicating quintiles.

[19] The number of livestock in 2009 was only collected from households that reported having been affected by the dzud. This information is missing for 42 households, corresponding to about 7 percent of the households in our regression sample. For these households, we estimated the number of livestock in 2009 as follows. Based on the information on the number of

location is rural. 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 2009/10 dzud for children residing in the most severely affected districts and who were alive or in utero when the dzud occurred. In order to obtain insights on the mechanisms through which the dzud affected child height, we estimate Eq. 2 separately for the full sample of children, for children from non-herding households, and for children from herding households.[20]

Next, we explore in more detail the impact of socio-economic characteristics on child height, augmenting Eq. 2 with a triple interaction term:

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

where $socioecon_i$ represents measures of three socio-economic characteristics, which are either child-specific or household-specific variables. Our interest lies in the estimated coefficient β_5, which captures the effect of socio-economic characteristics 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. This estimation as well as all following analyses focuses exclusively on the subsample of children from herding households. The first socioeconomic characteristic is a child's gender. Here, we test if parents allocate different amounts of food to sons and daughters. Second, we focus on experience in herding. The underlying hypothesis is that more experienced household heads were better positioned to defend their livestock against the weather shock and thus suffered fewer livestock losses. We proxy a household head's experience in herding with his or her age. The third characteristic is pre-dzud household wealth, proxied by the number of livestock households owned in 2009 (before the dzud). We test if wealthier households are better able to smooth consumption during the

livestock owned at the time of the interview and on the changes in livestock in the 12 months before the interview, we obtained the number of livestock owned in 2011. Then, we computed the number of livestock in 2009 by assuming an annual growth rate in total livestock of 0.15 (this value is the average growth rate of livestock in year 2012 – a non-dzud year – obtained from the district-level livestock census).

[20] We focus on households that were herders in 2009, before the dzud. Considering the full survey sample, out of 1,094 herding households in 2009, 125 (11.4 percent) lost a significant share of their livestock and dropped out of the herding economy following the dzud. The dzud might have had a particularly severe impact on children of households that stopped herding following the dzud. Defining herding households on the basis of herding activities in 2009, we thus obtain a more accurate estimate of the impact of the dzud on children from herding households. Focusing instead on the sample of households that were herders at the time of the survey collection would underestimate this impact.

2009/10 dzud and hence protect their children from negative consequences on their human capital than poorer households.

Furthermore, we test if mitigation channels alleviate the effects of the dzud on children's height, again using a triple-differences approach:

$$HAZ_{ikt} = \beta_1 X_i + \beta_2 exposed\ cohort_i + \beta_3(exposed\ cohort_i * most\ affected\ district_k) + \beta_4 channel_{ik} + \beta_5(exposed\ cohort_i * most\ affected\ district_k * channel_{ik}) + \alpha_k + \delta_t + \lambda_{kt} + \gamma_m + \varepsilon_{ikt} \quad (4)$$

where $channel_{ik}$ represents measures of each of four mitigation channels, which are either household-level or district-level variables. The first channel is a household's access to aid, which we proxy through its relationship to the local bag governor. Bag governors are elected officials, governing the smallest unit within Mongolia's public administration. Often herders themselves, bag governors keep records of the population in their respective bags, they implement governmental policies, and they organize livestock activities, such as coordinating seasonal work for the production of winter forage, collecting cashmere, and organizing veterinarian services. Moreover, in case of dzuds and other disasters, they organize emergency aid to households in collaboration with state agencies and other organizations (Government of Mongolia 2006). Our hypothesis is that households with close ties to local governors are better informed on aid programs and may even receive preferential access to support. We define a household-level variable taking the value one if the head of household knows the bag governor in his area well.[21]

The second channel is the availability of health facilities in the district center.[22] For pregnant women and young children, medical services and nutritional supplements during a period of extremely cold temperatures and stress on households' resources may be important. While all districts have a resident nurse, a physician and a pharmacy, some districts are also equipped with a health center, a maternity house and a hospital. We construct an indicator variable that is equal to one if a district has the maximum health facilities available.

The degree to which households benefit from health services and aid may be influenced by households' accessibility, which we analyze as the third channel. The district fixed effects

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[21] The original survey question is "How well do you know your bag governor?," with answer options ranging from 1 ("very well") to 5 ("not at all"). We define the variable to take the value one if a household knows the governor well or very well (answer 1 or 2).

[22] For households living in or close to the provincial capital, we consider the provincial center.

included in all specifications already capture the impact of variation across districts in remoteness, terrain features, weather conditions, and so on. However, the data at hand allow us to go beyond such district-level effects by using measures of accessibility at the household and bag levels: First, we consider a household's distance in kilometers to the nearest district center.[23] Second, we employ two measures of snow depth at the bag level (with children from 92 bags included in the regression sample): The average snow cover per day in centimeters during the 2009/10 dzud and an indicator variable taking the value one if snow depth in the bag is below the median.[24]

As the fourth channel, we focus on emergency aid provided to households during the dzud. As outlined above, the 2009/10 dzud was declared a national catastrophe, with the Mongolian government appealing the international community for emergency support in January 2010. We draw on district-level data on the total amount of food and animal fodder distributed to households during the dzud. The aid distribution data were compiled by MRCS and comprises aid provided by the central government, provincial governments, and NGOs. The amount of food aid and animal fodder distributed per district ranges between 0 and 82.3 tons across the 47 survey districts of our regression sample, with an average of 25.9 tons. By employing a district-level measure of the amount of aid distributed and by including district fixed effects, we limit potential problems of selection bias due to aid targeting. However, we caution that results on emergency aid should be considered as indicative evidence only.

In the last part of our analysis, we explore how the coping strategies applied by households during the dzud affected children's outcomes by estimating the following model:

$$HAZ_{ikt} = \beta_1 X_i + \beta_2 exposed\ cohort_i + \beta_3 (exposed\ cohort_i * most\ affected\ district_k) + \beta_4 coping_i + \beta_5 (exposed\ cohort_i * most\ affected\ district_k * coping_i) + \propto_k + \delta_t + \lambda_{kt} + \gamma_m + \varepsilon_{ikt} \quad (5)$$

[23] This variable relates to the location of a household's campsite at the time of the survey collection in 2012/13. Arguably, this measure is a rough approximation to the actual location of a household's campsite during the winter 2009/10, on which no precise information is available.

[24] The snow data – MARS data downscaled by MeteoConsult (Nl) based on ECWMF model outputs – were obtained from the Institute for Environment and Sustainability (2014). The dataset contains daily observations of snow depth in cm for 0.25 degree grid cells between October 1, 2009, and June 30, 2010. The grid-level data was matched to bags. On average, there are 1.8 data points per bag. For the 23 bags in which no data point was available, we assigned the average snow values of the neighboring bags. Snow depth reflects the thickness of the snow layer on the ground and is hence a good indicator for isolation of rural communities. Note that the survey module on migration history does not record information on the bag of residence in 2009. Hence, we match the bag-level snow indicators to a child's bag of residence at the time of the survey, which may introduce a small measurement error.

where $coping_i$ represents measures for six different coping strategies. The questionnaire module records whether households applied any of a precoded list of coping strategies in response to the dzud.[25] These strategies include borrowing money; asking for help from relatives; selling livestock during the dzud; building animal shelters and fences; splitting the herd; and going on temporary migration to ensure better grazing conditions.

While the analysis of coping strategies provides complementary insights into the effects of the dzud on children, a note of caution is warranted. The choice of strategies is likely to be correlated with unobserved household characteristics that may also explain child outcomes. For instance, households that give high priority to child care may also engage in labor-intensive herding strategies in order to minimize the adverse effects of the dzud on livestock. Despite the fact that we control for a large number of socio-economic characteristics, including education of the mother, number of children in the household and household wealth, we cannot rule out endogeneity. Hence, the estimated coefficients on coping strategies should be regarded as correlations only. Moreover, one additional concern is that the nature of the questionnaire design may introduce a selection bias. The module on coping strategies applied during the dzud was only asked to the subsample of households that reported being affected by the 2009/10 dzud, which reduces our sample by 53 children. Yet, as is discussed in Section 5.6 below, a Heckman approach did not reveal any systematic evidence of selection into being affected by the dzud.

5. Results and Discussion

5.1 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 Panel Survey*. The mean height-for-age z-score is -1.07 for the whole sample of children. Overall, about 24 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 percent of children are severely stunted, with z-scores more than 3 standard deviations below the median.

[25] This procedure of directly asking in the survey questionnaire for households' coping strategies in response to shocks is a rather new approach in the development economics literature. See, for instance, Heltberg and Lund (2009), Tongruksawattana et al. (2010), Takasaki et al. (2004), and Cameron and Worswick (2003).

Our figures fit well with the results of three recent national child surveys conducted in Mongolia. The Third National Nutrition Survey (Public Health Institute et al. 2006) implemented in 2004 found the average height-for-age z-score of children of age 6 to 59 months to be -0.97. 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. The Third Multiple Indicator Cluster Survey of 2005 (National Statistical Office and UNICEF 2007) collected data from a national representative sample of children age 0-59 months. The survey revealed that 20.9 and 5.9 percent of children were stunted and severely stunted at the national level, respectively. In western Mongolia, 28 percent of children were stunted and 8.2 were considered severely stunted. Lastly, the Fourth Multiple Indicator Cluster Survey of 2010 (National Statistics Office and UNICEF 2011) revealed that 16 percent of Mongolian children of age 0-59 months were 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 a similar prevalence of malnutrition as do three recent surveys 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 even before the 2009/10 dzud compared to other regions of Mongolia.

Table 2 also shows correlations between child anthropometrics and selected socio-economic characteristics. Boys have slightly higher 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. Height-for-age z-scores are also significantly lower for children in households where the head has only primary education and in households residing in rural areas. 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 562 out of the 802 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 not exposed to the dzud. The z-scores of children living in the most affected districts are not significantly different from those of children living in less affected districts. However, children in most affected districts are significantly more likely to be severely stunted. Lastly, children from households that applied at least one coping strategy during the dzud have significantly better nutritional outcomes.

5.2 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 (columns 1-3), for children from non-herding households (column 4), and for the full sample (column 5).

We find evidence of a strong negative impact of the weather shock on the height of children from herding households (table 3, column 1). Children who were exposed to the 2009/10 dzud as infants or during intrauterine life and who lived in the most severely affected districts (*Exposed*Most affected district*) have height-for-age z-scores 1.67 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 5 percent level. The magnitude of the effect of the 2009/10 dzud on children from herding households is large in comparison with findings on the impact of other types of shocks on child anthropometrics in other countries.[26]

Table A1 in the Appendix shows results for the baseline specification when adding control variables stepwise. The finding of a significant and negative effect of the dzud on child height holds even when no further socio-economic controls and district fixed effects are included (column 1). This underlines the robustness of the main result. Yet, the magnitude of the effect in this simple specification is much smaller (-0.51) compared to the final specification (-1.67). The magnitude of the estimated coefficient of the interaction term (*Exposed*Most affected district*) increases to -0.73 when including the full set of socio-economic controls (column 5). All statistically significant socio-economic controls have the expected signs: Children of better educated mothers are significantly taller than their peers, while children living in female-headed households have significantly worse anthropometric outcomes. Controlling for pre-existing differences in child outcomes across the survey area with district fixed effects (column 6) and additionally accounting for district-specific time trends (column 7) more than doubles the magnitude of the estimated coefficient of the interaction term. This illustrates the importance of controlling for location-specific factors.

In addition, we estimate regressions in which we employ month of birth fixed effects instead of year of birth fixed effects (Appendix, Table A2). Month of birth fixed effects capture

[26] For instance, the height-for-age z-scores of children are reduced by 0.53 standard deviations if they were exposed to the Burundian civil war (Bundervoet et al. 2009), by 0.41 standard deviations if they lived in regions affected by the Ivorian civil war (Minoiu and Shemyakina 2014), and by 0.45 standard deviations if they lived in regions affected by the Eritrean-Ethiopian war (Akresh et al. 2012b).

potential seasonal effects of nutrition and child health, while they come at the cost of significantly reducing the number of degrees of freedom. The estimated coefficient of the interaction term (*Exposed*Most affected district*) is still marginally significant at the 16 percent level for children from herding households, while the magnitude of the effect becomes smaller. Given the low number of observations in our sample, we do not include birth month fixed effects in our main specifications, but maintain birth year fixed effects.[27]

Furthermore, we estimate the determinants of height-for-age z-scores with a mother fixed effects specification (Appendix, table A3).[28] This specification accounts most comprehensively for a child's socio-economic environment, at the cost of reducing the sample size to 227 children, since only children with at least one sibling younger than six years are included in the regression sample.[29] Again, exposure to the dzud significantly reduces the height-for-age z-scores of children from herding households. The estimated coefficient of the interaction term (*Exposed*Most affected district*) has a very similar magnitude (-1.6) as in the baseline specification (-1.67).

Next, we employ a finer measure of length of shock exposure: the number of months a child experienced the dzud (table 3, column 2). Again, the estimated coefficient of the interaction term (*Number of months exposed*Most affected district*) is statistically significant at the 5 percent level. For exposed children living in the districts most severely affected by the dzud, one additional month of exposure reduces a child's height-for-age z-score by 0.26 standard deviations. This is a sizeable effect, as the following calculation shows. Consider a male child of average age (37 months) who lives in a most affected district. The corresponding standard deviation of height in the WHO Child Growth Standards dataset is 3.75. Hence, each additional month of dzud exposure reduces the boy's height by 0.975 (=0.26*3.75) centimeters compared to boys of the same age who live in less affected districts.[30] If the boy

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[27] Most of the results on the effects of socio-economic characteristics and mitigation channels presented in the remaining part of Section 5 also hold when using month of birth fixed effects (results not shown).

[28] See Bhalotra (2008) for a discussion of the advantages of using mother fixed effects.

[29] Our preferred specification would be one based on a sample of siblings of the same mother, in which at least one sibling belongs to an exposed cohort and at least one sibling being non-exposed to the dzud. Yet, such specification is not feasible due to limited sample size.

[30] The impact in centimeters is obtained by multiplying the estimated coefficients of the interaction term (*Number of months exposed*Most affected district*) with the standard deviation of height in the international reference dataset, which is age- and gender-specific. Reorganizing the definition of z-scores yields cm = (z-score)*(standard deviation of height-for-age)+median height. Thus the estimated difference in centimeters between exposed children in most affected districts and exposed children in less affected districts is given by cm = [(predicted z-score if most affected district)-(predicted z-score if less affected district)]*(standard deviation of height-for-age) = (estimated coefficient of the interaction Number of months exposed*Most affected district)*(standard deviation of height-for-age).

was exposed to the dzud for the average number of months (5.39 months), the reduction in height would amount to 5.25 (=5.39*0.26*3.75) centimeters. Moreover, we explore if there are non-linear effects in the length of dzud exposure by including triple interaction terms for children exposed to the dzud for one month up to eight months. Results are presented in Fig. 7. In addition to the results from the baseline specification (which includes year of birth fixed effects) we also show results from a specification which instead includes months of birth fixed effects. Results from both specifications indicate that the dzud had the worst effect for children exposed for 3 months.

The literature on child health provides evidence that the exact timing of shocks matters for child outcomes (e.g., Martorell 1997; Strauss and Thomas 2008). We explore whether the negative effect of the dzud is larger for children exposed during intrauterine life or for those exposed alive (table 3, column 3).[31] Children residing in the most affected districts and exposed to the dzud in utero have height-for-age z-scores reduced by 1.67 standard deviations, while for children exposed alive the z-score is reduced by only about one standard deviation.[32] There is hence some indication that pregnant women and their unborn babies are particularly vulnerable to the dzud.

Last, we estimate the baseline specification for the sample of children from non-herding households (table 3, column 4) and for the full sample of children (column 5). Interestingly, the dzud has no significant effects on the anthropometric outcomes of children from non-herding households. This finding suggests that it is not exposure to harsh weather conditions (to which all children are exposed), *per se*, that causes nutritional deficits in children. Rather, it appears that the mechanism through which the dzud affects children is the loss of livestock. Our results could possibly point towards asset-smoothing behavior of herding households that may have sacrificed their consumption during the dzud months in order to maintain their stock of animals in the medium term. Alternatively, the dzud may have affected pregnant women through stress, with herders seeing their animals perishing and thus their livelihood threatened. Recent studies provide evidence that stress during pregnancy lowers the birth

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[31] Due to the limited sample size, we refrain from conducting more elaborate comparisons between children exposed to the dzud at different ages or during different stages of the pregnancy.

[32] An F-test rejects the hypothesis that the two coefficients are equal at the 21 percent level. However, these results need to be taken with caution, given that the sample of children living in most affected districts and experiencing the dzud while in utero and alive is reduced to 40 and 95 children, respectively.

weight of newborns (e.g., Beydoun and Saftlas 2008; Camacho 2008; Mansour and Rees 2012).

5.3 The Effects of Socio-Economic Characteristics

Next, we present results from OLS regressions that explore whether socio-economic characteristics cushion the impact of the dzud, using triple interaction terms (table 4). Note that this analysis is only conducted for children from herding households.

We find that for girls exposed to the dzud and who lived in the most affected areas, the impact of the dzud is significantly less severe than for boys (column 2). The average height-for-age z-score of exposed girls living in the most affected districts is 0.54 (=0.68-0.14) standard deviations higher than for exposed boys who live in the most affected districts. This is a rather unusual finding in the child anthropometric literature. Most studies that differentiate the impact of shocks by gender either do not find significantly different effects for boys and girls (e.g., Akresh et al. 2012b; Dercon and Porter 2014; Minoiu and Shemyakina 2014; Tiwari et al. 2013) or they find a bias against girls (e.g., Akresh et al. 2011; Maccini and Yang 2009). However, our finding is consistent with recent results from the pediatric literature, showing that male embryos are more vulnerable than female ones (Kraemer 2000; Lawn et al. 2013).

Moreover, results indicate that head of household experience cushions the negative impacts of the dzud on child outcomes, with the coefficient of the triple interaction term being 0.05 (table 4, column 3). Given that the mean age of the head of household is 33.8 years, the magnitude of this effect is large. Older heads of household may be more knowledgeable in herding techniques and may also benefit from past experience in coping with dzuds.

Lastly, there is evidence that households with larger pre-dzud herd size are better able to protect their children against the negative effects of the dzud (table 4, column 4). Exposed children from households that were among the richest tercile of livestock owners in 2009 and who lived in a most affected district have height-for-age z-scores that are about one standard deviation higher than children from poorer households. The triple interaction term (*Exposed*Most affected district*Livestock in 2009, 3rd tercile*) is statistically significant at the 5 percent level. Possibly, the observed difference in child outcomes between wealthier and poorer households reflects consumption smoothing practiced by wealthier households that could afford to draw on their asset base. Wealthier households experienced both higher absolute and relative livestock losses than poorer households.[33] Yet, households with fewer livestock in 2009 were pushed by the dzud close to or even below the herd size considered the minimum for deriving a livelihood from herding. Those poorer households may have opted to sacrifice their consumption in order to protect their surviving livestock and stay in the herding economy in the long term.

5.4 The Effects of Mitigation Channels

In this section, we explore whether various mitigation channels countervailed the negative impact of the dzud, using triple interactions (table 5). The first mitigation channel is households' access to aid, which we proxy with a dummy variable indicating close ties to the local bag governor (column 2). Results indicate that a household's relationship to the bag governor does not make any difference for dzud-exposed children, with the interaction term (*Exposed*Most affected district*Knows bag governor well*) not being statistically significant.[34]

The second mitigation channel is the availability of health infrastructure. Our proxy – a district-level indicator variable measuring whether the district has the maximum possible number of health facilities – has no statistically significant effect in mitigating the negative effects of the shock (table 5, column 3).[35] This finding suggests that the availability of local health infrastructure did not matter during the dzud crisis.

An alternative explanation could be that households did not benefit from health services (and other services provided at district centers, such as shops) because they could not reach those facilities. We test this in table 5, columns 4 to 6. The triple interaction term based on a household's distance to the district center is not statistically significant. Hence, remoteness, *per se*, does not seem to matter for dzud-affected children. In contrast, results on the impact of snow depth are strong: The triple interaction terms (*Exposed*Most affected district*Average*

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[33] We estimate the determinants of household-level dzud intensity following the 2009/10 dzud, considering different dependent variables, such as the percentage of livestock losses, dummy variables indicating losses above certain thresholds, and a dummy variable equal to one if the household reported having been severely affected. We find that households belonging to the wealthiest tercile of livestock owners in 2009 had significantly higher losses than households in the poorest tercile (results not shown).

[34] Similarly, there is no evidence that a close relationship to the soum governor brings any advantages for dzud-exposed children. Also, we do not obtain statistically significant results when employing an indicator variable equal to one if the household head always lived in the same district (results not shown).

[35] Analogous, we do not obtain statistically results when considering instead the presence of a maternity house in the district (results not shown).

snow depth in bag) and (*Exposed*Most affected district*Average snow depth in bag below median*) are both statistically significant at the 5 percent level and of large magnitude. These findings provide further insights into the mechanisms through which the dzud affected households: The thick layer of snow may have posed obstacles for rural households to reach district centers and get food supplies and medical services. Alternatively, the snow cover may have prevented animals from reaching the grass and thus caused animal starvation.

Finally, we assess the role of emergency aid, using the tons of food and animal fodder distributed per district (table 5, column 7). Interestingly, the triple interaction term has a positive sign and is significant at the 1 percent level, suggesting 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 0.07 standard deviations for children of exposed cohorts who live in the most affected districts. Given that the average amount of aid delivered per district is 25.9 tons, the total positive effect of emergency aid on children's height is relatively large.

However, aid allocation was not random, but followed specific criteria. According to IFRC (2010b), aid was targeted to vulnerable households and those who experienced severe livestock losses during the dzud. Using a district-level measure of aid combined with district fixed effects is a first way to limit selection bias. Besides, we include in our regressions a set of household-level variables which influenced aid receipt. In order to assess which factors were most relevant for determining aid allocation, we exploit survey information on whether a household received food aid during the dzud and estimate a logit model of the determinants of aid receipt (Appendix, table A4). We find that poorer households, households with a larger share of children, and households that lost a high percentage of their herd during the dzud were significantly more likely to receive food aid. Aid distribution also appears to be influenced by households' accessibility, with households living at greater distance from the district center and those living in bags with higher snow depth being significantly less likely to receive food aid.[36] Regressions in table 5 include controls for household wealth and

[36] The amount of aid distributed per district is only very weakly correlated with the district-level dzud intensity index. Accessibility appears to partly explain this pattern. Figure A2 in the Appendix shows the spatial variation in aid receipt (a) and snow depth (b). Most of the districts that received a high amount of aid are characterized by relatively low snow depth. t-tests on the amount of aid distributed by district also show that districts with lower snow depth received significantly more aid than districts with higher snow depth.

household composition. Therefore, we limit as much as possible any selection bias due to aid targeting.[37]

5.5 Coping Strategies Applied during the Dzud

In this last part of our analysis, we explore the relationship between households' coping behavior during the dzud and child outcomes (table 6). As discussed in Section 4, we cannot establish a causal link between household behavior and child outcomes and caution that results should be regarded as correlations only. Households that were able to secure immediate help during the dzud – either by borrowing money (column 2) or by receiving help from relatives (column 3) – have significantly better child nutrition outcomes. In contrast to our expectations, selling livestock during the dzud (column 4) does not have any statistically significant association with child height. Building animal shelters and fences during the dzud (column 5) is a means of protecting livestock against the negative effects of excessive cold temperatures and snow. This activity is negatively correlated with child outcomes (although not statistically significant), possibly because it implies additional investments in material, which reduces resources available for consumption expenditures. Other labor-intensive but cost-neutral herding practices, such as splitting the herd to increase care given to animals (column 6) and going on temporary migration during the dzud to reach better grazing conditions (column 7) do not have any significant association with child outcomes.

5.6 Robustness Tests

We conduct a number of tests to verify the robustness of our results. First, we test to what extent our main findings are sensitive to the definition of dzud intensity. Recall that in our baseline specification, we calculated the dzud intensity index for 2010 based on district-level livestock mortality rates and defined as most affected districts those with an index above the 85th percentile of the distribution. In the first robustness test (Appendix, table A5, column 1), we change this threshold to the 80th percentile. In column 2, we now consider the average district-level livestock mortality in 2009 and 2010 and maintain the threshold fixed at the 85th percentile. This way, we account for the fact that dzud-related livestock losses started in late 2009. In column 3, we instead employ the continuous dzud intensity measure as defined in Eq. 1. Further, we employ a household-level measure of shock intensity (column 4), similar to

[37] The triple interaction term (Exposed)*(Most affected district)*(Amount of aid in district) remains positive and statistically significant also in regressions controlling for household-level livestock losses and accessibility measures (results not shown).

Minoiu and Shemyakina (2014) and Dercon and Porter (2014). While this measure is more precise than the district-level shock intensity measure, it is at the same time more likely to be subject to unobserved heterogeneity that may also affect child height. We define an indicator variable that takes the value one if a household self-reports the dzud to be extremely severe (values 0 or 1 on a 0-10 scale). The estimated coefficients of all alternative dzud measures are at least marginally statistically significant, with the t-statistic being always greater than 1.4. The coefficient of the interaction term is always negative and (in the case when the dzud measure is an indicator variable) of comparable magnitude as our baseline results. Moreover, all main results regarding the impact of socio-economic characteristics, mitigation factors and coping strategies are maintained when employing these alternative dzud measures (results not shown).

Next, we draw on snowfall data to derive an alternative measure of dzud intensity (Appendix, table A6).[38] Specifically, we construct an indicator variable that takes the value one if the snow depth in a given district between October 2009 and June 2010 was greater than the median depth across districts. We repeat the baseline regressions as displayed in table 3 with this snow indicator. Results shown in table A6 in the Appendix are very similar to the original estimates, both in terms of magnitude of the interaction terms and level of significance.[39] Again, results are only statistically significant for children from herding households. This underlines the robustness of our results to the choice of shock measure used.

Moreover, we test if our results are sensitive to the definition of the time window of dzud occurrence (Appendix, table A7). In our baseline specification, we define as dzud months those in which livestock died due to immediate weather conditions (November 2009 to June 2010). As a robustness test, we first extend the time window by two months, from October 2009 to July 2010 and then by six months, from August 2009 to September 2010 (see Fig. A1 in the Appendix for an illustration). When extending the time window of the dzud, the coefficient of the interaction term (*Exposed*Most affected district*) increases to 1.82 and 2.02, respectively (columns 1 and 2). Most likely, when extending the dzud time windows our coefficient of interest also captures the negative impact of diseases which may have spread

[38] See footnote 23 for a description of the data source.

[39] We obtain similar results when using the continuous measure of snow depth (results not shown).

following the dzud.[40] We hence consider our baseline specification as a conservative estimate resulting from exogenous weather conditions. Next, we explore whether our main results relate to the specific 2009/10 dzud by performing 'placebo' dzud tests. In these tests, we falsely define dzud intensity for the years 2008 and 2012 when deriving indicator variables for most affected districts (columns 3 and 4, respectively). As expected, none of the placebo dzud measures is statistically different from zero. These results confirm that our main analysis captures effects that are specific to the dzud in 2010. Also, we repeat the baseline specification but now use weight-for-age z-scores as dependent variable (column 5). Weight-for-age reflects a child's short-term nutritional status. In line with expectations, we do not find any significant effects of the 2009/2010 dzud on the weight of children measured three years after the shock.

Lastly, we test if there is evidence for selection into the subsample of dzud-affected households that were asked about their coping strategies applied during the dzud. We repeat the estimations using a Heckman procedure (Appendix, table A8). The exclusion restriction is a measure of the long-term local risk of experiencing dzud. More specifically, this variable is defined as the number of times a district experienced annual livestock losses above 10 percent in the period 1970-2009.[41] Results show that lambda is not statistically significant. This indicates that children from households that selected into the dzud-affected sample do not differ significantly in their height-for-age z-scores from children with average characteristics who were drawn randomly from the population. We conclude that OLS provides unbiased results.

6. Conclusions

In this paper, we explore the impact of the particularly harsh winter (locally referred to as *dzud*) of 2009/10 in Mongolia on the height of children younger than 6 years old. Even by Mongolian standards, where extreme weather events are not uncommon, the 2009/10 dzud caused catastrophic damage, resulting in the death of more than 10 million livestock. With global warming, it is likely that such extreme weather events will occur more frequently in the

[40] In the warmer months following the dzud, the thawing and decomposition of carcasses may spread infections to children and adults, either by direct contact, or through contamination of water sources (United Nations Mongolia Country Team 2010).

[41] In order to obtain a variable that varies at the household level, this district-level risk variable is interacted with household residence in rural areas.

future. We employ data on child anthropometrics stemming from a household survey that was particularly designed to investigate the impact of dzud. Our analysis exploits exogenous variation in the intensity of the 2009/10 dzud across time and space and thus identifies causal effects of the dzud on child height.

Results reveal that the 2009/10 dzud significantly slowed down the growth trajectory of exposed children living in the most affected districts compared to children of the same age but living in less affected districts. Yet, the dzud only had statistically significant effects for children from herding households. The magnitude of the negative effect of the dzud is large. This is particularly surprising given the fact that Mongolia is a lower middle income country. Our results are robust to alternative shock measures at the district and household level, to the inclusion of socio-economic controls, district fixed effects and district time trends, and to mother fixed effects specifications. Also, we can exclude potentially confounding effects due to dzud-related migration. Moreover, the negative impact of the shock is significantly less severe for children living in households with a more experienced head and in wealthier households. We interpret the latter finding as consumption-smoothing behavior of better-off households. There is also evidence for significant gender effects: Exposed boys living in the most affected districts are significantly shorter than exposed girls living in the most affected districts. Although unusual in the economics literature on shocks and child outcomes, this finding is consistent with recent pediatric research showing higher vulnerability for male than female embryos.

In terms of mitigation factors, having a close relationship to the local governor, the availability of health facilities, or a household's proximity to the next urban center does not influence the negative impact of the shock on children. Instead, accessibility – proxied by the depth of snow in the sub-district – significantly affects shock-exposed children. There is also indicative evidence that emergency aid mitigates the negative consequences of the dzud. Similarly, obtaining informal help during the dzud by borrowing money or receiving assistance from their relatives is correlated with better child nutrition status.

The negative effects of malnutrition can be curtailed with appropriate nutritional and psychosocial interventions that target young children (e.g., Gomes Victora et al. 2010; Schroeder et al. 1995). However, the time window for such interventions to be effective is short (Martorell 1997). Studies from various empirical contexts have documented that malnutrition during early childhood can lead to reduced school outcomes (Alderman et al. 2006), lower stature in adulthood (Akresh et al. 2012a; Alderman et al. 2006; Dercon and

Porter 2014), and worse health status as adults (Dercon and Porter 2014; Maccini and Yang 2009). These outcomes are in turn correlated with lower productivity and lower long-term income-earning capabilities (Strauss and Thomas 2008). These effects may also be transmitted to the next generation, as shorter mothers are more likely to have newborns with lower birth weight (Hoddinott and Kinsey 2001).

Applying those insights to the case of Mongolia has two implications. First, given that Mongolian children exposed to the 2009/10 dzud are on average 37 months old at the time of the survey collection, it is very likely that the effects of foregone growth will persist. With the continuation of the panel data collection – with anthropometric measures being recorded in every annual survey wave – we will be able to trace these children even further in the future and assess both their growth trajectories and their entry into school over time.

Second, our findings suggest that extreme covariate shocks such as the 2009/10 dzud are too severe for households to cope with these shocks by themselves. Bearing a cohort of children that very likely will not be able to make use of their full potential in cognitive skills, physical stature, and health as adults inflicts macroeconomic costs to the Mongolian society at large. Our results on the positive effects of emergency aid in mitigating the negative consequences of the shock are encouraging. Supporting households that have small infants or pregnant mothers among their members and that live in areas strongly affected by a dzud with nutritional supplements appears to be a cost effective intervention to prevent long-term damage in the human capital of children. This seems to be a promising area for policy interventions when signs of an extreme winter are occurring in the future.

7. References

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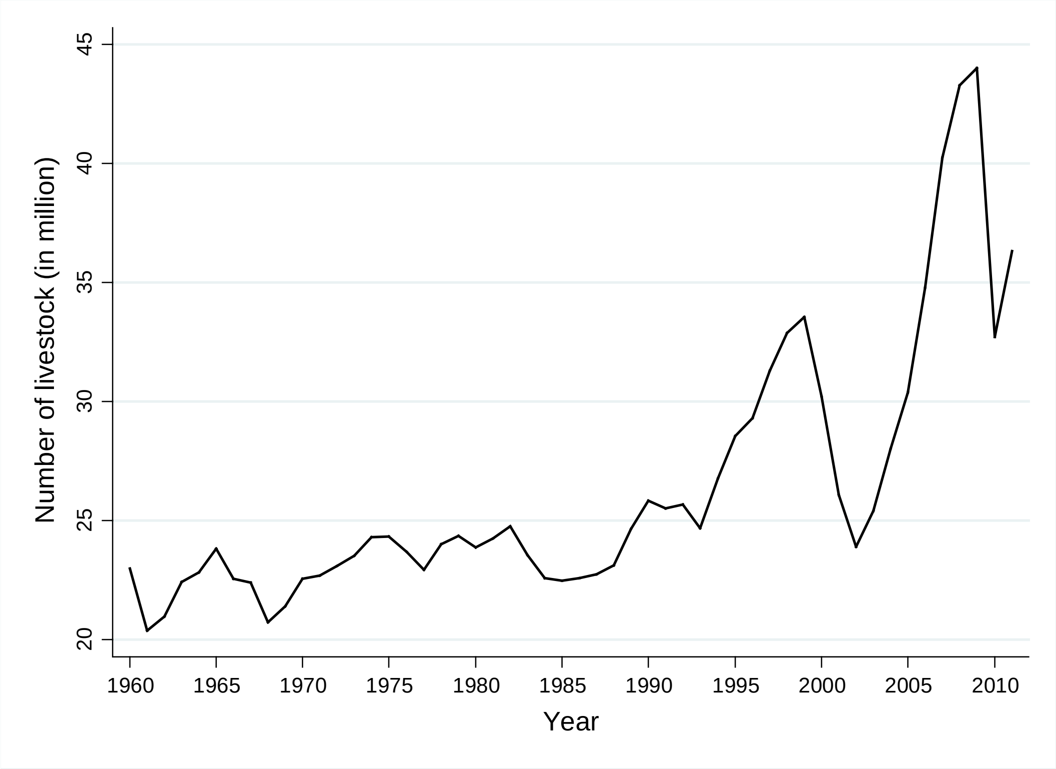
Figures and Tables

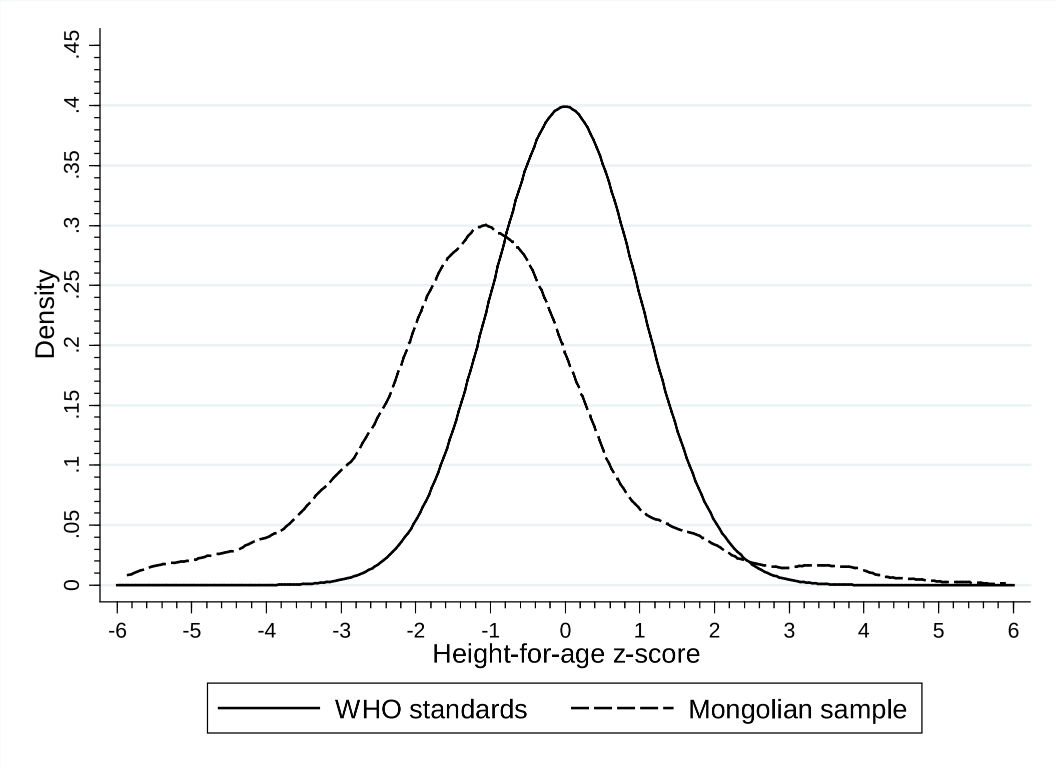
Fig. 1: Livestock development in Mongolia, 1960-2011



Source: Mongolia Livestock Census.

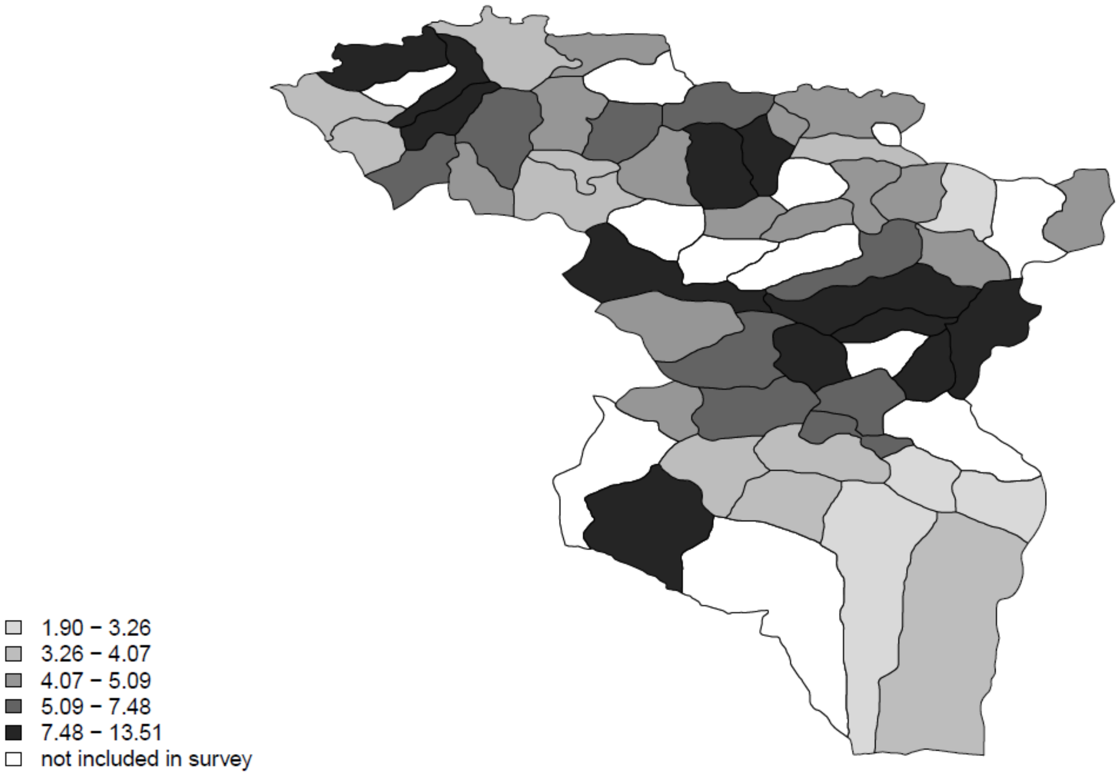
Fig. 2: Map of Mongolia, showing the location of the survey area

Fig. 3: Distribution of height-for-age z-scores in Mongolian sample and WHO reference dataset



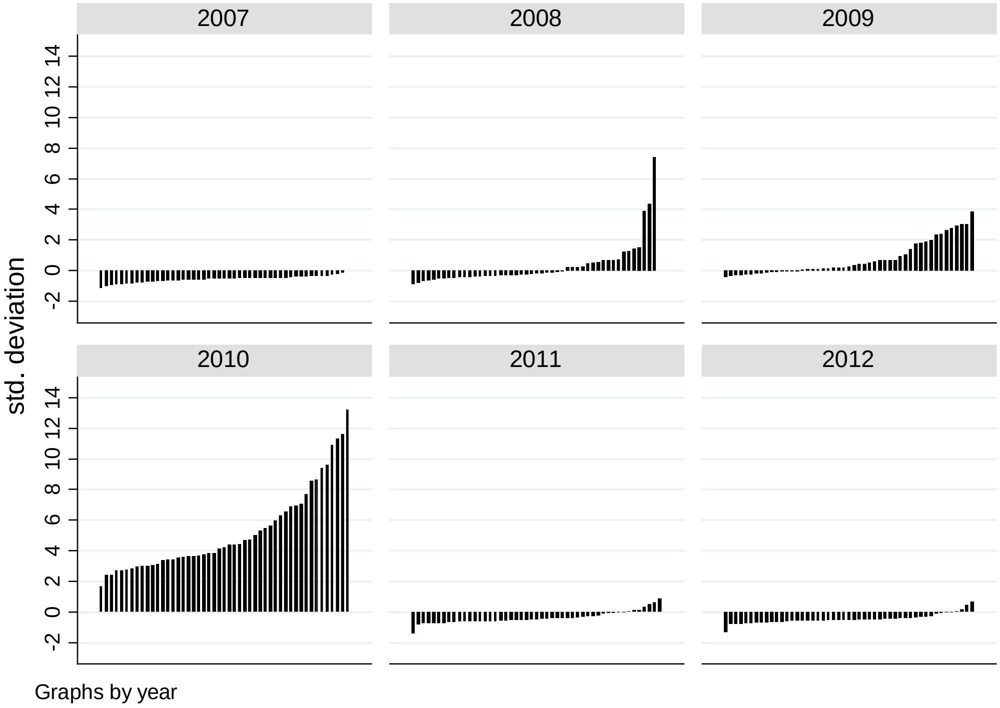
Source: Coping with Shocks in Mongolia Household Panel Survey and WHO Child Growth Standards dataset.

Fig. 4: Spatial variation in the dzud-intensity index across survey districts



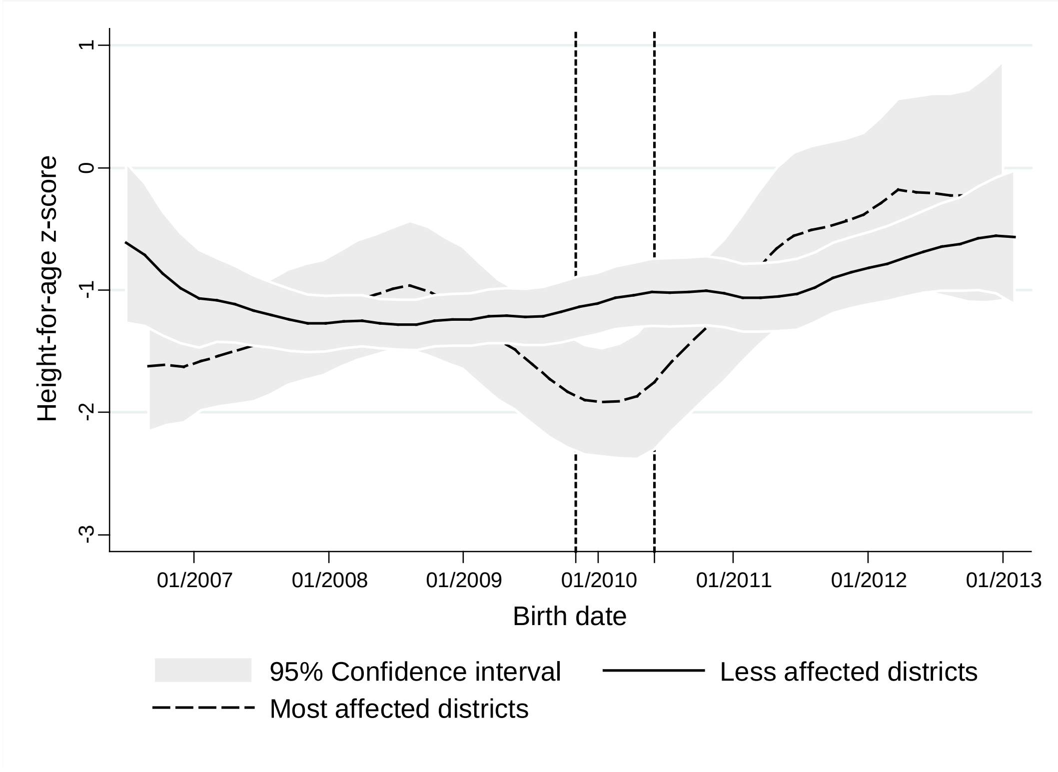
Note: Dzud intensity index calculated based on Eq. 1. Source: Mongolia Livestock Census.

Fig. 5: Distribution of dzud intensity between 2007 and 2012 across survey districts



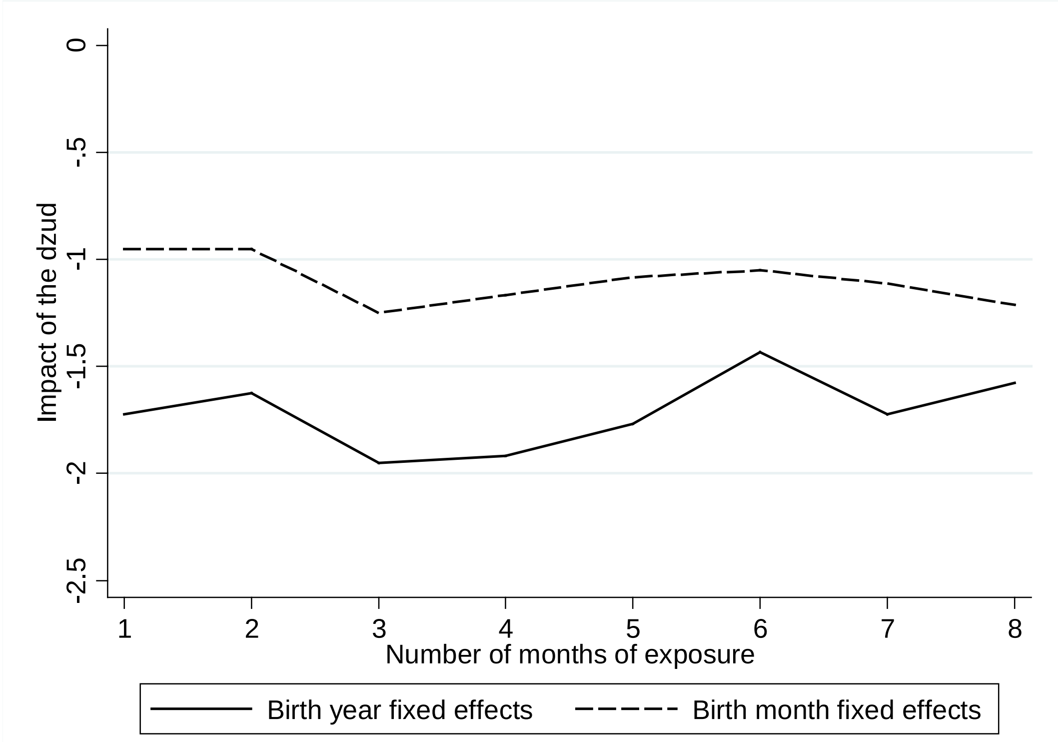
Note: Dzud intensity index calculated based on Eq. 1. Each bar represents one district. Source: Mongolia Livestock Census.

Fig. 6: Children's height-for-age z-scores over time in districts that were most affected and less affected by the 2009/10 dzud



Note: Nonparametric local polynomial regression with Epanechnikov kernel weights. 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. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Fig. 7: The impact of the dzud by months of exposure



Note: The sample only includes children from herding households. Each of the 16 points in the graph is derived from a separate regression, in which the dependent variable is height-for-age z-score. The straight line indicates results from regressions with the same set of control variables as in table 3, including year of birth fixed effects. The dotted line shows results from slightly modified regressions in which month of birth fixed effects were used instead of year of birth fixed effects (as in Appendix, table A2). The vertical axis reports the estimated coefficients on the interaction terms (*Most affected district*)*(*Exposed at least 1, 2, …, 8 months*). Regressions are weighted to account for sampling design. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Table 1: Summary statistics

	Mean	SD	Min	Max	Number of children
Dependent variable					
Height-for-age z-score	-1.07	1.60	-5.85	5.88	802
Dzud measures					
Exposed	0.72	0.45	0	1	802
Exposed in utero	0.21	0.41	0	1	802
Exposed alive	0.51	0.50	0	1	802
Number of months exposed	5.39	3.58	0	8	802
Most affected district[a]	0.24	0.43	0	1	802
Child controls					
Female	0.50	0.50	0	1	802
Khalkh ethnicity	0.59	0.49	0	1	802
Durvud ethnicity	0.19	0.40	0	1	802
Other ethnicity	0.21	0.41	0	1	802
Mother controls					
Age	30.49	5.91	17	58	802
Primary education	0.20	0.40	0	1	802
Secondary education	0.59	0.49	0	1	802
Tertiary education	0.21	0.41	0	1	802
Head of household controls					
Age	33.81	8.07	21	76	802
Primary education	0.35	0.48	0	1	802
Secondary education	0.56	0.50	0	1	802
Tertiary education	0.09	0.29	0	1	802
Female	0.05	0.21	0	1	802
Buddhist	0.65	0.48	0	1	802
Household controls					
Size	4.66	1.28	2	11	802
Number of children 0-5 years	1.61	0.69	0	3	802
Asset index[b]	-0.45	2.19	-3.36	6.24	802
Rural	0.52	0.50	0	1	802
Number of livestock in 2009	245.6	183.6	1.50	1180	465
Mitigation channels (herders 2009 only)					
Household knows bag governor well	0.80	0.38	0	1	465
Max. number of health facilities available in district	0.25	0.41	0	1	465
Household's distance to the district center, km	25.25	22.73	0	210	465
Avg. snow depth in bag, cm per day	4.37	3.29	0.24	14.32	455
Avg. snow depth in bag is below the median	0.46	0.47	0	1	455
Amount of aid distributed in district	28.79	21.56	0	82.26	465

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Table 1: Summary statistics (continued)

	Mean	SD	Min	Max	Number of children
Household coping strategies (dzud-affected herders 2009 only)					
Borrowed money	0.38	0.46	0	1	412
Asked relatives for help	0.19	0.37	0	1	412
Sold livestock	0.11	0.29	0	1	412
Built shelter and fences	0.12	0.30	0	1	412
Split the herd	0.17	0.35	0	1	412
Went on temporary migration	0.20	0.38	0	1	412

Notes: a. Most affected districts are defined as districts with a dzud intensity index above the 85^{th} percentile. b. 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 Panel Survey, Mongolia Livestock Census, MARS snowfall data, and MRCS emergency aid data.

Table 2: Nutritional status by socio-economic characteristics

	Mean height-for-age z-scores	Standard deviation of height-for-age z-scores	Percentage of children stunted[a]	Percentage of children severely stunted[a]	Number of children
All	-1.07	1.60	0.24	0.10	802
Children aged 0-24 months	-0.70	2.03	0.24	0.12	260
Children aged 25-81 months	-1.24	1.33	0.24	0.09	542
Difference	*0.54****		-0.01	0.03	
Male	-1.03	1.64	0.26	0.11	399
Female	-1.10	1.55	0.21	0.10	403
Difference	*0.07*		*0.05*	*0.01*	
Non-herding households in 2009	-0.89	2.01	0.25	0.12	337
Herding households in 2009	-1.17	1.37	0.24	0.09	465
Difference	*0.28***		*0.01*	*0.03*	
Head has secondary/tertiary education	-0.96	1.69	0.23	0.10	568
Head has primary education	-1.26	1.41	0.27	0.12	234
Difference	*0.30***		*-0.04*	*-0.02*	
Lives in district or provincial center	-0.93	2.06	0.26	0.11	492
Lives in rural areas	-1.20	1.17	0.22	0.09	310
Difference	*0.27***		*0.04*	*0.02*	
Non exposed cohort	-0.60	2.13	0.23	0.13	240
Exposed cohort	-1.25	1.33	0.24	0.09	562
Difference	*0.64****		*-0.02*	*0.04*	
Lives in less affected district[b]	-1.08	1.46	0.23	0.09	603
Lives in most affected district	-1.04	1.99	0.28	0.16	199
Difference	*-0.04*		*-0.05*	*-0.07***	
Household not affected by dzud[c]	-1.25	1.60	0.32	0.16	53
Household affected by dzud	-1.16	1.34	0.22	0.09	412
Difference	*-0.09*		*0.10*	*0.07*	
Household applied at least one coping strategy[d]	-1.08	1.34	0.21	0.07	330
Household did not apply any coping strategy	-1.46	1.30	0.30	0.14	82
Difference	*0.39***		-0.09	-0.07	

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. c. Herders in 2009 only. d. Dzud-affected herders in 2009 only. * significant at 10%; ** significant at 5%; *** significant at 1%. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Table 3: The impact of the 2009/10 dzud on child height (baseline), OLS

Dependent variable: Height-for-age z-score	Herding households			Non-herding households	Full sample
	(1)	(2)	(3)	(4)	(5)
Dzud measures					
(Exposed) * (Most affected district)	-1.668**			0.355	-0.632
	[-2.038]			[0.434]	[-1.068]
Exposed	-0.024			-0.312	-0.283
	[-0.071]			[-0.414]	[-0.840]
(Number of months exposed) * (Most affected district)		-0.258**			
		[-2.403]			
Number of months exposed		0.157			
		[1.623]			
(Exposed in utero) * (Most affected district)			-1.669**		
			[-2.094]		
(Exposed alive) * (Most affected district)			-0.986		
			[-1.057]		
Exposed in utero			-0.037		
			[-0.106]		
Exposed alive			-0.107		
			[-0.204]		
Observations	465	465	465	337	802
R-squared	0.444	0.447	0.445	0.385	0.323
Interview month FE	YES	YES	YES	YES	YES
Birth year FE	YES	YES	YES	YES	YES
District FE	YES	YES	YES	YES	YES
District-specific trend	YES	YES	YES	YES	YES
Child, mother and HH controls	YES	YES	YES	YES	YES

Notes: Regressions are weighted to account for sampling design. t-statistics in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. Most affected districts are defined as districts with a dzud intensity index above the 85th percentile. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Table 4: The impact of the 2009/10 dzud on child height by socio-economic characteristics, OLS

Dependent variable: Height-for-age z-score	Herding households			
	(1)	(2)	(3)	(4)
Dzud measures				
(Exposed) * (Most affected district)	-1.668**	-2.041**	-3.391***	-2.161***
	[-2.038]	[-2.525]	[-2.994]	[-2.605]
Exposed	-0.024	-0.063	-0.025	-0.048
	[-0.071]	[-0.182]	[-0.072]	[-0.139]
Gender				
(Exposed) * (Most affected district) * (Female)		0.677*		
		[1.850]		
Female	-0.028	-0.144	-0.039	-0.038
	[-0.192]	[-0.942]	[-0.272]	[-0.262]
Experience				
(Exposed) * (Most affected district) * (Head age)			0.054**	
			[2.145]	
Head age	0.028*	0.028**	0.019	0.028**
	[1.969]	[1.992]	[1.256]	[1.982]
Pre-dzud wealth				
(Exposed) * (Most affected district) * (Livestock in 2009, 2nd tercile)				0.723
				[1.427]
(Exposed) * (Most affected district) * (Livestock in 2009, 3rd tercile)				1.051**
				[2.139]
Livestock in 2009, 2nd tercile	0.020	0.011	0.034	-0.058
	[0.118]	[0.067]	[0.203]	[-0.320]
Livestock in 2009, 3rd tercile	-0.173	-0.156	-0.156	-0.304
	[-0.757]	[-0.674]	[-0.677]	[-1.186]
Observations	465	465	465	465
R-squared	0.444	0.448	0.450	0.448
Interview month FE	YES	YES	YES	YES
Birth year FE	YES	YES	YES	YES
District FE	YES	YES	YES	YES
District-specific trend	YES	YES	YES	YES
Child, mother and HH controls	YES	YES	YES	YES

Notes: Sample only includes children from herding households. Regressions are weighted to account for sampling design. t-statistics in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. Most affected districts are defined as districts with a dzud intensity index above the 85th percentile. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Table 5: The impact of the 2009/10 dzud on child height by mitigation channels, OLS

Dependent variable: Height-for-age z-score	Herding households						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dzud measures							
(Exposed) * (Most affected district)	-1.668**	-2.050**	-1.980*	-1.284	0.125	-2.325***	-3.134***
	[-2.038]	[-2.438]	[-1.963]	[-1.501]	[0.127]	[-2.988]	[-3.336]
Exposed	-0.024	-0.051	-0.036	-0.001	0.006	-0.003	-0.045
	[-0.071]	[-0.149]	[-0.104]	[-0.003]	[0.018]	[-0.009]	[-0.127]
Access to aid							
(Exposed) * (Most affected district) * (Knows bag governor well)		0.698					
		[1.073]					
Knows bag governor well		0.317					
		[1.098]					
Health infrastructure							
(Exposed) * (Most affected district) * (Max number health facilities in district)			0.779				
			[0.538]				
Accessibility							
(Exposed) * (Most affected district) * (HH's distance to district center, km)				-0.030			
				[-1.222]			
HH's distance to district center, km				-0.003			
				[-0.631]			
(Exposed) * (Most affected district) * (Average snow depth in bag, cm per day)					-0.388**		
					[-2.552]		
Average snow depth in bag, cm per day					0.320**		
					[2.593]		
(Exposed) * (Most affected district) * (Avg. snow depth in bag below median)						2.495**	
						[2.553]	
Avg. snow depth in bag below median						-0.535	
						[-0.675]	
District-level aid							
(Exposed) * (Most affected district) * (Amount of aid in district)							0.065***
							[3.750]
Observations	465	465	465	465	455	455	465
R-squared	0.444	0.453	0.444	0.447	0.457	0.453	0.456
Interview month FE	YES	YES	YES	YES	YES	YES	YES
District FE	YES	YES	YES	YES	YES	YES	YES
Birth year FE	YES	YES	YES	YES	YES	YES	YES
District-specific trend	YES	YES	YES	YES	YES	YES	YES
Child, mother and HH controls	YES	YES	YES	YES	YES	YES	YES

Notes: Sample only includes children from herding households. Regressions are weighted to account for sampling design. t-statistics in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. Most affected districts are defined as districts with a dzud intensity index above the 85th percentile. Sources: Coping with Shocks in Mongolia Household Panel Survey, Mongolia Livestock Census, MARS snowfall data, and MRCS aid distribution statistics.

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Table 6: The impact of coping strategies on child height, OLS

Dependent variable: Height-for-age z-score	Dzud-affected herding households						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dzud measures							
(Exposed) * (Most affected district)	-1.175	-1.176	-1.211	-1.179	-1.153	-1.157	-1.115
	[-1.195]	[-1.191]	[-1.219]	[-1.198]	[-1.185]	[-1.176]	[-1.127]
Exposed	0.268	0.307	0.269	0.268	0.315	0.259	0.192
	[0.717]	[0.829]	[0.729]	[0.718]	[0.846]	[0.686]	[0.485]
Coping strategies							
Borrowed money		0.234*					
		[1.660]					
Asked relatives for help			0.420**				
			[2.520]				
Sold livestock				0.221			
				[0.880]			
Built shelter and fences					-0.293		
					[-1.147]		
Split the herd						0.067	
						[0.345]	
Went on temporary migration							0.257
							[1.116]
Observations	412	412	412	412	412	412	412
R-squared	0.451	0.454	0.458	0.452	0.453	0.451	0.454
Interview month FE	YES	YES	YES	YES	YES	YES	YES
Birth year FE	YES	YES	YES	YES	YES	YES	YES
District FE	YES	YES	YES	YES	YES	YES	YES
District-specific trend	YES	YES	YES	YES	YES	YES	YES
Child, mother and HH controls	YES	YES	YES	YES	YES	YES	YES

Notes: Sample only includes children from dzud-affected herding households. Regressions are weighted to account for sampling design. t-statistics in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. Most affected districts are defined as districts with a dzud intensity index above the 85^{th} percentile. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Appendix

Fig. A1: Timeline

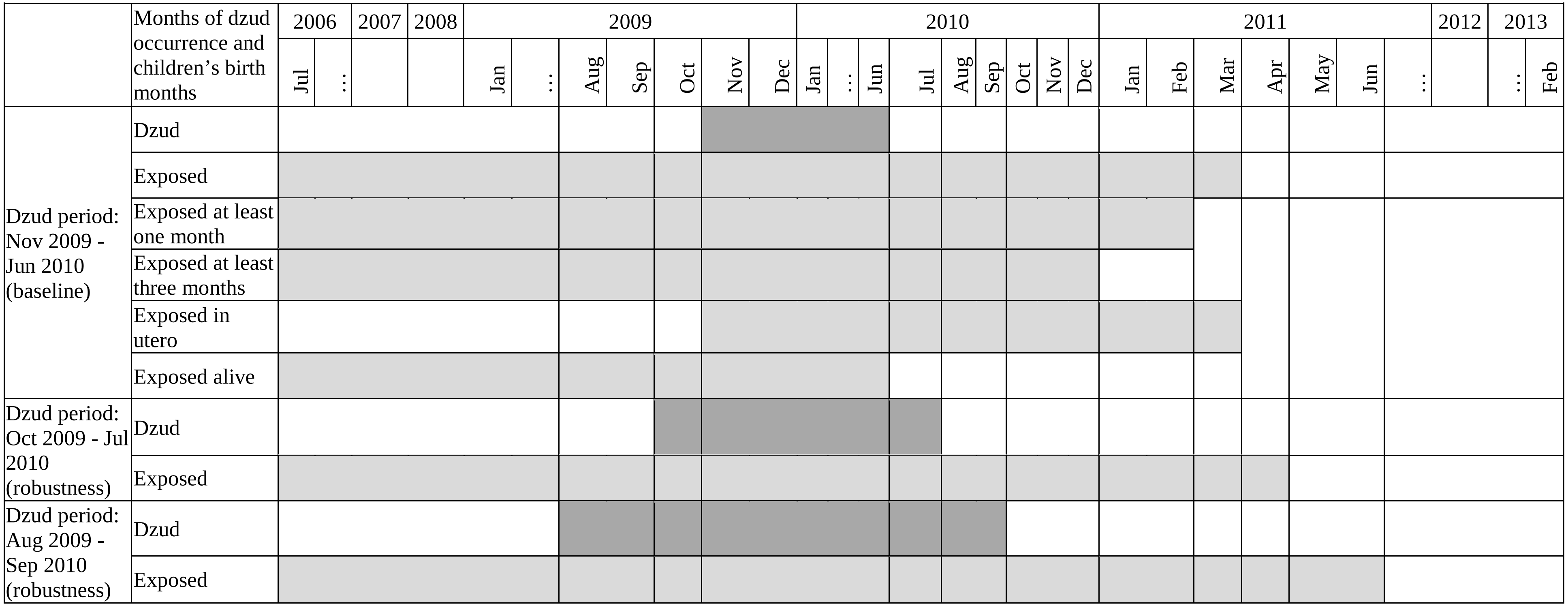
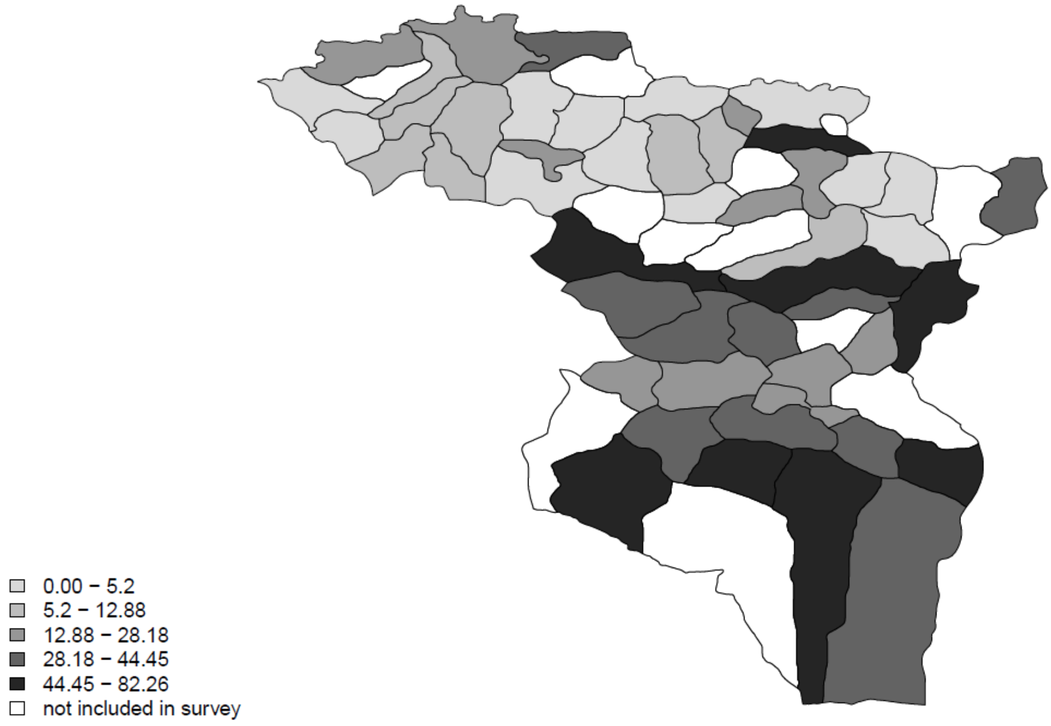
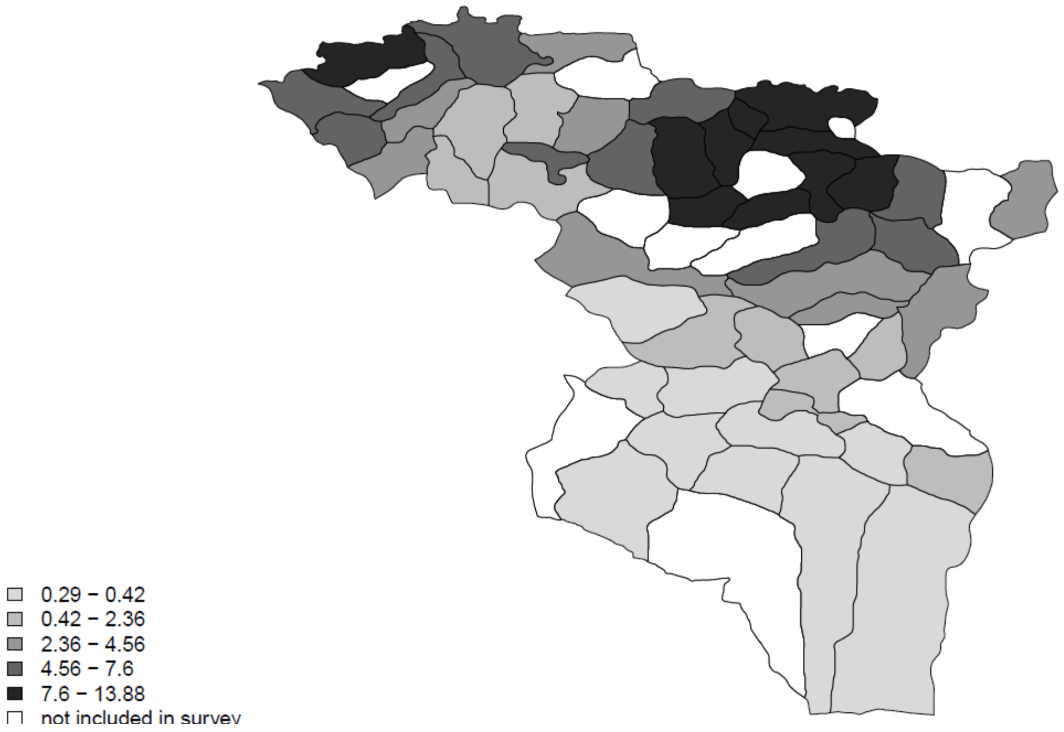


Fig. A2: Spatial variation in the distribution of emergency aid and snow depth across survey districts

(a) Amount of aid (tons of food and animal fodder) by district



(b) Snow depth (average cm per day) by district



Sources: (a) MRCS aid distribution statistics. (b) MARS snowfall data.

Table A1: Baseline regression with stepwise inclusion of control variables, OLS

Dependent variable: Height-for-age z-score	Herding households						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dzud measures							
(Exposed) * (Most affected district)	-0.508**	-0.538**	-0.563**	-0.664***	-0.728***	-1.196**	-1.668**
	[-2.335]	[-2.228]	[-2.279]	[-2.656]	[-2.793]	[-2.011]	[-2.038]
Exposed	-0.432	-0.468	-0.503	-0.425	-0.321	-0.175	-0.024
	[-1.015]	[-1.122]	[-1.189]	[-0.995]	[-0.777]	[-0.513]	[-0.071]
Child controls							
Female		-0.073	-0.047	-0.040	-0.050	-0.028	-0.028
		[-0.509]	[-0.330]	[-0.273]	[-0.361]	[-0.200]	[-0.192]
Durvud		-0.277	-0.387**	-0.390**	-0.377*	0.286	0.355
		[-1.437]	[-1.975]	[-2.033]	[-1.920]	[0.598]	[0.700]
Other ethnicity		0.126	0.113	0.144	0.199	0.476	0.500
		[0.535]	[0.452]	[0.555]	[0.736]	[0.895]	[0.909]
Mother controls							
Age			0.030**	0.020	0.022	0.028*	0.031*
			[2.217]	[1.209]	[1.311]	[1.767]	[1.921]
Secondary			-0.093	-0.244	-0.163	-0.086	0.023
			[-0.457]	[-1.179]	[-0.820]	[-0.452]	[0.122]
Tertiary			0.635**	0.332	0.448	0.509	0.740**
			[2.167]	[1.093]	[1.423]	[1.487]	[2.130]
Head of household controls							
Age				0.017	0.018	0.026*	0.028*
				[1.135]	[1.205]	[1.896]	[1.969]
Female				-0.804**	-0.823**	-0.807**	-0.872***
				[-2.324]	[-2.299]	[-2.443]	[-2.870]
Secondary				0.113	0.134	-0.069	-0.128
				[0.669]	[0.784]	[-0.424]	[-0.759]
Tertiary				0.630	0.643	0.370	0.170
				[1.456]	[1.438]	[0.798]	[0.382]
Buddhist				0.014	0.003	0.000	0.033
				[0.078]	[0.017]	[0.002]	[0.158]

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Table A1: Baseline regression with step-wise inclusion of control variables, OLS (continued)

Dependent variable: Height-for-age z-score	Herding households						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Household controls							
Size					-0.076	-0.126	-0.121
					[-0.964]	[-1.649]	[-1.615]
Number of children 0-5 years					-0.080	0.004	0.063
					[-0.658]	[0.039]	[0.534]
Asset index, 2nd quintile					-0.269	-0.192	-0.218
					[-1.275]	[-0.849]	[-0.941]
Asset index, 3rd quintile					-0.058	0.325	0.418
					[-0.209]	[1.020]	[1.258]
Asset index, 4th quintile					0.172	0.383	0.455
					[0.523]	[1.025]	[1.214]
Asset index, 5th quintile					-0.467	0.069	-0.019
					[-1.211]	[0.142]	[-0.039]
Rural					-0.064	0.003	0.075
					[-0.224]	[0.010]	[0.208]
Livestock in 2009, 2nd tercile					0.026	0.021	0.020
					[0.146]	[0.122]	[0.118]
Livestock in 2009, 3rd tercile					0.012	-0.248	-0.173
					[0.056]	[-1.077]	[-0.757]
Observations	465	465	465	465	465	465	465
R-squared	0.136	0.143	0.172	0.189	0.207	0.374	0.444
Interview month FE	YES	YES	YES	YES	YES	YES	YES
Birth year FE	YES	YES	YES	YES	YES	YES	YES
District FE	NO	NO	NO	NO	NO	YES	YES
District-specific trend	NO	NO	NO	NO	NO	NO	YES

Notes: Sample only includes children from herding households. Regressions are weighted to account for sampling design. t-statistics in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. Most affected districts are defined as districts with a dzud intensity index above the 85th percentile. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Table A2: Baseline regression with month of birth fixed effects, OLS

Dependent variable: Height-for-age z-score	Herding households			Non-herding households	Full sample
	(1)	(2)	(3)	(4)	(5)
Dzud measures					
(Exposed) * (Most affected district)	-0.981			0.640	-0.251
	[-1.414]			[0.810]	[-0.468]
Exposed	1.794*			-0.114	0.046
	[1.710]			[-0.091]	[0.043]
(N. months exposed) * (Most affected district)		-0.163*			
		[-1.719]			
N. months exposed		0.600			
		[1.122]			
(Exposed in utero) * (Most affected district)			-0.974		
			[-1.492]		
(Exposed alive) * (Most affected district)			0.421		
			[0.552]		
Exposed in utero			1.824*		
			[1.747]		
Exposed alive			4.095***		
			[2.709]		
N. observations	465	465	465	337	802
R-squared	0.587	0.589	0.592	0.565	0.420
Interview month FE	YES	YES	YES	YES	YES
Birth month FE	YES	YES	YES	YES	YES
District FE	YES	YES	YES	YES	YES
District-specific trend	YES	YES	YES	YES	YES
Child, mother and HH controls	YES	YES	YES	YES	YES

Notes: Regressions are weighted to account for sampling design. t-statistics in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. Most affected districts are defined as districts with a dzud intensity index above the 85th percentile. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Table A3: Baseline regression with mother fixed effects, OLS

Dependent variable: Height-for-age z-score	Herding households			
	(1)	(2)	(4)	(5)
Dzud measures				
(Exposed) * (Most affected district)	-1.481**	-1.595*		
	[-2.106]	[-1.802]		
(Exposed) * (Continuous dzud index)			-0.176*	-0.270**
			[-1.727]	[-1.999]
Exposed	0.396	0.935*	1.039	2.024**
	[0.919]	[1.752]	[1.635]	[2.463]
Female	-0.054	0.170	-0.090	0.133
	[-0.342]	[0.937]	[-0.573]	[0.728]
Observations	227	227	227	227
R-squared	0.740	0.813	0.733	0.814
Birth year FE	YES	YES	YES	YES
Mother FE	YES	YES	YES	YES
District-specific trend	NO	YES	NO	YES

Notes: Sample only includes children from herding households having at least one sibling. The set of controls only includes child-level variables (household-level controls are excluded because there is only one mother in each household). Regressions are weighted to account for sampling design. t-statistics in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. In columns 1-2, most affected districts are defined as districts with a dzud intensity index above the 85th percentile. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Table A4: Selection into receiving emergency aid, Logit

Dependent variable: Household received food aid during dzud	Dzud-affected herding households			
	(1)	(2)	(3)	(4)
Head of household controls				
Age above 60	0.098	0.100	0.115*	0.094
	[1.369]	[1.444]	[1.669]	[1.374]
Female	-0.006	-0.009	-0.008	-0.004
	[-0.109]	[-0.152]	[-0.142]	[-0.061]
Secondary	-0.022	-0.024	-0.026	-0.030
	[-0.633]	[-0.695]	[-0.775]	[-0.875]
Tertiary	-0.056	-0.066	-0.065	-0.036
	[-0.685]	[-0.779]	[-0.791]	[-0.455]
Buddhist	-0.020	-0.015	-0.022	-0.027
	[-0.493]	[-0.374]	[-0.540]	[-0.674]
Household controls				
Proportion of children	0.139*	0.134*	0.158**	0.153**
	[1.825]	[1.771]	[2.082]	[2.018]
Proportion of elderly	-0.278**	-0.287**	-0.314***	-0.282**
	[-2.342]	[-2.491]	[-2.790]	[-2.477]
Asset index, 2nd quintile	-0.128***	-0.120**	-0.129***	-0.131***
	[-2.726]	[-2.561]	[-2.796]	[-2.792]
Asset index, 3rd quintile	-0.141*	-0.134*	-0.159**	-0.126*
	[-1.924]	[-1.853]	[-2.293]	[-1.820]
Asset index, 4th quintile	-0.176**	-0.169**	-0.190***	-0.171**
	[-2.460]	[-2.417]	[-2.767]	[-2.517]
Asset index, 5th quintile	-0.413***	-0.392***	-0.419***	-0.336***
	[-3.255]	[-3.063]	[-3.408]	[-3.638]
Rural	-0.014	0.013	0.135*	0.154**
	[-0.223]	[0.207]	[1.895]	[2.277]
Livestock in 2009, 2nd tercile	0.039	0.050	0.037	0.025
	[0.786]	[1.026]	[0.769]	[0.515]
Livestock in 2009, 3rd tercile	0.089	0.108**	0.104*	0.100*
	[1.589]	[1.982]	[1.932]	[1.801]
Percentage of livestock lost due to the dzud		0.002***	0.002***	0.002***
		[3.434]	[3.245]	[3.368]
HH's distance to district centre, km			-0.005***	-0.005***
			[-3.207]	[-3.293]
Average snow depth in bag, cm per day				-0.065**
				[-2.130]
Observations	912	912	911	898
Interview month FE	YES	YES	YES	YES
District FE	YES	YES	YES	YES

Notes: Sample only includes dzud-affected herding households. Regressions are weighted to account for sampling design. Average marginal effects after logit are reported, with z-statistics in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. Sources: Coping with Shocks in Mongolia Household Panel Survey, Mongolia Livestock Census, MARS snowfall data, and MRCS emergency aid data.

Table A5: Baseline regression with alternative measures of dzud intensity, OLS

Dependent variable: Height-for-age z-score	Herding households			
	District-level dzud intensity above 80th percentile of dzud intensity measure	District-level dzud intensity above 85th percentile of dzud intensity measure averaged for 2009 and 2010	District-level continuous dzud intensity index	Households reporting being severely affected by dzud
	(1)	(2)	(3)	(4)
Dzud measures				
(Exposed) * (Most affected district, 80th percentile)	-1.587*			
	[-1.919]			
(Exposed) * (Most affected district, shock 2009 & 2010)		-1.295		
		[-1.433]		
(Exposed) * (Continuous dzud index)			-0.188	
			[-1.446]	
(Exposed) * (Severely affected Households)				-0.899**
				[-2.035]
Severely affected Households				0.981**
				[2.568]
Exposed	-0.034	-0.091	0.671	-0.131
	[-0.098]	[-0.257]	[1.030]	[-0.350]
Observations	465	465	465	465
R-squared	0.443	0.439	0.438	0.443
Interview month FE	YES	YES	YES	YES
Birth year FE	YES	YES	YES	YES
District FE	YES	YES	YES	YES
District-specific trend	YES	YES	YES	YES
Child, mother and HH controls	YES	YES	YES	YES

Notes: Sample only includes children from herding households. Regressions are weighted to account for sampling design. t-statistics in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Table A6: Baseline regression with dzud intensity measured with snow depth, OLS

Dependent variable: Height-for-age z-score	Herding households			Non-herding households	Full sample
	(1)	(2)	(3)	(4)	(5)
Dzud measures					
(Exposed) * (Snow depth above the median)	-1.333**			0.785	-0.809*
	[-2.515]			[0.957]	[-1.852]
Exposed	0.661			-0.551	0.122
	[1.316]			[-0.714]	[0.310]
(Number of months exposed) * (Snow depth above the median)		-0.242***			
		[-3.153]			
Number of months exposed		0.204*			
		[1.825]			
(Exposed in utero) * (Snow depth above the median)			-1.338**		
			[-2.538]		
(Exposed alive) * (Snow depth above the median)			-0.952		
			[-1.367]		
Exposed in utero			0.672		
			[1.338]		
Exposed alive			0.300		
			[0.415]		
Observations	465	465	465	337	802
R-squared	0.441	0.447	0.439	0.387	0.324
Interview month FE	YES	YES	YES	YES	YES
Birth year FE	YES	YES	YES	YES	YES
District FE	YES	YES	YES	YES	YES
District-specific trend	YES	YES	YES	YES	YES
Child, mother and HH controls	YES	YES	YES	YES	YES

Notes: Regressions are weighted to account for sampling design. t-statistics in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. Snow depth above the median is an indicator variable which is equal to one if the daily snow depth in the winter 2009/2010 in a given district was below the median. Sources: Coping with Shocks in Mongolia Household Panel Survey and MARS snowfall data.

Table A7: Baseline regression with alternative time window of dzud and placebo tests, OLS

	Herding households				
	Alternative dzud periods		Placebo tests		
	October 2009 - July 2010	August 2009 - September 2010	District-level dzud intensity above 85th percentile of dzud intensity measure in 2008	District-level dzud intensity above 85th percentile of dzud intensity measure in 2012	Impact of the 2009/2010 dzud on weight
Dependent variable:	Height-for-age z-score				Weight-for-age z-score
	(1)	(2)	(3)	(4)	(5)
Dzud measures					
(Exposed October 2009 - July 2010) * (Most affected district)	-1.816**				
	[-2.249]				
Exposed October 2009 - July 2010	-0.336				
	[-0.907]				
(Exposed August 2009 - September 2010) * (Most affected district)		-2.024***			
		[-2.636]			
Exposed August 2009 - September 2010		-0.604*			
		[-1.831]			
(Exposed) * (Most affected district, shock 2008)			-0.575		
			[-0.767]		
(Exposed) * (Most affected district, shock 2012)				-0.265	
				[-0.318]	
(Exposed) * (Most affected district)					0.238
					[0.359]
Exposed			-0.117	-0.208	-0.731
			[-0.300]	[-0.504]	[-1.602]
Observations	465	465	465	465	464
R-squared	0.448	0.457	0.433	0.432	0.221
Interview month FE	YES	YES	YES	YES	YES
Birth year FE	YES	YES	YES	YES	YES
District FE	YES	YES	YES	YES	YES
District-specific trend	YES	YES	YES	YES	YES
Child, mother and HH controls	YES	YES	YES	YES	YES

Notes: Sample only includes children from herding households. Regressions are weighted to account for sampling design. t-statistics in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Table A8: Impact of coping strategies on child height, Heckman

Dependent variable: Height-for-age z-score	Herding households						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dzud measures							
(Exposed) * (Most affected district)	-0.382	-0.386	-0.371	-0.380	-0.391	-0.364	-0.394
	[-1.565]	[-1.580]	[-1.524]	[-1.558]	[-1.608]	[-1.493]	[-1.614]
Exposed	0.102	0.107	0.101	0.101	0.133	0.071	0.134
	[0.220]	[0.232]	[0.221]	[0.220]	[0.290]	[0.154]	[0.290]
Coping strategies							
Borrowed money		0.056					
		[0.338]					
Asked relatives for help			0.317*				
			[1.675]				
Sold livestock				0.104			
				[0.417]			
Built shelter and fences					-0.423*		
					[-1.743]		
Split the herd						0.254	
						[1.268]	
Went on temporary migration							-0.183
							[-0.950]
Observations	465	465	465	465	465	465	465
Lambda	-0.190	-0.174	-0.160	-0.183	-0.157	-0.249	-0.218
z-stat of lambda	-0.288	-0.263	-0.243	-0.277	-0.239	-0.377	-0.330
Interview month FE	YES	YES	YES	YES	YES	YES	YES
Birth year FE	YES	YES	YES	YES	YES	YES	YES
District FE	NO	NO	NO	NO	NO	NO	NO
District-specific trend	NO	NO	NO	NO	NO	NO	NO
Child, mother and HH controls	YES	YES	YES	YES	YES	YES	YES

Notes: Sample only includes children from herding households (the number of uncensored observations, corresponding to dzud-affected herding households, is 412). Regressions are weighted to account for sampling design. t-statistics in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. Most affected districts are defined as districts with a dzud intensity index above the 85th percentile. Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.