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AT A GLANCE

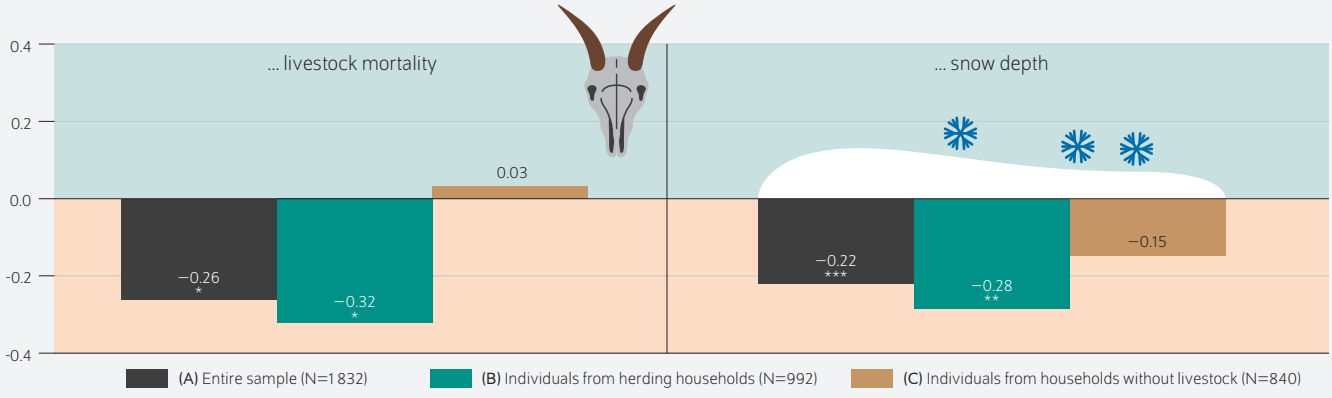
Extreme weather events drastically reduce school completion by Mongolian children

By Kati Kraehnert and Valeria Groppo

- Study uses Mongolia as an example to examine how extreme weather events affect schooling
- Data from a representative household survey conducted by DIW Berlin and the National Statistical Office of Mongolia were used
- Children who experience an extreme winter during their schooling years are 26 percent less likely to complete their entire mandatory education
- As education is a factor influencing income later in life, consequences can be long lasting
- Policymakers should take measures to enable children to complete their education, such as financial support possibly tied to school attendance

Students in Mongolia are 26 percentage points less likely to complete the full nine years of mandatory schooling if they have been affected by an extreme winter

Regression analysis; intensity of the extreme weather measured by ...



Sources: Coping with Shocks in Mongolia Household Panel Survey; Mongolia Livestock Census; ERA-Interim.

Note: Dependent variable: Completed nine years of mandatory education. Independent variable of interest: Affected cohorts x strongly-affected district. R^2 (Sample A)=0.36; R^2 (Sample B)=0.38; R^2 (Sample C)=0.39. Significance levels: * p<0.1, ** p<0.05, *** p<0.01.

FROM THE AUTHORS

The results show that households affected by extreme weather events are not able to send their children to school continuously. Policies should therefore consider emergency measures. One possibility would be to tie financial support to children's school attendance.

*— **Kati Kraehnert**, study author —*

DATA

The survey was conducted between **2012 and 2015** in three western Mongolian provinces (Govi-Altai, Uvs, and Zavkhan).

Extreme weather events drastically reduce school completion by Mongolian children

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ABSTRACT

As climate change progresses, extreme weather events are occurring more often, with developing countries suffering the brunt. Using Mongolia as an example, this study examines how extremely cold and snowy winters—which lead to high livestock mortality and thus threaten the livelihood of many households—impact children's school completion. The results, based on a representative household survey conducted by DIW Berlin and the Mongolian National Statistical Office, show that Mongolian children who experienced an extreme winter while of schooling age and lived in a severely affected district had a 20.1 to 26.1 percentage point lower probability of completing the nine years of mandatory education compared to their peers in unaffected areas. As education is a significant determinant of an individual's income, extreme weather events are likely to have long-lasting consequences for the children examined in this study. Policymakers should therefore implement support measures, including emergency aid, to enable children in affected households to attend school without interruption and complete their education.

Negative events, also known as shocks, which people are exposed to as children can have long-lasting consequences into adulthood.[1] For example, illnesses or economic crises—such as famine—that individuals experience as children may have long-term effects on their health and education.[2] The effects of such shocks on individuals, especially if affecting a large fraction of the population, translate into long-term macroeconomic losses, hampering a country's economic growth.[3]

The consequences of negative events during childhood are empirically well documented for OECD countries, where mostly high-quality individual-level data are usually available for research. The microeconomic research on the impact of shocks on individuals in developing countries is more limited, mainly due to a lack of data. However, there is currently a great need for research in these countries, as shocks there can cause relatively larger losses. This is mainly because many people in developing countries live close to the subsistence level, so a shock can hamper individual capacity to fulfill basic needs. Additionally, social security systems are hardly viable in most developing countries. Therefore, households are often left to their own devices when it comes to coping with negative events and maintaining a stable level of consumption.

This study examines the impact of a shock on the likelihood that children complete mandatory schooling in Mongolia. Mandatory schooling in this context lasts nine years. This study focuses on a special type of shock: extreme weather events. As climate change progresses, heat waves, heavy rain, and droughts are occurring more frequently and with

1 The research and data on which this report is based were funded by the German Federal Ministry of Education and Research under the "Economics of Climate Change" funding line (project "Coping with Shocks in Mongolia," research grant 01LA1126A). A detailed version of the results presented here has been published in Valeria Groppo and Kati Kraehnert, "The impact of extreme weather events on education," *Journal of Population Economics* 30, no. 2 (2017): 433-472.

2 Cf. Janet Currie and Douglas Almond, "Human capital development before age five," in *Handbook of Labour Economics Vol 4b*, eds. Orley Ashenfelter and David Card (North Holland, 2011), 1315–1486.

3 Cf. Sue Horton and Richard H. Steckel, "Malnutrition: Global Economic Losses Attributable to Malnutrition 1900–2000 and Projections to 2050," in *How Much Have Global Problems Cost the World? A Scorecard from 1900 to 2050*, ed. Bjorn Lomborg (Cambridge University Press, 2013), 247–272.

greater intensity.[4] Like other developing and lower-middle income countries, Mongolia has an especially high risk of being affected by extreme weather events.[5]

Extremely harsh winters threaten the livelihood of Mongolia's rural population

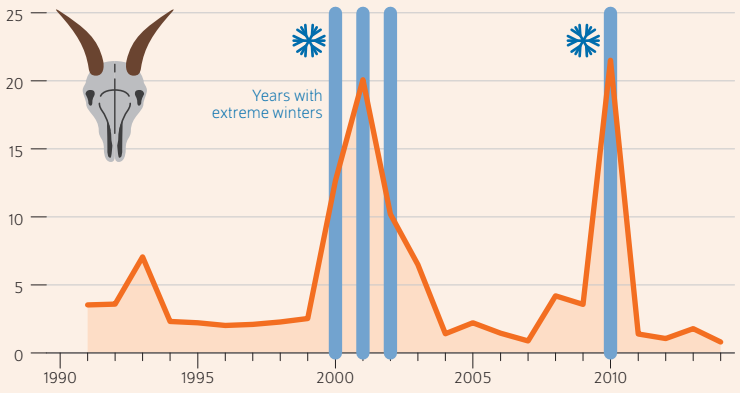
Mongolia's continental climate is not very suitable for commercial agriculture. Moreover, as manufacturing companies are based almost exclusively in the capital Ulaanbaatar, herding is the country's most important employment sector: in 2012, around 35 percent of the Mongolian workforce was employed in herding.[6] The majority of households outside of Ulaanbaatar have, at the very least, a small number of animals. About 19 percent of the population derives its livelihood entirely from herding.[7] Herding households typically own a mix of sheep, goats, horses, cows, and camels, which primarily cover their personal needs for milk and meat. The sales of animals and animal products—especially cashmere wool—are the main sources of income for herding households. In 2012, herding households had an average of 244 animals.[8] Most of these households lead a nomadic lifestyle and change campsites up to 25 times a year.

Extreme weather events represent the greatest risk for Mongolian herding households. These events take the form of unusually harsh winters—called *dzud* in Mongolian—which cause mass livestock death, threatening the livelihood of the rural population. Extreme winters are triggered by the interplay of several unfavorable climatic conditions, including excessive snowfall which prevents animals from grazing; extremely low temperatures which sharply increase the calories required by animals; strong temperature fluctuations above and below zero, leading to snow thawing and then freezing, making grazing more difficult; and insufficient precipitation either in the preceding summer or during the winter which limits vegetation growth.[9]

Mongolia has experienced four extreme winters since 1990 (Figure 1). Between 1999 and 2002, three consecutive extreme winters occurred, referred to as a triple *dzud;* the effects of these extreme winters are the focus of this study. Overall, 11.2 million animals died during these three years. In the winters of 1999/2000, 2000/2001, and 2001/2002, livestock mortality rates were 12.7 percent, 20.1 percent, and 10.2 percent, respectively. There was another severe winter in 2009/2010 which caused the death of over 10.3 million animals.

Figure 1

Annual livestock mortality in Mongolia
In percent of the total adult livestock population



Source: Authors' own calculations based on the Mongolia Livestock Census.

Extreme cold and snowy winters cause mass livestock mortality.

These extreme winters triggered considerable migratory movements to the cities, especially Ulaanbaatar. Many affected herding households no longer had enough animals to support their livelihoods in the rural economy and settled as wage earners near the cities, where poverty quickly increased. The number of herding households decreased by 7.4 percent between 1999 and 2002.[10]

New household survey data allows studies on the impact of extreme winters on education

This study uses data from a household panel survey, the *Coping with Shocks in Mongolia Household Panel Survey*, conducted by DIW Berlin in cooperation with the Mongolian National Statistical Office.[11] The survey was conducted between 2012 and 2015 in three western provinces, Govi-Altai, Uvs, and Zavkhan. The sample includes 1,768 households, of which 1,100 own animals, and around 7,200 individuals. The sample is representative of the rural and urban populations in each of the three provinces.[12] The household survey was conducted in 49 of the 61 districts in the three provinces.[13] Each household was interviewed three times,

4 Cf. Sonia I. Senevirante et al., "Changes in climate extremes and their impacts on the natural physical environment," in *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC)*, eds. Christopher B. Field et al. (2012), 109–230.

5 Cf. Virginia Murray et al., "Case studies," in *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC)*, eds. Christopher B. Field et al. (2012), 109–230.

6 Cf. National Statistical Office of Mongolia, *Mongolian Statistical Yearbook 2012* (2013).

7 Cf. National Statistical Office of Mongolia, *Mongolian Statistical Yearbook*.

8 Cf. National Statistical Office of Mongolia, *Mongolian Statistical Yearbook*.

9 Cf. Punsalmaa Batima, *Climate Change Vulnerability and Adaptation in the Livestock Sector of Mongolia* (2006); International START Secretariat and Daniel J. Murphy, "Going on Otor: Disaster, Mobility, and the Political Ecology of Vulnerability in Uguumur, Mongolia." Unpublished PhD dissertation, University of Kentucky, Lexington (2011).

10 Cf. National Statistical Office of Mongolia, *Mongolian National Statistical Yearbook 2002* (2003).

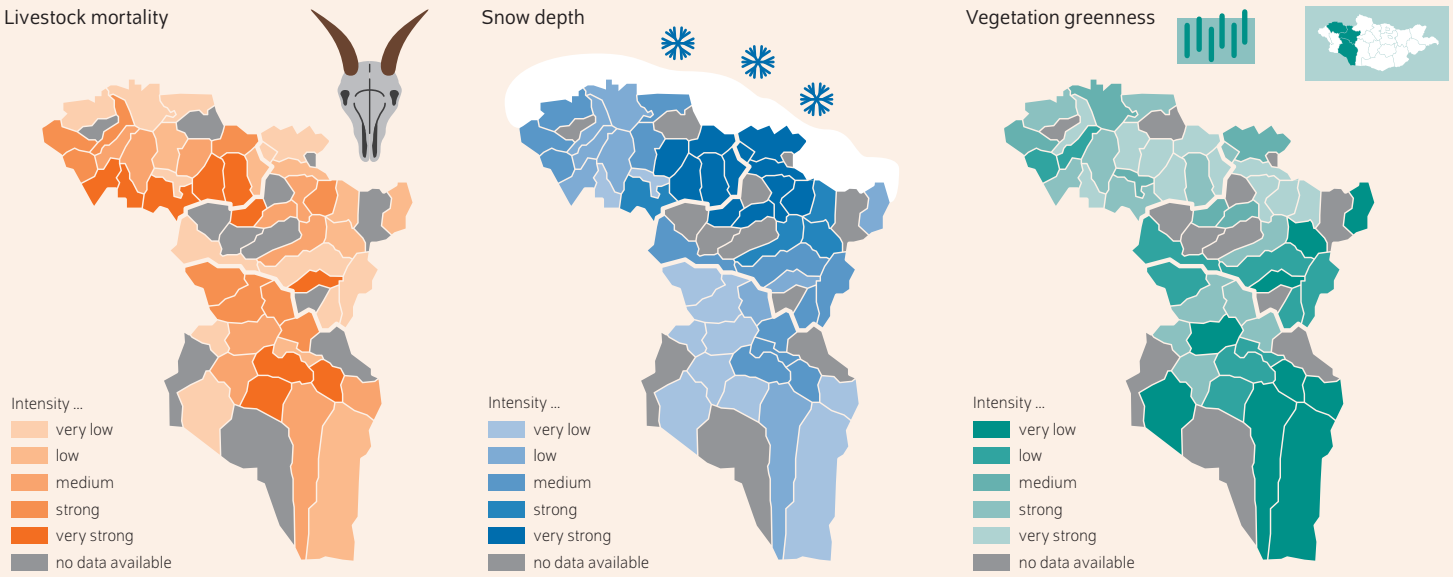
11 Kati Kraehnert, Katharina Lehmann-Uschner, Valeria Groppo, and Veronika Bertram-Huemmer, "Coping with Shocks in Mongolia Household Panel Survey," Wave 1-3, Version 1.0. German Institute for Economic Research and the National Statistical Office of Mongolia (2017).

12 The share of herding households in the total population is significantly higher than the nationwide average in the three provinces where the survey was conducted. Additionally, the herding households in the sample are slightly overrepresented to ensure that a sufficient number of these households participate in the survey.

13 The 49 districts in the survey region have an average size of 4,865 square kilometers and are home to around 1,002 households.

Figure 2

Spatial intensity of the three extreme winters between 1999 and 2002 across districts of the survey region
By alternative intensity measures



Sources: Coping with Shocks in Mongolia Household Panel Survey; Mongolia Livestock Census; ERA-Interim; NESDIS STAR VHP.

The intensity of the three extreme winters occuring between 1999 and 2002 varied strongly across districts.

although the analysis presented here only uses data from the first panel wave.

The survey covers demographic and socioeconomic characteristics of individuals, households, and districts. The study presented here uses the education section of the survey, in which the educational background of every household member over the age of six was recorded. A further section of the survey asks about the birth district and any moves across districts for all household members aged 15 years and older. This enables a restriction of the analysis to individuals with available information on their residential district in 1999, before the extreme winter of 1999/2000.

Using livestock census and climate data to measure the intensity of the extreme winters

Three data sources were used to measure the spatial intensity of the 1999–2002 triple *dzud*: Mongolia's annual livestock census, snow depth data, and vegetation data. Using these data, three alternative district-level intensity measures were constructed, representing complementary aspects of the extreme winters.

The first measure is based on aggregate data from the annual Mongolian livestock census. The Mongolian National Statistical Office has recorded livestock numbers and losses—separately for each of the five common species—over the previous twelve months each December since the 1950s. Using this data, a standardized measure of district-level livestock mortality during the 1999-2002 triple *dzud* was obtained. Livestock mortality during the period 1999-2002 is compared with the average long-term mortality between 1991 and 1998. In 47 of the 49 districts surveyed, livestock mortality during the shock period was above the long-term average.

The second measure of *dzud* intensity is based on snow depth data provided by the European Centre for Medium-Range Weather Forecasts. Daily data for the period September to May of each winter from 1991 to 2002 is used, aggregated at the district level.[14] Snow depth during the period between 1999 and 2002 is again compared to the long-term average snow depth in the same district.

The third measure of *dzud* intensity is based on the normalized differenced vegetation index (NDVI), which measures the greenness of an area and is used as an indicator of drought conditions. Weekly NDVI data for every summer from 1991 to 2002, obtained from the National Oceanic and Atmospheric Administration, is used. As before, the average district-level NDVI between 1999 and 2002 is compared to the long-term local average.

All three measures show considerable spatial variation in the intensity of the triple *dzud* from 1999 to 2002 across survey districts, suggesting that extreme winters occur very locally

14 The process of aggregating the snow and NDVI data is described in detail in Groppo and Kraehnert, "Impact of extreme weather events."

Table 1

Characteristics of individuals and households

	Average	Standard deviation	Minimum	Maximum
Dependent variable				
Individual completed mandatory education	0.76	0.41	0	1
Intensity measures of the three extreme winters 1999–2002 (district level)				
Livestock mortality	5.2	3.01	-0.35	16.51
Snow depth	0.04	0.02	0.01	0.1
Vegetation greenness	-0.59	0.58	-1.77	1.09
Individual characteristics				
Female (in percent)	0.49	0.49	0	1
Age (in years)	27.76	5.67	19	39
Person is head of household (in percent)	0.31	0.45	0	1
Person is child of head of household (in percent)	0.41	0.48	0	1
Person is spouse or relative of head of household (in percent)	0.28	0.44	0	1
Household characteristics				
Parents obtained upper secondary or tertiary education	0.38	0.47	0	1
Parents obtained lower secondary education	0.18	0.37	0	1
Parents obtained primary or no education	0.44	0.48	0	1
Herding household in 1999	0.62	0.47	0	1

Sources: Coping with Shocks in Mongolia Household Panel Survey; Mongolia Livestock Census; ERA-Interim; NESDIS STAR VHP.

(Figure 2). This strong spatial variation makes the prediction of such events very difficult.

To better interpret the three intensity measures, all three are transformed into dummy variables taking the value zero or one for the following regression analysis. The measures of livestock mortality and snow depth take the value one when a district is above the 75th percentile of the distribution, so severely affected by the triple *dzud*. The opposite interpretation applies to the vegetation measure: in this case, the measure takes the value one if a district belongs to the quartile of districts least affected by the drought.

Econometric approach

Do extreme weather events affect the completion of basic education in Mongolia? Various hypotheses as to how extreme winters affect schooling are conceivable: for example, they cause livestock losses which reduce household income; the nutrition of children from affected households deteriorates;[15] and some schools are forced to temporarily close due to the extremely low temperatures.[16] These mechanisms would suggest that severe winters have a negative effect. However, concerns over the viability of herding as a livelihood strategy could increase the demand for education to access alternative economic opportunities. Whether the overall effect of extreme winters is negative or positive must therefore be empirically investigated.

The dependent variable is a dummy variable which takes the value one if a person has completed the full nine years of mandatory schooling. Although nine years of schooling are required by law in Mongolia, only 76 percent of individuals in the sample completed the full amount (Table 1).[17] Mandatory education is used as a dependent variable for two reasons: first, Mongolia provides free education for the first nine years of schooling. This reduces the probability that wealth disparities between households are confounding the effect of extreme winters. Second, nine years of mandatory schooling minimizes the risk that differences in educational preferences across households—which depend on the level of educational attainment—influence the results.

A difference-in-differences approach is used to determine the causal effect of the 1999-2002 triple *dzud* on school completion. This approach exploits two sources of exogenous variation: first, individuals living in districts severely affected by the three extreme winters are compared to individuals from less affected districts. Districts are classified as "severely affected" or "less affected" based on the three intensity measures above described. As previously mentioned, the district of residence in 1999—before the first extreme winter of the triple *dzud*—is decisive for classification, and thus it can be ruled out that estimated impacts are confounded by households having resettled in regions that were less severely affected after the extreme event. Second, two birth cohorts are compared: an older cohort who was at least 16 years old in 1999 and thus should have completed the nine years of mandatory schooling under normal conditions before the first extreme winter, and a younger cohort who was of

15 Cf. Valeria Groppo and Katie Kraehnert, "Extreme Weather Events and Child Height: Evidence from Mongolia," *World Development* 86 (2016): 59–78.

16 Children from herding families who live further from urban centers usually live in school dormitories during the school year. Schools and dormitories are located in every district center. Nomadic families moving across district boundaries is unusual and must be reported to the district administration.

17 In Mongolia, mandatory education violations are not systematically sanctioned by the state—which explains why the share of people who have not completed the full nine years of mandatory education is relatively high.

Table 2

The impact of the 1999–2002 triple *dzud* on the completion of mandatory education

Dependent variable: individual completed mandatory education	Intensity of the triple *dzud* measured by...		
	Livestock mortality	Snow depth	Vegetation greenness
(A) Whole sample (N=1832)			
Exposed cohort x strongly affected district	−0.261*	−0.220***	0.201**
(B) Individuals from herding households (N=992)			
Exposed cohort x strongly affected district	−0.322*	−0.284**	0.250**
(C) Individuals from non-herding households (N=840)			
Exposed cohort x strongly affected district	0.033	-0.147	0.039
R^2, sample (A)	0.36	0.36	0.36
R^2, sample (B)	0.38	0.38	0.38
R^2, sample (C)	0.39	0.39	0.39

Note: Significance levels: * p<0.1, ** p<0.05, *** p<0.01. All regressions use control variables at the individual and household level, fixed effects for the year of birth and the district, and district-specific time trends.

Sources: Coping with Shocks in Mongolia Household Panel Survey; Mongolia Livestock Census; ERA-Interim; NESDIS STAR VHP.

school age (between eight and 15 years old) during the three extreme winters.[18]

A series of individual and household characteristics serve as control variables (Table 1). Furthermore, year of birth fixed effects, district fixed effects, and district-specific time trends are included. This way, the analysis takes into account that different birth cohorts faced different educational standards and that educational infrastructure differs across districts.

Extreme winters drastically reduce school completion

The results of the regression analysis show that—considering the entire sample of 1,800 individuals—the three extreme winters in 1999 to 2002 significantly reduced the likelihood that children completed schooling (Table 2). Individuals who were of schooling age during the extreme winters and lived in a severely affected district in 1999 were significantly less likely to complete the full nine years of mandatory schooling compared to their peers in less affected districts. The three alternative measures of spatial intensity of the triple *dzud*—livestock mortality, snow depth, and vegetation—provide very similar results, emphasizing the robustness of the analysis.[19] The effect of the extreme winters on schooling is not only statistically significant, but also large: individuals from affected districts are between 20.1 and 26.1 percentage points less likely to complete the nine years of mandatory schooling compared to their peers in less affected districts.

School closures cannot explain the negative effects of extreme winters

Next, a possible mechanism is examined more closely: school closings during the winter months. It can be very costly to maintain the partly dilapidated school buildings during the cold winter months; heating costs for schools and dormitories accounted for 18 percent of the national education budget in 2014.[20] When the temperatures reached record lows during the triple *dzud* of 1999-2002, the heating systems in some schools completely failed. As a result, some ceased operations for up to two months in severely affected districts.[21] To test if the negative effect of the extreme winters can be explained by school closures, the sample is divided in two groups: individuals from herding households and individuals from non-herding households. Both groups were equally affected by school closures, so the effects on schooling should be similar for the two groups if impacts were driven by school closures. However, the results differ considerably: while the shocks still have significant negative—and now even stronger—effects on individuals from herding households, there are no significant effects of the extreme winters on the education of individuals from non-herding households. This suggests that the reduced time spent in school due to school closures cannot explain the negative effects of extreme winters.

Nor does an increased need for child labor in herding explain the estimated impacts

Another possible mechanism that could explain the negative effect of the shock is the increased need for child labor

18 See Groppo and Kraehnert, "Impact of extreme weather events" for a discussion on the assumptions that must be fulfilled for a causal interpretation of the results of the DiD approach.

19 Note that if vegetation greenness is used as a measure of *dzud* intensity, the interpretation of the result will be opposite: people who lived in a district with a higher vegetation greenness (thus least affected by drought) were significantly more likely to complete all nine years of mandatory education than those who lived in a district that was severely affected by drought.

20 Cf. World Bank, *Public financing of education: Equity and efficiency implications* (2006).

21 Cf. United Nations, *Mongolia: United Nations Inter-Agency Appeal for Mongolia "DZUD 2000"—An Evolving Disaster* (2000). Data on the length of school closings or the affected schools are unfortunately not available.

Table 3

The impact of the 1999–2002 triple *dzud* on the completion of mandatory education, by gender and age

Dependent variable: individual completed mandatory education	Intensity of the triple *dzud* measured by...		
	Livestock mortality	Snow depth	Vegetation greenness
(A) By gender, individuals from herding households (N=992)			
Exposed cohort x strongly affected district x male	−0.052	0.050	0.051
Exposed cohort x strongly affected district	−0.304	−0.304**	0.229*
Strongly affected district x male	−0.005	-0.088	0.027
Exposed cohort x male	−0.098	0.039	0.065
Male	−0.241***	−0.175**	−0.258***
(B) By age, individuals from herding households (N=992)			
Exposed in primary school x strongly affected district	−0.594**	0.166	0.715***
Exposed in secondary school x strongly affected district	−0.410**	−0.165	0.368***
R2, sample (A)	0.38	0.39	0.39
R2, sample (B)	0.38	0.39	0.39

Note: Significance levels: * p<0.1, ** p<0.05, *** p<0.01. All regressions use control variables at the individual and household level, fixed effects for the year of birth and the district, and district-specific time trends.

Sources: Coping with Shocks in Mongolia Household Panel Survey; Mongolia Livestock Census; ERA-Interim; NESDIS STAR VHP.

in herding during the winter months. Mongolian herding households apply a strict division of labor by gender. Boys are responsible for looking after animals from an early age and assist their fathers with other livestock-related tasks while girls help with domestic work. A relatively stronger negative effect on boys' schooling relative to girls' would indicate that an increased need for child labor in herding is among the explanatory mechanisms. However, this does not seem to be the case (Table 3): school-age boys who lived in a severely affected district during the extreme winters are not significantly more affected by the shock than girls.

Younger children are more affected than older children

On the other hand, there is some evidence suggesting that younger children are more affected by the extreme winters than older children (Table 3). The negative effect of extreme winters on schooling is significantly larger for children who were exposed to extreme weather events during their primary school years compared to children who were in secondary school at that time. This result is obtained when shock intensity is measured using livestock mortality and vegetation greenness. One interpretation is that extreme winters negatively affect schooling because of income losses, which also entail malnutrition and health problems that affect younger children more intensely.

Conclusion: education support, including emergency aid, is needed for the future

Like in many other developing and lower middle-income countries, the rural population in Mongolia is directly affected by extreme weather events that cause mass livestock death. This report shows that the 1999–2002 triple *dzud* severely affected Mongolian children's schooling. Children living in severely affected districts were significantly less likely to complete the full nine years of mandatory schooling, compared to peers in less affected districts. The extreme winters especially affected children from herding households and young children, while boys and girls were affected to the same extent.

These results provide reason for concern and policy attention, especially in light of three considerations. First, the dependent variable—whether a person completed all nine years of mandatory schooling—was collected in 2012. This shows that in the ten years following the extreme winters, those affected were not able to compensate for the negative effects. Since education correlates with individual income potential, it is likely that extreme weather events also have long-term consequences for the children examined in this study.

Second, for methodological reasons, the study presented here focused on Mongolia's basic education, which is free. It can be expected that shocks have a much stronger impact on acquiring higher education, where institutions charge (sometimes very high) fees.

Third, the findings of the study are surprising considering that Mongolia belongs to a group of lower middle-income countries where adults have a comparatively high average level of education. In addition to nine years of free mandatory schooling, the Mongolian state also subsidizes school dormitories, where many children from herding families live. The fact that extreme weather events have such significant negative consequences despite the relatively favorable environment suggests that poorer developing countries are likely to be even more affected by extreme weather events.

The results of this study indicate that households affected by extreme weather events cannot, based exclusively on their own means, send their children to school without interruption.

Policymakers should therefore consider implementing support measures, including emergency aid, allowing children in affected districts to attend school without interruptions and complete their education. Financial support should be targeted to rural households in severely affected areas, covering school expenses and possibly being tied to actual school attendance. Preventive programs aiming at reducing household vulnerability to extreme weather events or the provision of weather insurance may also improve children's school completion in the face of extreme weather events.

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